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Measurement Issues Arising from the Growth of Globalization: Conference Papers

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MEASUREMENT ISSUES ARISING FROM THE GROWTH OF GLOBALIZATION

CONFERENCE PAPERS

November 6-7, 2009, Washington DC

W.E. Upjohn Institute for Employment Research
National Academy of Public Administration

AUGUST 2010

W.E. UPJOHN INSTITUTE FOR EMPLOYMENT RESEARCH

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MEASUREMENT ISSUES ARISING FROM THE GROWTH OF GLOBALIZATION*

November 6-7, 2009
Washington, DC

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and the
National Academy of Public Administration
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FRIDAY NOVEMBER 6

SESSION 1: SERVICES OFFSHORING

Chair: Kenneth Ryder (NAPA)

Measuring the Impact of Trade in Services: Prospects and Challenges, J. Bradford Jensen (Georgetown University and Peterson Institute for International Economics)

Measuring Success in the Global Economy: International Trade, Industrial Upgrading, and Business Function Outsourcing in Global Value Chains, Timothy Sturgeon (Massachusetts Institute of Technology) and Gary Gereffi (Duke University)

Discussant: Torbjorn Fredriksson (UNCTAD)

* The conference was funded with grants from the Alfred P. Sloan Foundation and the Bureau of Economic Analysis.

SESSION 2: MEASURING THE IMPACT OF OFFSHORING ON THE LABOR MARKET

Chair: Janet Norwood (NAPA)

Addressing the Demand for Time Series and Longitudinal Data on Occupational Employment, Katharine Abraham (University of Maryland) and James R. Spletzer (Bureau of Labor Statistics)

Understanding the Domestic Labor Market Impact of Offshore Services Outsourcing: Measurement Issues, Lori Kletzer (University of California-Santa Cruz and Peterson Institute for International Economics)

Discussant: Timothy Sturgeon (MIT)

SESSION 3: MEASUREMENT IMPLICATIONS OF TRANSFORMATION OFFSHORING AND IMPORTED INTERMEDIATE INPUTS

Chair: Ned Howenstein (Bureau of Economic Analysis)

Outsourcing, Offshoring, and Trade: Identifying Foreign Activity across Census Data Products, Ron Jarmin, C. Krizan, and John Tang (U.S. Census Bureau)

Effects of Imported Intermediate Inputs on Productivity. Lucy P. Eldridge and Michael J. Harper (Bureau of Labor Statistics)

Discussant: John Haltiwanger

SESSION 4: OFFSHORING AND PRICE MEASUREMENT: INDUSTRY CASE STUDIES

Chair: Jon Steinsson (Columbia University)

Offshoring and Price Measurement in the Semiconductor Industry, David Byrne (Federal Reserve Board), Brian Kovak (University of Michigan), and Ryan Michaels (University of Michigan)

Globalization, Prices of IT Software & Services Measurement Issues, Catherine Mann (Brandeis University and Peterson Institute for International Economics)

Imports of Intermediate Parts in the Auto Industry—A Case Study, Thomas H. Klier (Federal Reserve Bank of Chicago) and James M. Rubenstein (University of Miami, Ohio)

Discussant: Kimberly Zieschang (IMF)

SATURDAY NOVEMBER 7

SESSION 5: MEASUREMENT OF IMPORT PRICES

Chair: Michael Horrigan (Bureau of Labor Statistics)

Bias Due to Input Source Substitutions: Can It Be Measured? Erwin Diewert (University of British Columbia) and Alice Nakamura (University of Alberta)

Are there Unmeasured Declines in Prices of Imported Final Consumption Goods?, Marshall Reinsdorf and Robert Yuskavage (Bureau of Economic Analysis)

Discussant: Barry Bosworth (Brookings Institution)

SESSION 6: MEASUREMENT OF IMPORT AND INPUT PRICES

Chair: Julia Lane (National Science Foundation)

Offshoring and the State of American Manufacturing Susan Houseman (W.E. Upjohn Institute), Christopher Kurz (Federal Reserve Board), Paul Lengermann (Federal Reserve Board), and Benjamin Mandel (Federal Reserve Board)

Producing an Input Price Index, William Alterman (Bureau of Labor Statistics)

Discussant: Emi Nakamura (Columbia University)

SESSION 7: MEASUREMENT OF IMPORT PRICES AND IMPORT USES: EVIDENCE OF BIASES

Chair: Carol Corrado (Conference Board)

Imported Inputs and Industry Contributions to Economic Growth: An Assessment of Alternative Approaches, Erich Strassner, Robert Yuskavage and Jennifer Lee (Bureau of Economic Analysis)

Evaluating Estimates of Materials Offshoring from U.S. Manufacturing, Robert C. Feenstra (University of California-Davis) and J. Bradford Jensen (Georgetown University and Peterson Institute for International Economics)

Discussant: William Milberg (New School for Social Research)

Errors from the Proportionality Assumption in the Measurement of Offshoring: Application to German Labor Demand, Deborah Winkler and William Milberg (Schwartz Center for Economic Policy Analysis, The New School for Social Research)

PANEL DISCUSSION: PRIORITIZING STEPS FOR THE STATISTICAL AGENCIES

Chair: Susan Houseman (W.E. Upjohn Institute)

Panel members: Katharine Abraham (University of Maryland), Erwin Diewert (University of British Columbia), Robert C. Feenstra (University of California-Davis), Keith Hall (Bureau of Labor Statistics), and Steven Landefeld (Bureau of Economic Analysis)

CONCLUDING COMMENTS AND ADJOURNMENT

Susan Houseman and Kenneth Ryder

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LIST OF CONFERENCE PAPERS
(in order presented)

SESSION 1: SERVICES OFFSHORING

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DISCUSSANT: Torbjorn Fredriksson (UNCTAD)

Measuring the Impact of Trade in Services: Prospects and Challenges

J. Bradford Jensen
McDonough School of Business, Georgetown University
Peterson Institute for International Economics
Georgetown Center for Business and Public Policy

October 2009
(revised May 2010)

This paper was prepared for the conference "Measurement Issues Arising from the Growth of Globalization," held in Washington, DC, November 6–7, 2009.

EXECUTIVE SUMMARY

The large share of employment in the service sector and growing services trade present the potential for trade in services to have a significant impact on the U.S. economy and highlight the importance of being able to analyze the impact.

International trade theory and previous empirical work on the manufacturing sector stress several key considerations for understanding the impact of globalization:

1) The prevalence (how many activities?), scale (how much is being traded?), and direction (who is trading with whom?)of trade in services.
2) How trade in services evolves over time.
3) The factor intensities used in services provision.
4) The factor intensities across locations.
5) Firm-level heterogeneity (in size, factor intensities, productivity, trade activity) within and across industries and countries.

Currently available data on the service sector do not support these data needs. Two broad areas require improvement:

1) Increased industry and geographic detail in trade in services statistics. Current trade in services statistics are not detailed enough to support robust empirical analysis. Increasing the detail will require increased resources to collect information from larger sample of firms, improved access to an adequate sampling frame to support representative sampling, and lower reporting thresholds.
2) More detailed information on inputs used services production in the United States. Current data on service sector production within the United States do not provide enough information on the factor inputs used in production. More information should be collected on skill intensity, capital intensity, and purchased services. These data should be collected at the establishment level to the extent possible to increase the industry and geographic detail available.

Improving our ability to analyze the impact of trade in services will require

1) more funding for service sector data collection, and an
2) improved sampling frame for the Bureau of Economic Analysis' data collection.

The need for an improved sampling frame and potential efficiencies in data collection suggest the costs and benefits of moving data collection activities currently performed by the Bureau of Economic Analysis to the Census Bureau should be investigated.

MEASURING THE IMPACT OF TRADE IN SERVICES: PROSPECTS AND CHALLENGES

The service sector accounts for a large share of employment in the United States. Trade in services is growing rapidly. The large share of employment in the service sector and growing services trade present the potential for trade in services to have a significant impact on U.S. firms and workers.

Despite the potential importance of trade in services, the amount of empirical research on the impact of trade in services relative to empirical research of the impact of trade in goods is quite small. An important source of the relative scarcity of work on the service sector in general and trade in services in particular is the fact that the service sector is not measured as well as the goods producing sector.

The organizers of this conference asked me to 1) provide my perspective on whether measuring the impact of trade in services is potentially important, 2) assess the prospects for measuring the impact of trade in services, and 3) identify any data needs, provide priorities for the data needs, and (somewhat provocatively) suggest organizational changes that might improve the statistical system.

This is not new ground. Other organizations have produced reports on varying aspects of the impact of outsourcing, offshoring, services trade, and data availability.[1] I will not report on all previous efforts, but will draw on the MIT/Sloan Offshoring Working Group report (Sturgeon and Levy 2006), as I was a contributor and I think it still accurately reflects needs and priorities.

The purpose of this paper is to take stock of the current prospects for measuring the impact of trade in services on the U.S. economy. I will describe progress economists have made over the past 10–15 years using detailed, establishment-level microdata to examine the impact of trade in goods on the manufacturing sector. I will argue that to investigate the impact (or potential impact) of trade in services on the United States, one (or at least I) would want to use similar methods.[2] I will then describe what data would be needed to conduct this research and how much of that data is currently available.

I then propose priorities for improving the ability of researchers to examine the impact of trade in services on the U.S. economy. First, I provide a brief overview of developments in the U.S. service sector.

[1] Other organizations that have produced reports on this or related topics include the National Academy of Public Administration, National Academy of Sciences, and Government Accountability Office.

[2] This would be a good place to put my perspective in context. I am someone who has done microdata research examining the impact of trade on the U.S.` manufacturing sector and tried to do the same for the service sector; not a necessarily representative perspective but one that should support other types of analysis (aggregate data is only as good as the microdata). So, while not everyone prefers to use microdata to examine these types of issues, conducting similar studies on more aggregated data would require collecting the same information.

THE SERVICE SECTOR

Service Sector Employment

The service sector accounts for the lion's share of employment in the United States (and most other advanced economies). While services have traditionally been viewed as nontradable, services trade is growing and there is an increasing sense that technological change is making it easier and less expensive to provide services from a distance.

Table 1

NAICS Code	Sector	Employment 2007	Share of Total Employment 2007	Employment Growth 1997-2007
21	**Mining**	**703,129**	**0.5%**	**38%**
22	**Utilities**	**632,432**	**0.5%**	**-10%**
23	**Construction**	**7,399,047**	**5.5%**	**31%**
31-33	**Manufacturing**	**13,333,390**	**9.9%**	**-21%**
42	**Wholesale trade**	**6,295,109**	**4.7%**	**9%**
44-45	**Retail trade**	**15,610,710**	**11.5%**	**12%**
48-49	**Transportation and warehousing**	**4,435,760**	**3.3%**	**52%**
51-56	**Business Services**	**33,430,809**	**24.7%**	**29%**
51	Information	3,428,262	2.5%	12%
52	Finance and insurance	6,562,546	4.9%	12%
53	Real estate and rental and leasing	2,249,353	1.7%	32%
54	Professional, scientific, and technical services	8,121,171	6.0%	51%
55	Management of companies and enterprises	2,915,644	2.2%	11%
56	Administrative and support and waste remediation services	10,153,833	7.5%	38%
61-81	**Personal Services**	**34,595,857**	**25.6%**	**23%**
61	Educational services	562,210	0.4%	75%
62	Health care and social assistance	16,859,513	12.5%	24%
71	Arts, entertainment, and recreation	2,070,524	1.5%	30%
72	Accommodation and food services	11,587,814	8.6%	23%
81	Other services (except public administration)	3,515,796	2.6%	8%
	Federal Government	**2,462,000**	**1.8%**	**--**
	State and Local Government	**16,400,000**	**12.1%**	**--**

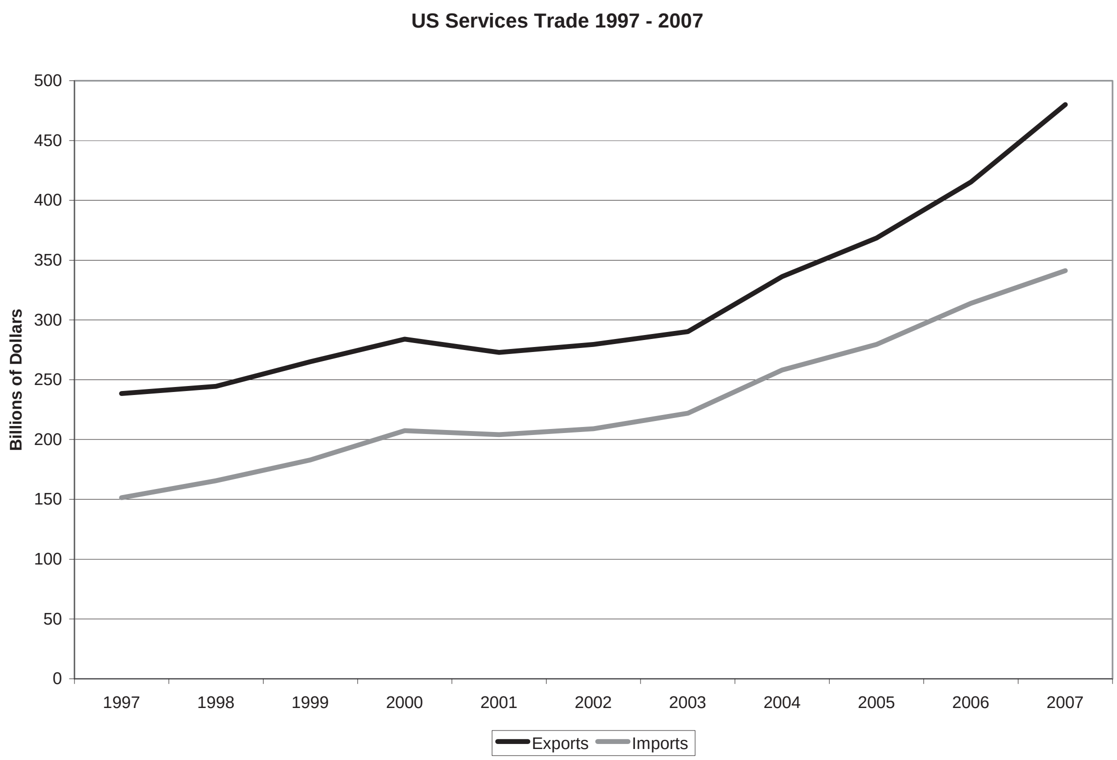
Table 1 presents information on employment and employment growth from the 1997 and 2007 economic censuses. Depending on the definition one uses, the service sector accounts for between more than 60 percent to more than 80 percent of employment. Further, employment in the service sector is growing, in contrast to the manufacturing sector. Services are a large and growing part of the U.S. labor market.

Just because services are a large and growing portion of the U.S. economy does not necessarily imply that trade in services is likely to affect the U.S. economy in a significant way. But the confluence of a variety of changes (e.g., decreasing travel and telecommunication costs, decreasing IT hardware costs, increasing Internet availability worldwide) seem to have significantly increased the ease with which services are traded and expanded the scope of service activities that can be provided at a distance. As a result, trade in services is growing.

Trade in Services: Official Statistics

Figure 1 shows the steady increase in U.S. service imports and exports. Both U.S. services exports and imports about doubled between 1997 and 2007. Services now account for 30 percent of U.S. exports and about 17 percent of U.S. imports.

Figure 1



Source: Bureau of Economic Analysis.

Figures 2 and 3 show the composition of U.S. service exports and imports over the period 1992–2007. While all of the categories exhibit growth, the “Other private services” category is growing the fastest (both imports and exports more than doubling over the period) and contributes the most to overall services import and export growth—Other private services account for more than half of the overall increase in services exports and accounts for half of the increase in services imports.

Other private services are comprised of the following activities: Education, Financial services, Insurance services, Telecommunications, and Business, professional, and technical services. Import and export data for these components of Other private services are only available starting in 1997. For both imports and exports, the Business, professional, and technical services category is the largest at the end of the period and contributes the most to Other private services growth over the period. A long time series of the BPTS category is not available, so it is not possible to decompose its growth into more detailed components.

Figure 2

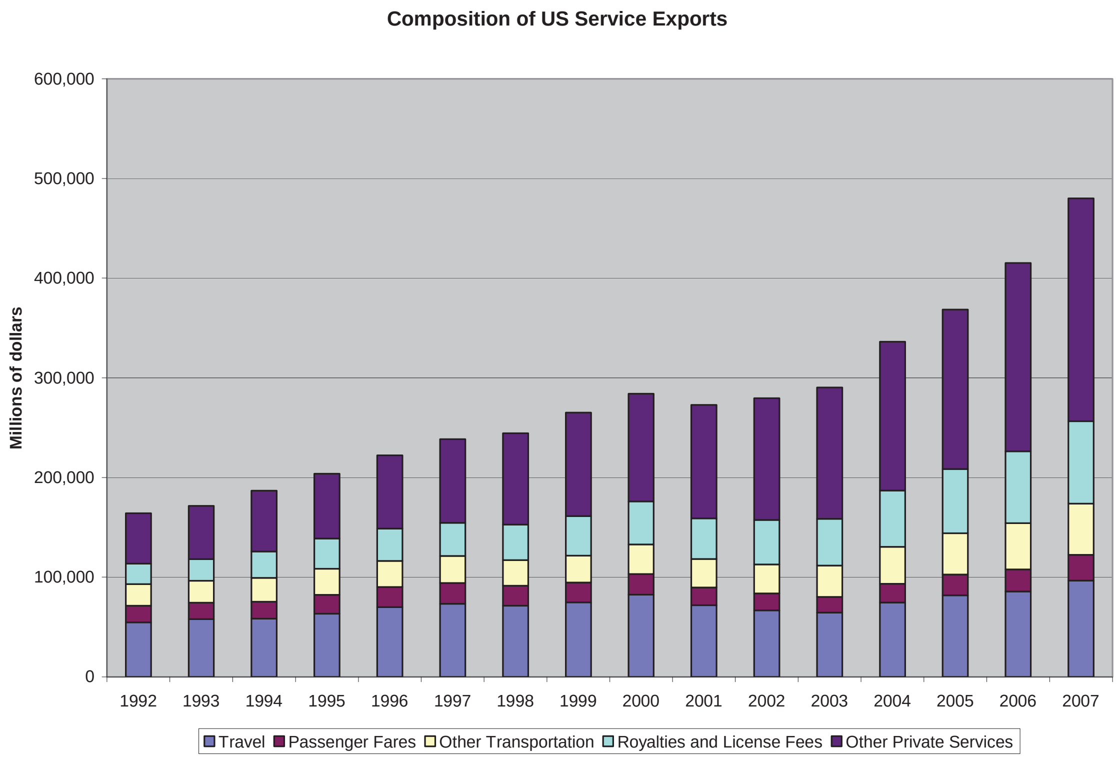
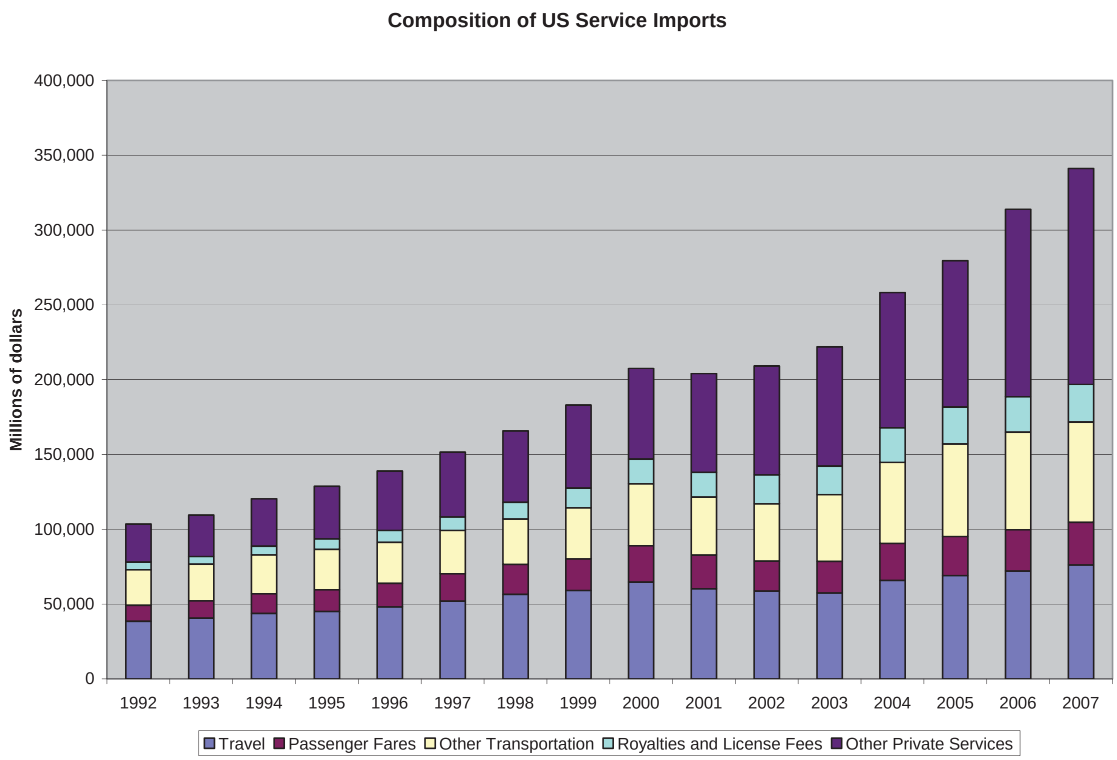


Figure 3



Business, professional, and technical services; Financial services; and Insurance services account for a significant share of service sector growth over the past 15 years. We would like to understand better how trade in these types of services is affecting the United States. As discussed in this section, the availability of detailed data going back in time poses a significant impediment to researchers. And while the level of detail for trade in services data is improving, the level of detail is still far more aggregated than in the manufacturing sector. The lack of historical data and the ongoing lack of detailed industry-level data are two examples of the challenges in measuring and analyzing trade in services. In the next section, I describe an alternative methodology for assessing the potential scope of trade in services.

Tradable Services: A Different Perspective

Another less conventional (but more detailed) perspective on the potential for service trade to affect the U.S. labor market is from work that Lori Kletzer and I (Jensen and Kletzer 2006) did examining the tradability of service activities. We use the geographic concentration of service employment across metropolitan areas within the United States to identify service activities that are tradable. The intuition is that if services production is geographically concentrated (more than demand for the service), it is probably being traded. As an example of this intuition, think of personal services like haircuts or divorce lawyers. These service activities tend to be distributed in proportion to the population in a region (and thus we don't see big concentrations of these types of service activities in one place). But increasingly, there are services that don't seem to require face-to-face interaction and thus might be tradable—think software development or securities and commodities trading. We used this feature to distinguish between service activities that are tradable and those that require face-to-face interaction (and thus are far less likely to be traded).

We find that many service activities—such as movie and music recording production, securities and commodities trading, software, and engineering services—appear to be traded within the United States and thus are at least potentially tradable internationally. Approximately 14 percent of the workforce is in service industries classified as tradable. By comparison, about 12 percent of the workforce is in manufacturing industries classified as tradable. When workers in tradable occupations (such as computer programmers in the banking industry or medical transcriptionists in the health care industry) in nontradable industries are included, the share of the workforce in tradable service activities is even higher.

While many service activities appear tradable, in related work (Jensen and Kletzer 2008), we argue that only about one-third of the jobs in these activities will face meaningful competition from low-wage countries (or risk being offshored) in the medium term. Tradable service jobs, such as those at engineering or research and development firms, are good jobs. Workers in tradable service activities have higher than average earnings. Part of this premium is due to workers in these activities having higher educational attainment than other workers, but even controlling for educational and other personal characteristics differences, workers in tradable service activities have 10 percent higher earnings. Within the set of professional service industries, a worker in a tradable industry and a tradable occupation has almost 20 percent higher earnings than a similar professional service worker in a nontradable industry and occupation.

High earnings in tradable service activities do not mean that these jobs will be "lost" to low-wage countries. High-wage, high-skill activities are consistent with U.S. comparative advantage. In the manufacturing sector, it is low-wage, labor-intensive industries like apparel that are most vulnerable to low-wage import competition. The United States continues to have strong export performance in high-wage, skill-intensive manufacturing industries.

The United States currently exports high-wage, high-skill services like computer software and satellite telecommunications services. Most commentators on the offshoring issue focus on the jobs that will be lost to offshoring but neglect that the United States has comparative advantage in many service activities. Increased exports of services (and "inshoring") are likely to benefit many U.S. firms and workers.

About two-thirds of tradable business service jobs are skilled enough to be consistent with U.S. comparative advantage. U.S. service workers and firms are likely to be beneficiaries of increased trade in services through increased export opportunities.
The relationship between skills, wages, and trade highlights the need to have detailed data covering the service sector.

MEASURING THE IMPACT OF TRADE IN SERVICES

How would researchers analyze the impact of trade in services on the U.S. economy? The literature, both classical trade theory and more recent empirical and theoretical work, give us a good idea of where to start. Traditional trade theory and more recent theoretical and empirical advances suggest several important considerations: factor intensities and factor abundance, productivity differences across countries, industries and within industries, and producer heterogeneity within and across industries.

Lessons from Trade Theory

International trade theory emphasizes a number of features that help explain the sources and implications of international trade. Traditional trade theory emphasizes that countries will trade goods in which they have a comparative advantage—either through relative productivity differences or through differences in relative factor endowments. Countries will tend to export goods that they are relatively efficient at producing, either because they have a technological advantage or because they are relatively abundant in the factor important to a good's production. Thus, capital-intensive countries like the United States tend to export capital-intensive products and import labor-intensive products from countries where labor is abundant and wages are relatively low.

These traditional trade theories also described the mechanism through which trade can affect relative factor returns (i.e., wages and the returns to capital)—when countries specialize across industries that differ in their use of different inputs, the relative returns to the inputs may change. When industries that make relatively intensive use of unskilled labor (e.g., apparel production) shrink, employment prospects and wages for unskilled workers are likely to suffer.

This traditional trade theory emphasized how differences across countries will influence the patterns of trade. Yet, a large share of international trade takes place between relatively similar trading partners, apparently within industries (see Grubel and Lloyd [1975]). Germany and the United States, for example, exchange automobiles. This fact and others led to the creation of "new" trade models that emphasize economies of scale in production and consumer preferences for different varieties. In these models, otherwise similar firms (operating in countries with similar factor endowments) specialize in different varieties, spurring two-way or "intra-industry" trade between countries (see Ethier [1982], Helpman [1981], and Krugman [1980]).

Recent Lessons from Empirical Research in Manufacturing

One feature of both old and new trade theory is that the theories typically assume a representative firm—that is, they assume all firms within an industry are the same. There is a growing body of empirical research using plant- and firm-level microdata for the manufacturing sector that demonstrates that the traditional assumption of a "representative" firm in an industry is not appropriate for many research questions, including understanding the impact of globalization.[3] Plants, even within narrowly defined industries, exhibit considerable heterogeneity both in their cross-sectional characteristics and in their behavior over time. The heterogeneity of plants and firms and the variation in their responses to globalization have clear implications for the impacts of trade in services.

Within Industry heterogeneity in manufacturing

Bernard and Jensen (1995) provide some of the first plant-level results on U.S. exporters and find that exporters are relatively rare. Even in industries in which the United States has a comparative advantage, the majority of plants do not export, while even in import-competing sectors like textiles and apparel some firms export. In addition to being relatively rare, exporters are strikingly different from plants in the same industry. Exporters are significantly larger than nonexporters in the same industry. Exporters are also more capital intensive, more skilled-worker intensive, and pay higher wages than plants of similar size, in the same industry, in the same state. Exporters are also more productive than nonexporters in the same industry and region.

Bernard and Jensen (1999, 2006) also show that exporters are more likely to survive and have higher employment growth than nonexporters of similar size, in the same industry, in the same region. Because exporters have different characteristics than nonexporters, and because they have differential growth and survival rates, the potential exists for the behavior of exporters to be associated with 1) a reallocation of economic activity that affects aggregate measures like industry and aggregate productivity and 2) the demand for and returns to different factors of production (e.g., skilled workers).[4]

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[3] This section is not meant to be exhaustive or representative. For more comprehensive reviews see Bernard et al. (2007), Helpman (2006), and Roberts and Tybout (1996), which focus on developing market contexts. Here, I draw mostly on work I have been involved in to demonstrate how one might go about this type of research.

[4] These relationships are not restricted to export participation. Researchers have also examined the characteristics and behavior of multinational corporations using plant- and firm-level microdata. Doms and Jensen (1998) find that U.S. manufacturing plants owned by MNCs—either foreign MNCs or U.S.-based MNCs—have superior operating characteristics relative to domestic-owned plants. Bernard and Jensen (2007) explore the behavior of MNCs over time and show that plants owned by U.S. MNCs are unconditionally more likely to survive, though controlling for

Economists are now incorporating these empirical regularities into models of international trade and investment (for example, see Bernard et al. [2003]; Bernard, Redding, and Schott [2006]; and Melitz [2003]). While differing in their details, these models have several shared implications. As trade costs fall, low productivity nonexporters are more likely to fail, high-productivity nonexporters are more likely to start exporting, and existing exporters should increase their exports.

These models have direct implications for how increased trade will affect firms and workers. If trade costs are reduced differentially across industries (either because of policy or technology), industries with larger reductions in trade costs are likely to see more churning within the industry. Because low-productivity plants tend to use low-skill and low-wage workers more intensively, the increased likelihood of plant failure has implications for the demand for low-skill workers. To the extent that particular industries or low-productivity producers are concentrated in particular geographic areas, this will also affect distributional outcomes. In this section we review results that examine the impact of international trade on U.S. manufacturers explicitly.

Competition from low-wage countries

Bernard, Jensen, and Schott (2006a) examine the role of import-competition from low-wage countries on the reallocation of U.S. manufacturing within and across industries from 1977 to 1997. They focus on where imports originate (rather than their overall level), motivated by the factor proportions framework and the significant increases in import shares from low-wage countries like China. Their use of plant-level data provides a richer examination of U.S. producer responses to international trade, including plant exit and product switching, than is possible with more aggregate data. Specifically, their analysis identifies whether reallocation within industries is consistent with U.S. comparative advantage.

They show that low-wage country import shares and overall penetration vary substantially across both industries and time. Both components tend to be higher and to increase more rapidly among labor-intensive industries such as Apparel and leather. Other industries such as Textiles see only modest rises in both series. Finally, more capital- and skill-intensive sectors such as Transportation and industrial machinery experience rapid growth of import penetration but little or no increase in the share of imports from low-wage countries. They find that plant survival and employment growth are negatively associated with industry exposure to low-wage country imports. Within industries, they show that manufacturing activity is disproportionately reallocated toward capital-intensive plants. Because there is an observed empirical regularity that capital-intensive plants also tend to be more skill (nonproduction worker) intensive, the reallocation to more capital-intensive plants will likely have implications for the relative demand for skilled and unskilled workers.[5]

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the superior operating characteristics of MNCs, MNC-owned plants are actually more likely to close. Firm participation in international markets is significantly correlated with both plant characteristics and behavior over time.

[5] Bernard and Jensen (1997) examine the impact of reallocation to exporters on the relative demand for and wages paid to skilled workers in the U.S. manufacturing sector.

Falling trade costs

In separate but related work, Bernard, Jensen, and Schott (2006b) examine the impact of falling trade costs (both tariffs and transportation costs) on U.S. manufacturers. They find that when trade costs in an industry fall, plants are more likely to close. This is one channel by which international trade can affect the distribution of economic activity, aggregate productivity growth, and the demand for labor. Falling trade costs tend to reduce the amount of economic activity at the low end of the productivity distribution. This tends to raise aggregate productivity (even without any technological change at the plant level) by truncating the low end of the productivity distribution. Because low productivity plants also tend to be production-worker intensive, this change is likely to affect the relative demand for unskilled workers.

They find that relatively high-productivity nonexporters in industries with falling trade costs are more likely to start exporting. They also find that existing exporters increase their shipments abroad as trade costs fall. Exporters are relatively high-productivity plants, and the expansion of the high end of the productivity distribution will tend to raise aggregate productivity (even if no plant changes its productivity). Because exporters are skill and capital intensive, this will also tend to increase relative demand for these factor inputs. Bernard, Jensen, and Schott also find that decreases in trade costs, and the increased competitive pressure associated with it, are associated with increased productivity at the plant level. Not surprisingly, given the number of channels by which falling trade costs shift the distribution of economic activity toward more productive plants, they find that industries experiencing relatively large declines in trade costs exhibit relatively strong productivity growth.

U.S. multinationals and outsourcing

Hanson, Mataloni, and Slaughter (2005) examine multinational behavior with regard to the choice of the location of production using confidential data from surveys conducted of all U.S. multinationals. They use a direct measure of input flows associated with vertical production networks: foreign affiliates' imports from U.S. parent firms (and other U.S. entities) of intermediate inputs for further processing. They estimate the sensitivity of demand for imported intermediates for additional processing to host-country and industry trade costs, factor prices, taxes, and other variables suggested by theory.

Manson, Mataloni, and Slaughter find that imports of intermediate inputs are strongly negatively correlated with trade costs facing affiliates. They find that vertical production networks are sensitive to labor costs—imported-input demand is decreasing in host-country wages for less-skilled workers and increasing in host-country wages for more-skilled workers. They find that foreign affiliates do more processing of imports in countries with relatively cheap, less-skilled labor. A third finding is that vertical production networks also depend on other host-country policies and characteristics. Imported-input demand is higher in host countries with export-processing zones, and is decreasing in host-country market size and corporate tax rates.

The examples of research described in this section demonstrate the usefulness of detailed, comprehensive microdata in analyzing the impact of globalization. In the next section I describe data needs to produce similar analyses for the service sector.

DATA NEED TO ANALYZE GLOBALIZATION IN THE SERVICE SECTOR

We know a considerable amount about the reaction of firms to changes in the global trading environment in the manufacturing sector. If a researcher were interested in conducting similar research on the service sector, what are the prospects?

To understand how increased trade in services might affect the U.S. economy, both theory and previous empirical work stress some key considerations for understanding the impact:

1) The prevalence (how many activities?), scale (how much is being traded?), and direction (who is trading with whom?)of trade in services.
2) How trade in services has evolved over time.
3) The factor intensities used in services provision.
4) The factor intensities across locations.
5) Firm-level heterogeneity (in size, factor intensities, productivity, trade activity) within and across industries and countries.[6]

Measuring Trade in Services

The Bureau of Economic Analysis (BEA) collects information on trade in services and presents aggregate data on international services transactions through three publication programs: 1) cross-border trade in services data in the international transactions accounts; 2) sales of services through affiliates of multinationals, some portion of which represent cross-border trade; and 3) benchmark input-output tables.

The cross-border trade in services publication program provides the basis for all of the BEA's services trade data. As a result, this publication program provides the best sense of the trade data the BEA collects:

> The estimates of cross-border transactions cover both affiliated and unaffiliated transactions between U.S. residents and foreign residents. Affiliated transactions consist of intra-firm trade within multinational companies—specifically, the trade between U.S. parent companies and their foreign affiliates and between U.S. affiliates and their foreign parent groups. Unaffiliated transactions are with foreigners that neither own, nor are owned by, the U.S. party to the transaction.
>
> Cross-border trade in private services is classified into the same five, broad categories that are used in the U.S. international transactions accounts—travel, passenger fares, "other transportation," royalties and license fees, and "other private services." (*Survey of Current Business*, November 2001)

[6] While not exactly a data need, if researchers are to use information on producer heterogeneity, they need access to producer-level information, i.e., microdata, which is often collected under a pledge of confidentiality. Thus, access to producer-level microdata is an additional dimension of data needs.

Affiliated transactions are collected through the BEA's U.S. Direct Investment Abroad and Foreign Direct Investment in the U.S. programs. Comprehensive benchmark surveys are collected every five years, and less comprehensive collections are conducted annually.

The BEA collects data on U.S. international transactions in private services with unaffiliated foreigners through 11 surveys. These surveys fall into three broad categories: 1) the surveys of "selected" services, which cover mainly business, professional, and technical services; 2) the specialized surveys of services, which cover construction, engineering, architectural, and mining services, insurance services, financial services, and royalties and license fees; and 3) the surveys of transportation services. These collection programs are the principal source of the BEA's estimates of trade in services, but the estimates of some services are based on data from a variety of other sources, including U.S. Customs and Border Protection and surveys conducted by other Federal Government agencies, private sources, and partner countries.

Need: Increased detail—industry and country

Detailed data on international services transactions for cross border trade are currently available from 1986 through 2006. Service imports and exports are reported for approximately 30 (1986–1991) to 35 (1992–2006) service types (with additional detail on whether the transactions are between affiliated or unaffiliated parties available for some categories). These data are available by country for approximately 35 countries and country groupings for 1986–2006.

Figure 4 exhibits the detail on trade in services (both affiliated and unaffiliated) published by the BEA over time. It shows the significant increase in detail over the past decade. The figure also shows how large the gap is between the detail available for the manufacturing sector (where information is available for over 8,000 export categories and over 10,000 import categories) and the service sector. The published aggregates are moving in the right direction, but we clearly have a ways to go.

Figure 4 – Categories reported in the BEA Table 1b 1992–2006

1992	1997	2001	2006
Travel [2]	Travel [2]	Travel [2]	Travel [2]
Passenger fares [3]	Passenger fares [3]	Passenger fares [3]	Passenger fares [3]
Other transportation	Other transportation	Other transportation	Other transportation
Royalties and license fees	Royalties and license fees	Royalties and license fees	Royalties and license fees
Other private services [4, 15]	Other private services [4, 15]	Other private services [4, 15]	Other private services [4, 15]
Education [5]	Education [5]	Education [5]	Education [5]
	Financial services [16]	Financial services [16]	Financial services [16]
Insurance services [6]	Insurance services [6]	Insurance services [6]	Insurance services [6]
Telecommunications [7]	Telecommunications [7]	Telecommunications [7]	Telecommunications [7]
	Business, professional, and technical services [16]	Business, professional, and technical services [16]	Business, professional, and technical services [16]
	Computer and information services [8, 16]	Computer and information services [8, 16]	Computer and information services [8, 16]
		Management and consulting services [9]	Management and consulting services [9]
		Research and development and testing services [9]	Research and development and testing services [9]
	Operational leasing [16]	Operational leasing [16]	Operational leasing [16]
	Other business, professional, and technical services [10, 16]	Other business, professional, and technical services [10, 16]	Other business, professional, and technical services [10, 16]
			Accounting, auditing, and bookkeeping services
			Advertising
			Architectural, engineering, and other technical services
			Construction
			Industrial engineering
			Installation, maintenance, and repair of equipment
			Legal services
Medical services [11]	Medical services [11]	Medical services [11]	Medical services [11]
			Mining [12]
			Sports and performing arts
			Trade-related services [13]
			Training services
			Other [14]
Other services	Other services	Other services	Other services
Film and television tape rentals	Film and television tape rentals	Film and television tape rentals	Film and television tape rentals
Other	Other	Other	Other

> "What is most troubling for us is that the seventeen industry categories listed in the first column of Table 4 exhaust the detail on services trade collected by United States government statistical agencies. What is going on in the other service product categories that have been mentioned as moving offshore, such as the wide variety of back-office functions like accounting, customer support, and software programming? What about the interpretation of radiology images, market and legal research, and research to support financial services? Are customized software services staying onshore while only basic software coding is moving offshore, or is higher-skilled work and work related to innovation and new product creation also being imported? Because very few questions are asked, very little detail is collected, leaving us with extremely thin data on services trade, even if steps are taken to improve data quality. Contrast the seventeen descriptive categories for traded services products in Table 4 with the more than 16,000 detailed product codes for goods collected by the United States Department of Commerce and the magnitude of the data gap becomes clear. It is clearly infeasible to collect as much product detail on services trade as is generated by the customs forms filled out when goods are shipped across borders. But much more detail could and should be collected."
> (Sturgeon and Levy 2006)

Progress is being made. The BEA has resolved the inconsistency between the survey formats for affiliated and unaffiliated trade. This now permits greater detail in reporting the types of services traded. While this represents progress, it does not resolve the issue of the need for greater detail.

Need: Lower reporting thresholds

> "While the BEA surveys that ask firms to quantify their trade in services are mandatory, firms are exempted from reporting categories of services in which they have import transactions of less than $6M per year and export transactions of less than $8M per year. In the case of services, in particular, because firms tend to be smaller than firms engaged in goods trade, the current thresholds very likely exclude many transactions. Because of this, we believe that the thresholds for mandatory reporting of international services transactions should be lowered."
> (Sturgeon and Levy 2006)

Need: Increased sample/improved sampling frame

Related to the issue of lowering reporting thresholds, the BEA needs to improve its capacity to develop survey frames.

> "Another explanation for the apparent undercounting of services trade is that the BEA is not collecting data from the right companies, or is sending inappropriate surveys to the companies on its mailing lists. To test for potential undercounting of U.S. services imports, the Government Accountability Office (GAO) provided the BEA with a list of 104 firms identified from press and company reports as likely to be importing services from India. The BEA was asked to compare this list with the survey responses it had received from firms on its mailing lists. The BEA had 87 (84 percent) of the firms

identified by the GAO on its mailing lists. The BEA stated that it had dropped some of the missing companies from its mailing lists because they had not previously met the reporting thresholds for services trade."

> "Furthermore, only 54 (52 percent) of the firms identified by the GAO had received appropriate surveys from the BEA (e.g., firms with offshore affiliates were not sent the survey on affiliated trade). Finally, only 15 (14 percent) of the 104 firms identified by the GAO as likely to be importing services from India reported such imports (GAO 2005b, p 19). One explanation for the low level of reporting of services trade with India is that firms that had transactions valued beneath the thresholds mentioned above, while not required to do so, nevertheless filled out the BEA surveys but did not provide detail on the source or destination countries associated with their international transactions because they were not required to do so."

> "Still, the BEA believes that its data on services trade is of good quality. When the BEA contacted the companies on the GAO list that were missing from its mailing lists, it did not identify any company with substantial imports of services that were not already being reported. Nevertheless, the BEA recognizes that more resources need to be allocated toward maintaining lists of survey respondents since the identity of transactors may change from year to year. The BEA has a variety of initiatives underway to improve its mailing lists and improve survey compliance (GAO 2005b, p. 20). The BEA also plans to merge the collection of its data on affiliated international services transactions with its data on unaffiliated international services transactions, so that a given type of service is covered in exactly the same detail, whether it is imported or exported, and whether it is with an affiliated or an unaffiliated foreign party. We believe that these efforts are significant and very helpful, especially if combined with lower thresholds for mandatory survey compliance."
> (Sturgeon and Levy 2006)

The BEA is now collecting information from on unaffiliated and affiliated international service transactions using the same collection form. This resolves the issue of the information being collected at different levels of detail.

The BEA has undertaken efforts to improve its sampling frame. It commissioned the Census Bureau to add a question to the 2006 Company Organization Survey to ask whether firms imported services. The purpose of this additional question is to improve the sampling frame for the BEA's data collection programs.

Measuring the Impact of Services Trade on the U.S. Economy

To understand how increased trade in services is likely to affect the U.S. economy, requires the detailed information on trade flows described above and the ability to link it to detailed information on domestic producers. Specifically, I would want detailed information on the inputs service firms use (labor, capital, land, buildings, accounting services, intellectual property, etc.) and the outputs they produce (computer programs, lawsuits, ad campaigns, medical operations, etc.). These data would help me understand the relationship between growth in demand for particular services and the demand for inputs to those services. These data would also help me understand whether productivity within the service sector is increasing over time (and whether this growth is in response to particular changes in the environment). To understand how the service sector affects employment outcomes across regions within the United States, I would want these data on a (hopefully detailed) geographic basis. I would also need to be able to link these data to detailed information on international trade in services (the type of information discussed above).[7]

Need: More detailed industry classification

The data covering the service sector within the United States are not as robust as the data for the manufacturing sector in a number of dimensions. The information collected from the service sector—for both inputs and outputs—is less detailed. A simplistic example of how output in the service sector is not collected at as detailed a level as the manufacturing sector is looking at NAICS codes per worker across sectors in the economy.[8] NAICS contains about 470 industrial codes for the manufacturing sector (NAICS 31–33). For the service sector (NAICS 51–81), NAICS contains about 325 industry codes. The manufacturing sector employed about 13 million people and the service sector employed about 68 million workers in 2007. In terms of workers per industry code, there were about 28,000 workers per NAICS code in manufacturing in 2007 and about 208,000 workers per NAICS code in the service sector. By this crude metric, the service sector is substantially underclassified (almost 10 times so).

While the number of industries in the service sector relative to the manufacturing sector is low, the implementation of NAPCS is improving the level of detail for the output of establishments in the service sector. The 2007 economic census forms for the service sector have considerable detail for output product categories within service industries.[9]

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[7] As described above, this type of data is available for the manufacturing sector. The Census Bureau and made available publicly in aggregated form and made available in disaggregated form to approved researchers at the Center for Economic Studies. The research community has learned a great deal about the manufacturing sector across a wide range of topics—productivity dynamics, job creation and destruction, impact of environmental regulation, and impact of trade, just to name a few—through access to producer level information at the Census Bureau.

[8] While this is not necessarily the only (or best) way to think about classification, if one is interested in labor market impacts it is instructive to note the significant difference in the industry detail available across sectors.

[9] While this is helpful, an issue with classifying establishments into broad industries and collecting detailed product information is that it is difficult to allocate inputs across outputs. Additional refinement of the service sector industry codes would improve the ability to measure things like productivity.

Need: More detailed information on inputs to the production process

Another way in which the service sector data are less robust than the manufacturing sector is with regard to the collection of data on inputs into the production process.

> "The Census Bureau has developed detailed classification schemes for material inputs and manufactured products that it uses to collect information on what individual manufacturing establishments buy and sell. These product categories have been developed with a great deal of care, and government surveys have been tuned to specific sectors. For example, establishments in the plastics industry are required to provide detailed information about the consumption of chemical feedstock and the production of various kinds of plastics while establishments producing furniture are required to provide detail about the consumption of wood, metal, hardware, glue, and fabric and the production of various kinds of furniture. This pattern holds true across the manufacturing sector. The U.S. Census Bureau's Numerical List of Manufactured and Mineral Products contains hierarchically organized descriptions of the principal products and services of the manufacturing and mining industries in the United States. These codes are used to collect data for the Economic Census and are used by the Bureau of Economic Analysis for the input-output matrix that underlies the national accounts. But as in international trade in services, far less detail is collected on the services products that are consumed and produced domestically. Again, there are more than 6,000 codes for physical products but fewer than 100 for services.
>
> The lack of detail on domestic trade in services means that the Bureau of Economic Analysis largely estimates the contribution of services to the national accounts. While resulting estimation cannot claim precision, BEA analysts believe that their techniques capture the magnitude and direction of change in services accurately enough to support policy. While this may be true today, we think the view of the U.S. Census Bureau, quoted in full in the previous section, bears repeating, "If [the information gap between manufacturing and services goes] unaddressed, economic policymakers will be increasingly misinformed and misdirected about changes in the real economy, related to rates and sources of growth in output, prices, productivity, and trade." Clearly, an accelerated and sustained effort to collect more detail on domestic trade in services is required. Our second recommendation, therefore, is for the U.S. Census Bureau to accelerate the completion the North American Product Classification System (NAPCS), and fully and rapidly deploy it in the Economic Census, at the establishment level, for both inputs and outputs." (Sturgeon and Levy 2006)

The recommendation above is with regard to purchased inputs used to produce services. I think this is an important improvement that would be beneficial to helping to understand how the service sector functions.

In addition to increased information on purchased services, I would like to suggest two other improvements. We learned from the literature on the impact of trade on the manufacturing sector that factor intensities (both capital intensity and skill intensity) are important determinants of how establishments behave in response to international competition. It would be useful if the Census Bureau would collect information on the skill intensity of the workers that are employed in the service sector. Currently, the economic censuses do not consistently collect information on labor inputs other than total employment and salaries and wages.[10] It would be beneficial if the Census Bureau collected more information than just total employment and wages. I recognize that detailed information on skills or educational attainment would be costly to collect and burdensome to provide. However, I think that the research in the manufacturing sector demonstrates that it is possible to collect very crude classifications (in the case of manufacturing production and nonproduction workers) that still provide important information regarding the skill intensity of firms' production processes.

For services, the production/nonproduction worker classification might not make sense, but an analogous classification might be exempt and nonexempt employees.[11] While not an ideal measure of skill, this classification is likely to capture meaningful variation in skill intensity across producers and industries. It would be relatively easy to collect and probably relatively straightforward for firms to report.

Another input that has proved to be an important determinant in plant survival in the manufacturing sector is capital intensity. Currently, the economic censuses do not consistently collect capital information. While it might not be particularly meaningful for some service industries, for others it is not difficult to imagine that capital intensity would have something to do with firm performance. (One can imagine that capital intensity of hospitals would be systematically related to outcomes and, perhaps, likelihood of participating in international trade.)

Need: Information on a geographic basis

The Census Bureau does collect information on capital expenditures in the Annual Capital Expenditure Survey (ACES); however, ACES is an enterprise-level survey. Because many large firms by employment and output operate in multiple industries and multiple geographic markets, enterprise-level information on capital expenditures makes allocating capital service inputs to locations and industries difficult. This highlights another desirable feature of information on the service sector—geographical information.

To understand how international trade is affecting regions within the United States, it is important to be able to examine how producers in different regions may vary in factor intensity and productivity. This need highlights the importance of collecting as much information as possible at the establishment level.

Collecting information at the establishment level enables researchers to place the economic phenomena in a region and also enables a much tighter alignment of inputs used and outputs (industries/products). Collecting information at the enterprise level seriously reduces the level of

[10] For some industries, the censuses collect information on the type of worker (by training or activity, give examples from engineering, lawyers, doctors' offices).
[11] Employees whose jobs are governed by the Fair Labor Standards Act (FLSA) are either "exempt" or "nonexempt." Nonexempt employees are entitled to overtime pay.

product and geographical specificity of the data. For some purchased inputs (e.g., advertising) it may be difficult to collect the information at the establishment level. Yet, for inputs like physical capital, it seems feasible to collect capital stock and flow data at the establishment level. (Capital stock information is collected in the census of manufactures.)

Need: Researcher ability to access ad link microdata

As I described above, research using microdata provides a better understanding of how globalization affects the U.S. economy. Researchers need access to microdata to conduct this type of research.

> "Steps should be taken to extract as much information as possible from the data that is currently collected by government programs. An inventory of current and potential microdata resources should be made, and as many "micro-data" sets as possible should be archived, maintained, and made available to both government and academic researchers.
>
> Micro-data are the data that supports government administrative programs and underlies published statistics. In general, quantitative research based on micro-data can provide a better and more detailed view of services offshoring and its effects than research based on published statistics."
> (Sturgeon and Levy 2006)

A minor note related to microdata access is the desirability of permitting researchers to combine data that has already been collected in different agencies to answer important questions. This is a cost effective way of increasing the usefulness of data that has already been purchased.

> "Finally, it is important to encourage research that links various sets of micro-data. While there can be legislative and institutional barriers to sharing micro-data across agencies, reducing these barriers could enable some extremely powerful research. For example if the outbound foreign affiliate investment collected by the Bureau of Economic Analysis in its surveys of multinational firms were to be combined with the firm, establishment, and trade data collected by the U.S. Census Bureau, it would help researchers create a more comprehensive picture of the operations of U.S. firms—both at home and abroad. The combined data could reveal domestic activity at the establishment level (with product level information, geographic information, and export information), the relationship between the establishments within the firm, the amount of trading the firm does (using the matched transaction and firm data), and the nature of the firm's foreign affiliate operations (employment, wage bill, location, local sales, trade with parent, etc). This would allow researchers to examine the relationship between domestic activity, trade, and foreign direct investment."
> (Sturgeon and Levy 2006)

I understand the need to protect the confidentiality (and the perception of confidentiality) of respondent level information. My strong sense is that the protocols and infrastructure necessary to protect the confidentiality and perception of confidentiality are in place to restrict access to approved uses within the Census Bureau, the BEA, and the BLS. It is my sense, however, that bureaucratic impediments continue to impede researchers' ability to combine and link datasets from different statistical agencies.

IMPEDIMENTS TO IMPROVEMENT

In this section I describe what I perceive as impediments to improving the quality of data needed to evaluate the impact of trade in services on the U.S. economy.

Resource Issues

As described in the first section of the paper, services are a large, important, and growing sector of the U.S. economy. Yet, the infrastructure for collecting information on the service sector is not as robust as that for other sectors like manufacturing. A primary reason for this disparity is that Congress does not allocate the same level of resources (proportional to the size of the service sector) as it does to the manufacturing or other sectors. Given this, it should not come as a surprise that one impediment to improving statistics on trade in services and domestic service activity is the need for additional resources.

As a simple metric of the disparity in resources devoted to the various sectors, the table below shows the FY 2009 budget for the economic census by sector. I also show the number of employees and the number of establishments in each sector. I then calculate the budget dollars per employee and per establishment across sectors. The table shows that the resources devoted to the service sector on a per employee basis or per establishment basis are significantly lower than those devoted to manufacturing or mining.

On a per establishment basis, Congress allocates more than six times more money for data collection in the manufacturing sector than in the service sector. On a per employee basis, the disparity is smaller, but still more than twice is much is spent per employee in manufacturing than in the service sector. If one compares mining, the disparities are even greater.

Economic Census Program Components (dollars in millions) FY 2009:

U.S. Census Bureau Data Collection Sector	FY 2009 Budget (millions)	2007 Employment	2007 Establishments	Budget per Employee	Budget per Establishment
Services	$39.9	68,026,666	4,382,720	0.59	9.10
Retail Trade	$23.7	15,610,710	1,122,703	1.52	21.11
Manufactures	$17.8	13,333,390	293,919	1.33	60.56
Wholesale Trade	$12.6	6,295,109	432,094	2.00	29.16
Construction	$6.8	7,399,047	725,101	0.92	9.38
Transportation, Communication, and Utilities	$3.1	5,068,192	234,805	0.61	13.20
Minerals	$1.7	703,129	21,169	2.42	80.31

Note: These numbers represent the budget for FY 2009. Not all periodic census activity associated with the Economic Census occurs in FY 2009. However, because the timing of the processing for the various sectors within the Economic Census is similar, I am assuming that the relative size of the budgets is representative of the total costs associated with each sector.
Source: U.S. Census Bureau, Periodic Censuses and Programs Budget Amendment FY 2009, as presented to Congress June 2008, Exhibit 12

This is a simple (maybe simplistic) metric, but it makes the point that service sector data collection is relatively resource poor. To bring the data available for the (domestic) service sector to a similar level as the data available for the manufacturing sector will require a commensurate investment of resources.

To provide information on trade in services comparable to the information on trade in goods does not seem feasible because goods pass through ports and are required to file customs forms or shippers export declarations. These administrative systems provide a relatively inexpensive means for collecting very detailed information on trade in goods. Because traded services do not necessarily pass through ports, there is no obvious low-cost data collection system. It seems likely that collecting information on trade in services will require survey responses from firms. This is obviously more expensive than piggy-backing off administrative systems. To collect better information on services, trade will at a minimum require a significant investment of more resources. In the next sections, I describe what I perceive as additional prerequisites for collecting better trade in services data.

Sampling Frame

An issue identified in the MIT Offshoring Working Group report is that the BEA does not have access to an adequate sampling frame for conducting its surveys of international service transactions. The BEA recognizes the need to improve its sampling frame and is, as described above, taking steps to do so. Yet, I think it remains an open question of whether these modest steps to improve the sampling frame are sufficient. What the BEA needs is access to a sampling frame similar to that maintained by the Census Bureau.

Data-sharing legislation provides authorization for the statistical agencies to share confidential data, but the situation is complicated by the fact that the Census Bureau's business sampling frame contains federal tax information provided by the Internal Revenue Service. For the Census Bureau to share its sampling frame with the BEA or the BLS, companion legislation would have to be passed that would amend section 6103(j) of Title 26 (governing the use of federal tax information). This companion "j-bill" has not passed. If the Census Bureau could provide sampling frame information to the BEA, it would be a significant improvement in the BEA's capacity to conduct surveys. I do not know what the current thinking is on the prospects for passage of the companion "j-bill," but evidence to date leaves one less than optimistic about passage.

As a result of the lack of an adequate sampling frame, resource constraints, and the fact that the principal mission of the BEA is to produce aggregate economic accounts, the BEA focuses its data collection efforts on large organizations that they deem to be likely to trade services. My impression is that the international transaction surveys are not statistically representative samples across service sector industries, firm size classes, or geography. To improve the level of detail available for trade in services statistics, the BEA will need to increase the number of organizations it surveys and, presumably, increase the statistical representativeness of the sample. These will require access to an adequate sampling frame.

Organization Structure

The conference organizers asked that I give some thought to organizational changes that might facilitate improvements in service sector data. This is a potentially provocative topic, so I approach it with some trepidation. Yet, if one takes a step back and looks at the organizational structure for the collection of trade in services data, the choice of organization across agencies is striking. The BEA is a recipient of large amounts of data collected by other statistical agencies (including the BLS and the Census Bureau). It is also a data collection agency. In contemplating this, I was left with the question: Why does the BEA collect information on multinational enterprises and international service transactions?

While not based on much historical research, it is my impression that trade in services statistics have historically been collected largely to fulfill the needs of national income and product account (NIPA) construction. Other types of production and international trade data are collected for a broad range of uses (including and importantly for the NIPAs). Historically, there has not been large demand for detailed trade in service statistics beyond the need to complete the NIPAs. I imagine that as a result of this feature of the data need, it made sense for the BEA to collect the trade in services data.

Yet, I think this is beginning to change. As services share of the U.S. economy increases and trade in services grows, there will be an increasing need to analyze the impact of a broader range of phenomena associated with increased trade in services (e.g., the regional implications within the United States, the impact of the service components of trade agreements).

As I argue in this paper, the need to understand the impact of trade in services—from a variety of perspectives, e.g., impact of trade agreements, exchange rate impact, impact on local and regional economies—require much more detailed data regarding trade in services. Researchers and policymakers need comprehensive data across detailed industry classifications and geographical regions within the United States—ideally not only which firms participate in global services trade, but also which firms don't. The data should be consistent with other production-related data and easily linked to other production data.

Collecting detailed, statistically representative information on trade in services across detailed industries, countries, and regions within the United States is a major undertaking. An open question is whether the BEA is the most appropriate agency to conduct the data collection.

There may be reasons why it makes sense to have a dedicated statistical agency within the BEA for collecting this type of information. However, I see some significant drawbacks for this type of fragmented collection system.

The first drawback is that data collection has fairly significant fixed costs—especially with regard to developing and maintaining a sampling frame. As described above, the BEA's inability to access an adequate sampling frame is a significant impediment to improved trade in services data collection. While I would not present myself as an expert in data collection methods, I can imagine other examples of fixed costs in data collection (e.g., forms design expertise, survey processing and follow-up capacity).

So, I think the big institutional question is why does the BEA collect these data? As identified above, the lack of a proper sampling frame poses a significant impediment to the BEA's ability to carry out a statistically representative sampling of trade in service activity.

Another drawback is data consistency and potential problems with data integration. As an example, when the BEA and the Census Bureau were directed to produce statistics at the establishment level on foreign direct investment in the United States, the data comparability and matching issues were not insignificant. If the foreign direct investment surveys and international service transactions surveys were collected by the Census Bureau using the bureau's sampling frame and industrial and geographic coding systems, it would significantly increase the ease with which the data could be used in conjunction with other production data.

There may be advantages to having the BEA conduct the survey that I am not aware of. The BEA and the Census Bureau work closely on other aspects of data collection for the NIPAs. The bureau has the infrastructure to collect detailed, statistically representative statistics on trade in services. For example, it has arguably the best sampling frame for this type of application within the statistical system. The Census Bureau already surveys all the relevant firms and establishments. It appears to me that the efficiencies in data collection and improvements in comparability from having these data collection activities within the bureau are potentially significant. The costs and benefits of moving the foreign direct investment and international service transactions data collection programs to the Census Bureau should be investigated.

APPENDIX A
SLOAN OFFSHORING WORKING GROUP RECOMMENDATIONS

Our working group had two purposes: 1) to evaluate the data available for characterizing and measuring services offshoring and its effects on the United States economy, and 2) to make recommendations for improvements in data collection, dissemination, and analysis.

We see three broad solutions to this problem, each of which should be aggressively pursued: 1) more and better data on services trade should be collected, 2) more information should be extracted and published from existing data resources, and 3) quantitative research methods should be combined with qualitative methods to provide a better view of the context and character of services offshoring.

Our five recommendations are as follows:

1) Collect more detail on international trade in services.

   The BEA should collect more detail on services products that are traded internationally (affiliated and unaffiliated services imports and exports). It currently collects data on only 17 categories of traded services products. In contrast, import and export statistics for the United States are currently available for more than 16,000 categories of goods. Without a more detailed view of which services are traded internationally, it will remain impossible to determine which sectors experience pressure from import competition. As a result, we cannot know where in the economy to look for the effects of services offshoring with any precision. This in turn renders other data on services less useful.

2) Collect more detail on domestic trade in services.

   The U.S. Census Bureau should accelerate its efforts to collect more detailed statistics on services traded within the United States (services inputs and outputs). These more detailed statistics will help to provide a better view of the role that services play in the economy of the United States. Services account for more than 85 percent of U.S. private sector GDP, but we have very little information on the services that are bought and sold by companies.

3) Collect more detail and publish time series data on employment by occupation.

   Because service work plays a role in all industries, adequate data on employment by occupation is necessary to determine the employment and wage effects of services offshoring. Data should be collected at the establishment level to enable links to data on domestic and international trade. We recommend two concrete steps in this regard:

   1) The BLS should publish consistent time series on employment by occupation from the Occupational Employment Statistics (OES) program. If possible these data should be published by industry at the national, state, and metropolitan

levels. Time-series data will allow policymakers to track employment trends in the occupations most vulnerable to job loss from services offshoring.

2) The BEA should collect data on more occupational categories in its surveys on the activities of U.S.-based multinational firms. More detail on the occupations created by multinational firms, at home and abroad, will provide a clearer picture of the employment effects of services offshoring.

4) Archive and provide access to more microdata resources.

   Steps should be taken to extract as much information as possible from the data that is currently collected by government programs. An inventory of current and potential microdata resources should be made, and as many microdata sets as possible should be archived, maintained, and made available to both government and academic researchers. Microdata are the data that supports government administrative programs and underlies published statistics. In general, quantitative research based on microdata can provide a better and more detailed view of services offshoring and its effects than research based on published statistics.

5) Accelerate research that combines quantitative and qualitative research methods.

   No single approach or dataset can hope to bring the complex and dynamic phenomena of services offshoring into complete focus. An interdisciplinary, collaborative approach is needed to combine insights from data collected by government programs with insights from researcher-generated surveys and field interviews. Quantitative methods allow researchers to estimate the magnitude and speed of economic change and to implement causality tests, while qualitative methods can provide a rich and nuanced picture of the complexity, context, and dynamics of services offshoring.

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Measuring Success in the Global Economy: International Trade, Industrial Upgrading, and Business Function Outsourcing in Global Value Chains

An essay in memory of Sanjaya Lall

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This article contributes to an assessment of the scholarly work of Sanjaya Lall, especially as it relates to improved measures of industrial upgrading and technological learning. We argue for the collection of new statistics, in addition to reworking and linking existing datasets. Changes in the global economy, especially the rise of global value chains (GVCs), have created measurement problems that require not only continued innovation in the use of existing data sources, but also the development and deployment of new measures that analyze GVCs more directly. Specifically, we advocate for the collection of establishment-level economic data according to *business functions*. Data collected according to a standardized set of generic business functions can provide researchers and policy-makers with a better map of the value

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chain, reveal the roles that domestic establishments, firms, and industries play within GVCs, and offer a unique view of the competitive pressures facing domestic firms and industries.

Keywords: global value chains, international trade, business function outsourcing, industrial upgrading, technological learning

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This article contributes to an assessment and celebration of the scholarly and policy work of the late Sanjaya Lall. As Rasiah (2009) highlights, Lall's work was at once broad, deep, and intensely focused. Over his long career, Lall and his many collaborators used the lenses of the transnational corporation (TNC), competitiveness, globalization, and technological learning to uncover the determinants of economic change—or lack thereof—in the developing world. There is a clear continuity to this intellectual path, one that reveals Lall's commitment to empirical investigation, his skepticism of conventional wisdom, his openmindedness, and his sustained focus on improving the lot of those in the world who have less.

During his early career, a time when TNCs were driving rapid economic development in pockets of the developing world, he did not simply celebrate or demonize their presence in host economies; he explored both their positive impact (such as local linkages and technology transfer) and their negative effects (such as crowding out of domestic firms and international transfer pricing). With the organizational fragmentation that came with global outsourcing and the rise of more advanced capabilities in the developing world, Lall added questions related to globalization and technological learning. What is most admirable is that Lall adapted his research and shifted his policy targets as the world economy evolved, while retaining his central focus on the key agents of change and their implications for developing countries. This is the path of a pragmatic, observant and curious mind, guided by a strong moral compass.

The focus of this article is narrower. We assess a single aspect of Lall's work, his technological classification of exports, and related research utilizing international trade statistics, from the point of view of global value chains (GVCs). We see this work on international trade as useful but ultimately limiting. While the techniques for estimating the technological content of trade can certainly be further refined by constructing more sophisticated and detailed product-based analyses of trade flows within or across industries, there is an urgent need to enrich existing metrics with additional data resources and measures that allow us to investigate GVCs more directly. In our view, changes in the global economy, and especially the rise of GVCs, have created measurement problems that require new information and new methods. In an effort to be constructive as well as critical, we propose one possible approach: the collection of economic data according to a generic and parsimonious list of *business functions*.

TRACKING GLOBAL SHIFTS: CONCEPTUAL AND MEASUREMENT ISSUES

Among the enduring mysteries of political economy is why some places surge ahead in the global economy while others grow more slowly or fall behind in relative or even absolute terms. Is it sound macroeconomic policy, the development of human capital, protection under the geopolitical umbrella of a superpower, sector-specific industrial development policies, natural resource endowments, or some combination that have led to the success of certain countries, especially in East Asia (Deyo 1987; World Bank 1993)? There are also debates about the optimal industry structures for technological learning and industrial upgrading. Is a concentrated industrial structure best because large firms can afford to invest in major research and development (R&D) efforts, or are open, flexible networks of small and medium-sized firms better able to identify and fit into ephemeral niches of a fast changing global economy (Piore and Sabel 1982; Amsden 1989; Wade 1990)? The institutional basis for development has also been a topic of much debate (Evans 1995; Berger and Dore 1996; Hall and Soskice 2001).

For Sanjaya Lall and many others (e.g., Kimura 2007), learning is the key to industrial upgrading. For places that are behind, learning must, at least in part, come from absorbing knowledge created elsewhere. Many mechanisms for this have been examined, from arms-length technological "borrowing" (Amsden 1989) through a range of practices that encompass technology licensing, reverse engineering, the injection of equipment and know-how through foreign direct investment, and firm-level adaptation to demands made by both foreign affiliates and overseas buyers (Gereffi 1994; Feenstra and Hamilton 2006).

Answers to these questions are complex, and debates about what shapes economic development outcomes will certainly continue. However, we are now at a critical juncture where rising complexity in the global economy has begun to overwhelm the slow and partial analytical progress that has been made in the past 25 years. Recent examples, such as how firms based in the United States, Japan, the Republic of Korea, and Taiwan Province of China interact with each other and with local firms to produce Apple iPods in southern China for export to world markets (Linden et al. 2007), illustrate both the intricacies of economic globalization and the limits of existing data. In this setting some of the core assumptions of mainstream economics—that demand begets supply, that nations draw mainly on their own knowledge and physical resources to compete with other nations, that exports reflect the industrial capabilities of the exporter, that firms and individuals act independently, rationally and at arms-length, and so on—appear, if not as gross distortions, then as quaint reminders of simpler times. But if the tools of mainstream economics are being blunted by global integration, so too are those offered by other social science disciplines, which typically assume levels of institutional and cultural cohesiveness and economic autarky that no longer exist.

For us, the GVC framework provides a useful guide as we seek answers to questions about the dynamic political economy of industries.[12] GVC analysis highlights three basic characteristics of any industry: 1) the geography and character of linkages between tasks, or stages, in the chain of value added activities; 2) how power is distributed and exerted among firms and other actors in the chain; and 3) the role that institutions play in structuring business relationships and industrial location. These elements help explain how industries and places evolve, and offer clues about possible changes in the future. The chain metaphor is purposely simplistic. It focuses on the location of work and the linkages between tasks as a single product or service makes its way from conception to end use.

The analysis of GVCs identifies new actors in the global economy (e.g., global buyers and global suppliers) and shows how their emergence alters the ways that industries are organized and governed across borders (Gereffi 2005). Recent theorizing about the governance of GVCs highlights three key determinants that affect the organization and power dynamics within GVCs (complexity, codifiability, and supplier competence), and characterizes three distinct business network forms (modular, relational and captive) that lie between the classic duality of arms-

[12] See www.globalvaluechains.org for more detail on this approach and a list of publications and researchers that directly engage with it.

length markets and hierarchies (i.e., vertically integrated firms) (Gereffi et al. 2005). The GVC governance types were derived from direct field observation in a variety of global industries, including footwear and apparel (Bair and Gereffi 2001, Gereffi 1999; Schmitz 1999), horticulture (Dolan and Humphrey 2000), bicycles (Galvin and Morkel 2001), electronics (Borrus et al. 2000; Lee and Chen 2000; Sturgeon 2002), and motor vehicles (Humphrey 2003; Sturgeon and Florida 2004).

Qualitative industry research and conceptual theory building of this sort have been extremely helpful in developing the framework, in identifying emerging trends in GVCs, and in providing researchers and policymakers with a vocabulary to discuss some of their key features without getting bogged down in industry-specific nomenclature. The framework has been used, challenged and extended in recent research on industries such as tourism (Barham et al. 2007), electronics (Vind and Fold 2007), textiles and apparel (Evgeniev 2008), motor vehicles (Sturgeon et al. 2008), and coffee and tea (Neilson and Pritchard 2009), and in regions such as Latin America (Pietrobelli and Rabellotti 2007) and East Asia (Kawakami and Sturgeon forthcoming).

A major impediment to using qualitative research and conceptual theories to support specific policy interventions is the lack of comparable and detailed data on the industrial capabilities of firms, industries, and countries and the roles that they play in the global economy. The GVC framework provides a conceptual toolbox, but quantitative measures are lacking. While the development of objective, industry-neutral measures of GVC governance is a laudable goal, and survey questions are currently being fielded to collect data on the governance character of interfirm linkages in both cross-border and domestics sourcing relationships, better information to characterize the roles of firms, regions, and countries in GVCs is urgently needed.[13]

In this article, we examine the state of the art in GVC metrics and chart a way forward. First, we summarize some of the best recent academic research that has used official statistics to examine issues related to GVCs and industrial upgrading, including Lall's (2000) technological classification of exports, Feenstra and Hamilton's (2007) trade-data archeology, research on intermediate goods trade, and efforts to enrich trade data by linking it to "microdata" underlying national statistics and policy programs. We then point to what is perhaps the most glaring data gap of all: the appallingly poor level of product detail in international services trade.

While the research we review provides useful insights into the dynamics of GVCs and helps to identify some of the key drivers of industrial upgrading, we are left with a dilemma. The rise in intermediate goods trade strongly suggests that countries no longer rely only or even primarily on domestic resources to develop and export products to the rest of the world. Countries and regions do not make products and deliver services in their entirety, but they have come to specialize in specific functions within larger regional and GVCs. Surging trade in services complicates the picture. As a result, industrial output and trade statistics provide a very partial and even misleading view of where value is created and captured in the global economy.

[13] Specifically, Statistics Canada, in an international sourcing survey currently being tested, asks firms if relationships with important suppliers are simple market relationships or something more complex, and if transactions involve the exchange of codified or tacit information.

Even the best trade statistics, as they currently exist, can only hint at what is happening in GVCs and how this sort of "integrative trade" (Maule 2006) is shaping development outcomes. If key GVC-related questions are not asked on any official survey and do not exist on any administrative form, then existing data resources can never yield adequate results. Thus, there is an urgent need to collect new information. To illustrate, we present a new business function classification scheme that is currently being developed and deployed by statistical agencies and academic researchers in North America and Europe in the hope that it will soon be standardized and adopted more broadly.[14]

WHAT TRADE STATISTICS CAN REVEAL ABOUT GLOBAL VALUE CHAINS

Data on international trade in physical goods and commodities are available in considerable detail online in the United Nations Statistical Division's Commodity Trade Statistics Database (known as UN COMTRADE). The database contains import and export statistics reported by the statistical authorities of nearly 200 countries, from 1962 to the most recent year, currently 2006 to 2008, depending on the country.[15] Because these data are collected from many different national statistical agencies, they vary in quality and coverage. Nevertheless, the UN COMTRADE database provides information on imports and exports by value and in some cases by the number of units or volume shipped, according to seven different product (commodity) lists, the most detailed being the 2002 Harmonized Tariffs Code list, which at the 6-digit level includes more than 8,000 product descriptions.[16]

The fine-grained product detail and the ease of access to COMTRADE data have allowed researchers to create alternatives to the industry classification schemes that its commodity lists are based on. While industries are an important and often relevant category, they typically contain products that are very heterogeneous in terms of labor or capital intensity, technological content, and so on. This section examines three distinct approaches to analyzing trade data that shed light distinct aspects of GVC development and industrial upgrading. The first is Sanjaya Lall's (2000) classification of technological sophistication, which groups products based on their technological requirements. Increases in "high technology" exports suggest that learning and industrial upgrading is taking place in the exporting country. Second is the trade-data archaeology approach developed by Feenstra and Hamilton (2006), which tracks highly detailed export flows from the Republic of Korea and Taiwan Province of China to the United States over long periods of time. This approach reveals that specific products, rather than broad industries, have been key to upgrading in these countries (e.g., microwave ovens from the Republic of Korea, not white goods in general; computer monitors from Taiwan Province of China, not electronics in general). Feenstra and Hamilton also tie these exports of narrow product categories to the strategies of United States retailers and marketers to show how buyer-driven GVCs have influenced development outcomes in East Asia. The third is work on the relationship between

[14] See, for example, the National Science Foundation–funded Project, "A National Survey of Organizations to Study Globalization, Innovation and Employment." http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0926746&version=noscript.
[15] See http://unstats.un.org/unsd/comtrade/.
[16] The United States data, published by the Department of Commerce, is available at the 10-digit HTC level and includes more than 16,000 product descriptions.

GVCs and intermediate goods trade. Increases in intermediate goods trade signals the geographic fragmentation of the production process driven, we argue, by the increasing importance of GVCs in international trade.

Upgrading As Learning: Sanjaya Lall's Technological Classification of Exports

Gereffi (2005, p. 171) defines industrial upgrading as "the process by which economic actors—nations, firms and workers—move from low-value to relatively high-value activities in global production networks." Lall et al. (2005) share this view and start with a reasonable assumption, that the learning required to export high value-added, technology-intensive products will be greater than for simpler products. Even if the knowledge embedded in imported intermediate inputs and machinery and know-how from foreign affiliates and global buyers is invisible in export statistics, as they typically are, we can at least assume that technology-intensive exports heighten the *potential* for rapid learning by local actors.

To examine the path of technological learning in the global economy using export statistics, Lall (2000) devised a technological classification of goods exports. To provide an example of how we can assess industrial upgrading for export-oriented economies, we examine shifts in the technology content of China's and Mexico's exports over time. Following Lall (2000), we divide each country's exports into five product groupings, which are listed in ascending levels of technological content: primary products; resource-based manufactures; and low-, medium-, and high-technology manufactures (see Table 1).[17] The main contributing industries to each category (agroforest products, textile and apparel, automotive, and electronics) are broken out to simplify the analysis.

[17] Lall (2000) developed this technological classification of exports based on 3-digit Standard International Trade Classification (SITC) categories. His article provides the detailed list of products under each category.

Table 1. Lall's Technological Classification of Exports

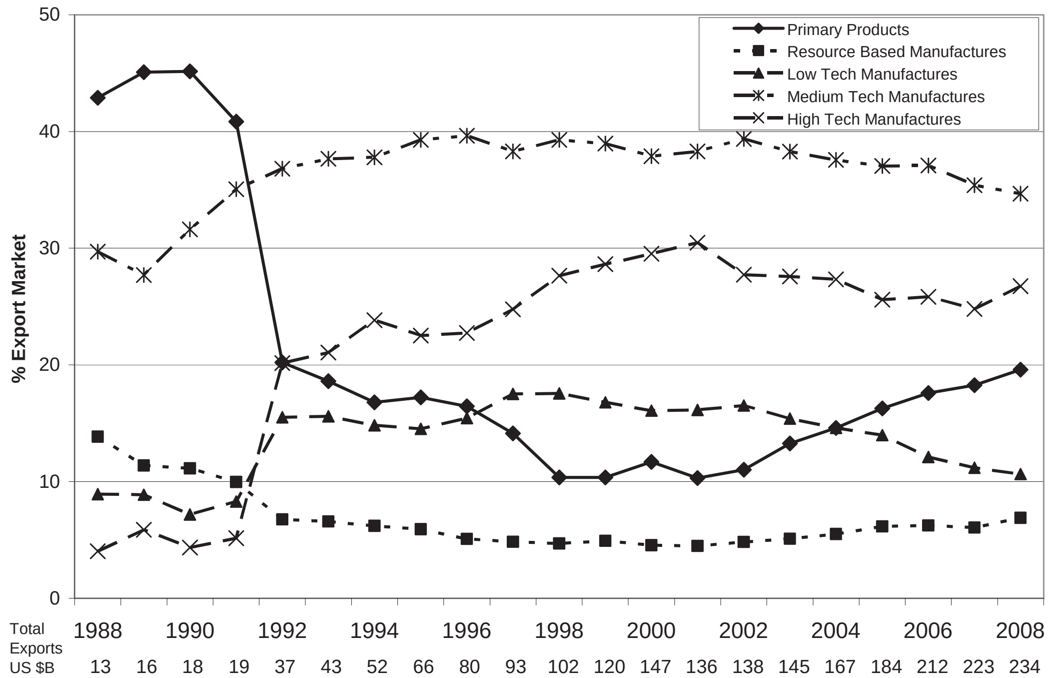
Classification		Examples
Primary products (PP)		Fresh fruit, meat, rice, cocoa, tea, coffee, wood, coal, crude petroleum, gas
Manufactured products		
Simple Manufactures	RB: Resource based manufactures	
	RB1: Agro/forest based products	Prepared meats/fruits, beverages, wood products, vegetable oils
	RB2: Other resource based products	Ore concentrates, petroleum/rubber products, cement, cut gems, glass
	LT: Low technology manufactures	
	LT1: Textile/fashion cluster	Textile fabrics, clothing, headgear, footwear, leather manufactures, travel goods
	LT2: Other low technology	Pottery, simple metal parts/structures, furniture, jewellery, toys, plastic products
Complex Manufactures	MT: Medium technology manufactures	
	MT1: Automotive products MT2: Medium technology process industries	Passenger vehicles and parts, commercial vehicles, motorcycles and parts Synthetic fibres, chemicals and paints, fertilizers, plastics, iron, pipes/tubes
	MT3: Medium technology engineering industries	Engines, motors, industrial machinery, pumps, switchgear, ships, watches
	HT: High technology manufactures	
	HT1: Electronics and electrical products	Office/data processing/telecom equip, TVs, transistors, turbines, power gen. eqp.
	HT2: Other high technology	Pharmaceuticals, aircraft, optical/measuring instruments, cameras
Other transactions		Electric current, cinema film, printed matter, special transactions, gold, works of art, coins, pets

Source: Lall (2000, p. 341).

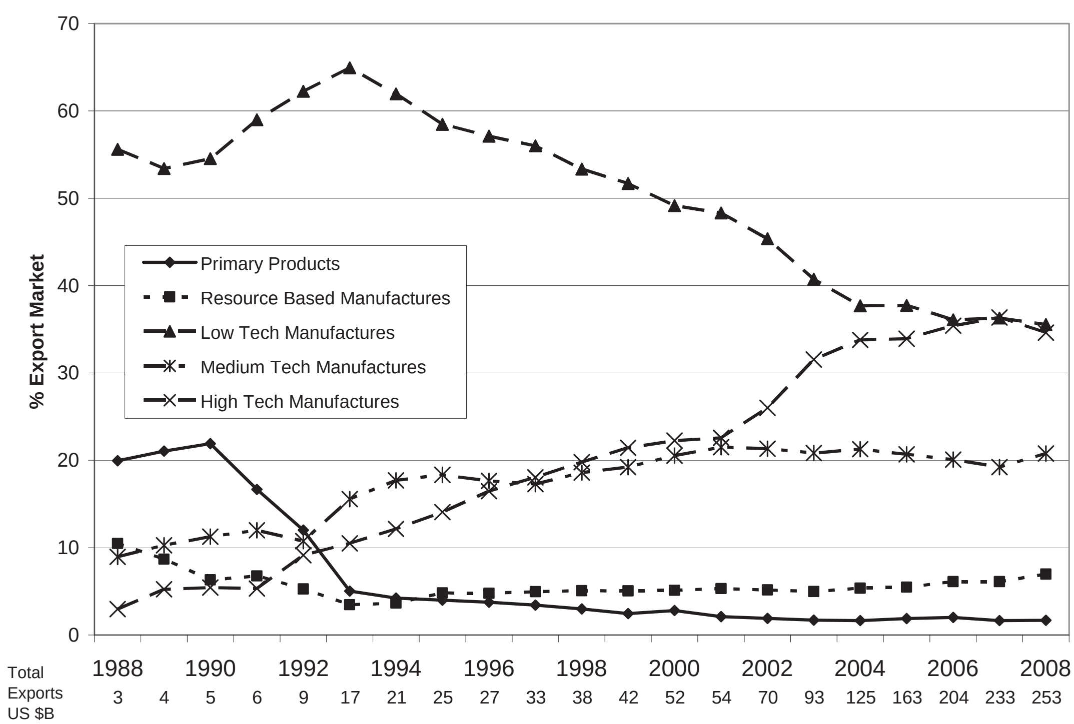
In Figure 1, panel 1, we see that in 1988, 45 percent of Mexico's total exports to the United States market were primary products, the most important of which was oil. In 1993, one year prior to the establishment of the North America Free Trade Agreement (NAFTA), medium-technology manufactures (mainly automotive products) and high-tech manufactures (largely electronics items) moved ahead of raw materials in Mexico's export mix. By 2008, over 60 percent of Mexico's exports of $234 billion to the United States market were in the medium- and high-technology product categories, followed by primary products with 20 percent of all exports (which rebounded from their nadir of 10 percent of total exports in 2001) and low-technology manufactures (such as textiles, apparel, and footwear). Thus, in just two decades, Mexico's export structure was transformed from one based on raw materials to one dominated by medium- and high-technology manufactured items.

Figure 1. Technological Composition of Mexico's and China's Exports to the United States, 1988 – 2008

Panel 1: Technological Composition of Mexico's Exports to the United States



Panel 2: Technological Composition of China's Exports to the United States



Source: UN Comtrade (http://comtrade.un.org/db/dqBasicQuery.aspx).

In Figure 1, panel 2, we see the composition of China's exports to the United States market during the 1988–2008 period. Unlike Mexico, the leading product category in China's exports to the United States market in 1988 was low-technology manufactured goods. These were primarily made up of a wide variety of light consumer goods, such as apparel, footwear, toys, sporting goods, housewares. These products accounted for about two-thirds of China's overall exports to the United States in the early 1990s. By 2008, however, high-technology exports had increased to 35 percent of China's total exports to the United States market, and were virtually tied with low-technology exports for the top spot in China's export mix.

Thus, Mexico and China have a number of commonalities in their export trajectories to the United States market during the past two decades. Both are diversified economies, with a range of export product types. In both cases, manufactured exports are more important than primary product or resource-based exports; within manufacturing, high- and medium-technology exports are displacing low-technology goods. While these export data have limitations as indicators of industrial upgrading, as we will discuss below, both economies appear to be increasing the technological sophistication of their exports.

Trade-Data Archaeology

Feenstra and Hamilton (2006) utilize highly disaggregated international trade statistics to shed new light on the debate surrounding the origins of the "East Asian miracle." Conventional explanations of East Asia's economic success—beginning with Japan in the 1950s and 1960s, and including the Republic of Korea, Taiwan Province of China, Hong Kong (China), and Singapore in the 1970s and 1980s—revolve around the role of markets and states in promoting export-oriented industrialization in this region. The World Bank and neoclassical economists have favoured the market-friendly explanation, which focuses on the solid macroeconomic fundamentals in the early East Asian industrializers (World Bank 1993), while other scholars have highlighted the directive role of the state in promoting this transition (Amsden 1989, Wade 1990, Evans 1995). Feenstra and Hamilton offer a contending demand-side perspective to account for the sustained export success of the Republic of Korea and Taiwan Province of China, which ties their performance to the retail revolution and the rise of "big buyers" in the United States (see also Gereffi [1999]).

Using what they call "trade-data archaeology," Feenstra and Hamilton recreate the export trajectories of the Republic of Korea and Taiwan Province of China, not merely at the level of industries, but by tracing the flow of very specific products over several decades from the early 1970s to the present. This approach reveals that the Republic of Korea's and Taiwan Province of China's dramatic export success was actually concentrated in a handful of product categories, such as garments, footwear, bicycles, toys, televisions, microwave ovens, computers and office products. The analysis shows that although exports from Taiwan Province of China and the Republic of Korea were in the same industries, they specialized in different kinds of products within these industries: the Republic of Korea's large vertically integrated *chaebol* firms emphasized mass-produced, standardized items, while Taiwan Province of China excelled in making a wide variety of more specialized products that fit the capabilities of the smaller firms that dominate the island's diversified economy.

The authors go beyond standard supply-side accounts of East Asia's export success by showing precisely how these exports were linked to the "retail revolution" in the United States, where retailers (such as Sears, JC Penney, Kmart, and Wal-Mart) and companies with global brands (such as Nike, Liz Claiborne, Disney, and many others) set up international sourcing networks to tap and expand the global supply base. It was the dynamics within GVCs, as much as any supply-side market or state-society characteristics, that fuelled the export-oriented development model that has been promoted by the World Bank and a variety of international development agencies since the 1980s. The fact that both the Republic of Korea and Taiwan Province of China developed these "demand-responsive" economies has important theoretical implications for economic sociology and international trade theories alike (Hamilton and Gereffi 2008).

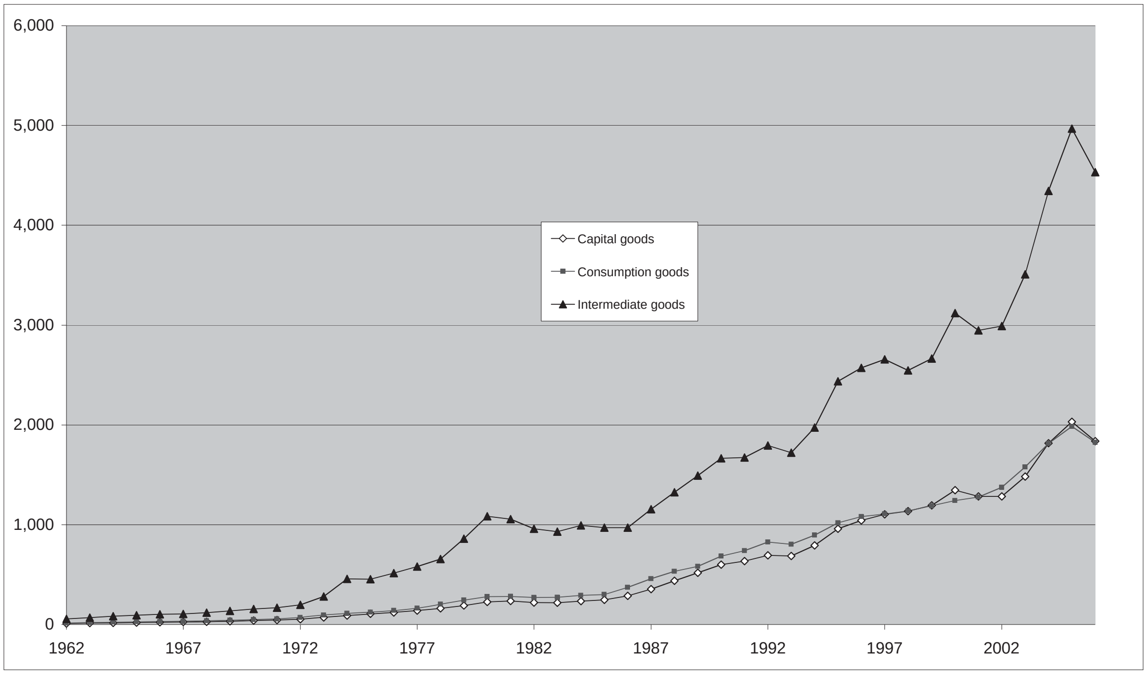
Examining Intermediate Goods Trade

Merchandise trade has increased dramatically since the 1970s, far surpassing pre-World War I peaks in most OECD countries. Feenstra (1998) notes a sectoral shift in U.S. imports away from agricultural products and raw materials and towards capital and technology-intensive goods. Explanations include trade liberalization, falling transportation costs, and equalization of gross domestic products (GDPs) among trading countries, given the tendency for countries of similar size trade more than countries of disproportionate size. Of course, there are many other possible explanations for these shifts, including rising production skills and better capital stock in poor countries and speedier transportation, which opens up trade for perishable goods such as fresh vegetables as well as for goods with very volatile prices, such as computer memory.

The rise of GVCs is not only enabled by these factors, but is itself a cause of trade increases. As Feenstra (1998, p. 36) argues, the geographic fragmentation of production causes increases in the volume of total trade because intermediate inputs may cross borders several times before final products are delivered to end users. Thus, the trade content of an average product rises when it is made in the context of GVCs.

The fact that intermediate goods trade is rising much faster than overall trade has stimulated a vast body of research and multiple labels, including a new international division of labor (Fröbel et al. 1980), multistage production (Dixit and Grossman 1982), slicing up the value chain (Krugman 1995), the disintegration of production (Feenstra 1998), fragmentation (Arndt and Kierzkowski 2001), vertical specialization (Hummels et al. 2001), global production sharing (Yeats 2001), offshore outsourcing (Doh 2005), and integrative trade (Maule 2006). Sturgeon and Memedovic (forthcoming), using the UN's broad economic categories of consumption, capital, and intermediate goods, calculate that global trade in intermediate goods has far outpaced these other categories (Figure 2). This rise is most dramatic after 1992, when the developing world was linked more systematically in GVCs. The share of worldwide imports of intermediate goods by developing countries increased from only 25.5 percent in 1992 to 35.2 percent in 2006. During this period total trade in intermediate goods grew 2.2 times in industrialized countries and 3.4 times in developing countries.

Figure 2. Intermediate, capital, and final goods trade, 1962–2006 (millions of constant U.S. dollars)



Source: Sturgeon and Memedovic (forthcoming).

While soaring intermediate goods trade is a strong indicator of the rise of GVCs, their growing dominance of world trade can lead to odd and confusing metrics. For example, because Malaysia imported so many intermediate goods for inclusion in exports, its ratio of exported goods and services to GDP in 2005 reached 123.4 percent (World Development Indicators 2007). Such ratios are not uncommon in classic entrepôt economies such as Singapore and Hong Kong (China), and as a comparative measure of trade integration this is fine, but upon seeing such statistics without reference to GVCs, one has to wonder how a country can export more than it produces.

Clearly, the global economy is changing. Rising intermediate goods trade means that goods are flowing, increasingly, within the same industry. Research on intraindustry trade (Grubel and Lloyd 1975; Lloyd and Lee 2002) has shown steady increases of about 4–5 percent per year in countries trading the same or seemingly similar products. This challenged the central tenet of Ricardian trade theory: country specialization according to factor-based comparative advantage that would lead only to interindustry trade. Finger (1975) claims that coarse industry classifications disguised vast heterogeneity within industries; in other words, countries could specialize within the same industry, especially in intermediate inputs versus final goods.

For Krugman (1991), intraindustry trade is driven by firms seeking increasing returns from large-scale production, thereby generating exports, while consumer demand for product variety stimulates imports of very similar products. Although this work was based on horizontal differentiation (of similar products), the quality ladder-growth models from Grossman-Helpman

(1991), which are formally very similar to Krugman's model, have a vertical dimension that includes intermediate goods. Others have tested and refined these theories in the context of East Asia's economic rise (Ng and Yeats 1999) and provided evidence of increasing "vertical" specialization in intermediate inputs (Hummels et al. 2001). Using updated statistics, Brülhart argues that ". . . since the 1990s, [the increase in intraindustry trade] appears to be driven to a significant extent by the international fragmentation of vertical production chains" (Brülhart 2008, abstract).

Our argument is that trade statistics can only hint at the changes occurring in the global economy. Trade statistics alone contain very partial information about the location of value added, and no information about ownership of productive assets and output, where profits are reaped, or how these increasingly complex systems are coordinated. Certainly, work will continue on the causes and meaning of interindustry trade. But there are limits to what can be learned from trade statistics alone.

USING ADMINISTRATIVE AND MICRODATA RESOURCES TO UNDERSTAND GLOBAL VALUE CHAINS

Linking trade statistics to other datasets can enhance their usefulness. Through careful matching, or by taking advantage of especially rich administrative data,[18] researchers can sometimes push beyond the limitations of published statistics. A host of government programs collect detailed economic data. Typically more detailed microdata underlie what is ultimately made available to the public. While these data are usually confidential, researchers who gain security clearance and have their proposals accepted by data collection agencies can gain access, as along as government personnel screen the results before the research is published. Some microdata sets have also been assembled by data agencies and released, with confidential information removed, as public-use files. Over the past decade, a burgeoning body of research has relied on government-collected microdata. In this section, we provide a few examples.

Feenstra and Hanson (2004, 2005) take advantage of administrative data from Mainland China and Hong Kong (China) to reveal new information about the workings of GVCs. Specifically, the data contain reexport values for Hong Kong and information about factory and input ownership in China. These data allow the authors to estimate the mark-up charged by Hong Kong–based GVC "intermediaries" such as Li and Fung, a trading company. The authors also use these data to calculate the share of China's exports to Hong Kong that are reexported (45.4 percent in 1998), an indicator of the important coordination role that companies like Li and Fung play in GVCs, especially in apparel and other consumer-goods industries. By taking advantage of data that describe the ownership of factories exporting from China, the authors are able to show that independent suppliers working under "export processing" arrangements (i.e., suppliers that are provided with inputs by intermediaries and their customers) are much more likely to send goods through Hong Kong for reexport than exporting factories that are wholly owned by non-Chinese firms.

[18] Governments collect data for the purpose of administering their programs such as tax collection, compliance with environmental protection laws, and the like. For this reason, such data are typically referred to as "administrative data."

Feenstra and Spencer (2005) use the same Chinese data, from 1998 through 2000, to explore the relationship between outsourcing arrangements (arms-length vs. contractual) and the proximity of suppliers (on-shore vs. offshore). They find that relationships vary according to the technological sophistication of the product being outsourced. The more technologically sophisticated the product, the more likely it is that firms will source from affiliates or outsource to suppliers located nearby. Dani Rodrick and his collaborators (Haussman et al. 2006) use these data to show that the basket of goods exported by China is of higher technological content than would be predicted by its GDP per capita (using averages for all other countries' export mixes).

By linking these same data to Chinese input-output data, Dean, Fung, and Wang (2007) estimate that China's "vertical specialization," that is, the use of imported intermediate inputs in exported goods, increased between 1997 and 2002 in most industries. This is the opposite of what one would expect. Instead of engaging in progressive import substitution as domestic capabilities rise, as most theories of development predict, China increased its reliance on imported intermediates as exports increased. Here we see that, because of the intricacies of production and trade networks within GVCs, we cannot assume deterministic causal linkages between export-led industrialization, the technological content of exports, and industrial upgrading.

Researchers have creatively used microdata to explore specific questions related to GVCs. For example, Bernard et al. (2005) link administrative data from U.S. census mailing lists to the universe of import and export transactions for 1993–2000, revealing a detailed picture of the characteristics of firms that do and do not trade.[19] Harrison and McMillan (2006) and others have used the parent and foreign affiliate microdata from the Bureau of Economic Analysis surveys on TNCs to examine the relationship between affiliate activity and United States employment. Swenson (2005) has examined the permanency of offshore assembly arrangements using extremely detailed data from United States International Trade Commission (USITC) reports. Kletzer (2002) has used microdata from the Displaced Worker Survey to explore the experiences of workers displaced from manufacturing industries associated with increased foreign competition, and has made policy recommendations based on her findings.

Administrative microdata from public surveys and linked datasets can enrich our view of how domestic firms engage with the global economy. Microdata collected from TNCs, for example, when combined with data on international trade, can provide new information about the cross-border activities of TNCs and how they use local resources in offshore locations. Such approaches can be difficult to replicate and extend, however, because not all researchers can access confidential microdata, and because the painstaking work of cleaning and matching raw microdata files can be very difficult for other researchers to understand and replicate. Furthermore, unique administrative datasets tend to be available only for individual countries, and data collected in support of specific policy initiatives are commonly phased out after the

[19] We are referring here to the United States Census Bureau's Business Register, which is the sampling frame used for the Economic Census. Data included are business name, address, a unique establishment-level identifier, industry, employment, and the identity of the firm that owns the enterprise. Data about ownership allows the enterprises in the Business Register to be aggregated to the firm level. Jarmin and Miranda (2002) have assembled the Business Register into a time-series for 1976-2002, referred to as the Longitudinal Business Database (LBD).

programmes they were intended to support come to an end. As a result, studies based on microdata can have limited scope with regard to multiple countries and longer-term trends.

WHAT TRADE STATISTICS HIDE

The easy availability and richness of UN COMTRADE data has led to their wide use among researchers and policymakers. However, we need to keep in mind what trade statistics do not tell us, and even what they might obscure. First, trade data contain no actual information about the process by which products are made. Certain production processes, such as semiconductor wafer fabrication, involve the manipulation of items so small, or require tolerances so exact, that they have moved beyond the limits of human dexterity and must always be carried out by machines. Other processes, such as sewing, have so far resisted automation and can only be done by hand. But for a very wide range of products and processes, the labor content of production is variable. The degree of labor or capital intensity used in production is, in many instances, a strategic managerial choice rather than an intrinsic characteristic of the product. Thus, we cannot rigidly associate technological content or capital requirements with most specific categories or classes of products. Industries are even poorer indicators of technological sophistication.

Furthermore, the technological content of high-technology exports may be embodied in imported components, subsystems, or production equipment. The highest value-added elements of high-technology exports from developing countries are often produced in a third country. Even if these "high-tech" inputs are produced locally, and final assembly processes are truly technology intensive, they may be carried out by foreign-owned and operated firms with few meaningful linkages to the local economy. With rising wages, worker militancy, political friction, or even a prolonged natural disaster, such footloose firms might easily pack up and move elsewhere. Thus, trade statistics run a real risk of overstating the technological competence of exporters, and especially of local firms.

Even when production is carried out by local firms and is truly technology intensive, the reality of GVCs is that the innovative work of product conception, design, marketing and supply-chain management may well continue to be conducted outside of the exporting country. These "intangible assets" cannot be measured by current international trade statistics. The value of imports plus the intangible assets held by the most powerful firms in GVCs, such as lead firms with global brands, suppliers with platform leadership (Gawer and Cusumano 2002), and large retailers, can be extremely high.

For example, Linden et al. (2007) estimate that only $4 of the $299 retail price of an Apple 30 gigabyte video iPod MP3 player is captured in China, where they are assembled and tested by the contract manufacturers based in Taiwan Province of China, Hon Hai (also known as Foxconn), Asustek, and Inventec. This is in part because iPods are assembled from components made mostly in other countries, such as the United States, Japan, and the Republic of Korea. But more importantly, it is because Apple, which conducts high-level design work and software development in house and orchestrates the product's development, production, marketing, and distribution, is estimated to capture $80 of the sale price. This study also estimates that $83 is captured in the United States by Apple's technology suppliers and by retailers. Clearly, assigning the $183 per unit wholesale price of exported iPods (as would be reported in trade statistics) to the Chinese economy misrepresents where value is created in the global economy. It also would be a mistake to conclude that Chinese firms have the capability to develop and market products such as the iPod simply because the country is the source of exports.

A Glaring Data Gap: Services Trade

The easy availability and richness of UN COMTRADE data has tilted research on international trade toward the goods sector. While this work has contributed greatly to our understanding of international trade and its impacts on various national economies and industries, the lack of similar detail or global coverage on international trade in services has created a significant knowledge gap. In the case of the United States, the Bureau of Economic Analysis collects import and export data for only 17 service product categories (see Table 2). Statistics Canada collects only 28, and the OECD, which relies on member countries for data, publishes only 11. Contrast the poor detail in traded services with detail on goods in the COMTRADE database (8,000 product codes) and the magnitude of the data gap becomes clear.

Because of this data gap, we lack the basic knowledge about services trade needed to even glimpse trends in industrial upgrading driven by services. The paucity of detail in services means that we have no information about what is happening in the service product categories that have been mentioned as moving offshore from developed to developing countries, including back-office functions such as accounting, customer support, R&D, and software programming.

Why are the data resources related to services so poor? One reason is that the data are difficult to collect. While companies might track the source of every physical input to manufacturing, for warranty or quality control purposes, services expenditures are typically grouped into very coarse categories, such as “purchased services.” The absence of tariffs on services, and their nonphysical character, means that when service work moves across borders, no customs forms are filled out and no such data are generated. Another reason is that service work has historically been thought to consist of nonroutine activities that require face-to-face contact between producers and users. Services as different as haircuts and legal advice have traditionally been consumed, in place, as soon as they are produced. The customized and ephemeral nature of many services has led them to be considered “nontradable” by economists or at least very “sticky” in a geographic sense relative to the production of tangible goods. Finally, services have long been viewed as ancillary to manufacturing, either as direct inputs (e.g., transportation) or as services provided to people who worked in manufacturing (e.g., residential construction, retail sales, etc.). As such, services have been viewed as a by-product, not a source, of economic growth. Thus, data collection on services has been given a low priority by statistical agencies.

Table 2. The 17 product categories collected by the U.S. Bureau of Economic Analysis for traded services

Travel, passenger fares, and other transportation services (1)	**Royalties and license fees (2)**	**Education (3)**
Financial services (4)	**Insurance services (5)**	**Telecommunications** services **(6)**
Business, professional, and technical services		
Computer and information services Computer and data processing services (7) Database and other information services (8)	Management and consulting services (9)	Research, development and testing services (10)
Construction, architectural, engineering services (11)	Industrial engineering services (12)	Operational leasing services (13)
Installation, maintenance, and equipment repair services (14)	Advertising services (15)	Legal services (16)
Other business, professional, and technical services (17)		

Source: U.S. Bureau of Economic Analysis.

Nevertheless, services trade is burgeoning, both domestically and internationally. Computerization is allowing a growing range of service tasks to be standardized, fragmented, codified, modularized, and more readily and cheaply transported between producers and consumers who might be at great distance. As in goods production, the application of information technology to the provision of services allows some degree of customization within the rubric of high volume production, or what Pine and Davis (1999) call “mass customization.” With computerization and inexpensive data storage, the second defining feature of services, that they cannot be stored, has also become less true than in the past. With deregulation, business process outsoucing, and the rise of the Internet, services have become the focus of intense international competition and rampant innovation. Clearly, the assumptions behind current data regimes have changed and statistical systems must catch up.

Recent progress has been made in the context of NAFTA. In the spring of 2006, the U.S. Census Bureau, in collaboration with its counterpart agencies in Canada and Mexico, completed the development of 99 detailed product lists that identify and define the significant products of about 370 service industries. Work to date on the North American Product Code System (NAPCS) has focused on the products made by service industries in 12 two-digit industry sectors (48–49 through 81). In all, more than 3,500 individual service products have been defined. The NAPCS product definitions are extremely detailed in terms of what they do, and in many cases do not, include. This level of detail, if fully deployed, would go a long way toward filling the data gap in services trade.[20]

[20] For more information on NAPCS, see http://www.census.gov/eos/www/napcs/napcs.htm.

To sum up, data resources are falling behind economic realities. Innovative work to create new classification schemes from disaggregated datasets, to mine microdata from government surveys and administrative records (as well as from private sources), and to combine and match data to create new data resources, is breaking new ground and providing important insights. A few of the most severe data gaps could eventually be filled. However, more needs to be done to collect data specifically designed to provide insights into the characteristics and effects of GVCs. Work of this sort is proceeding along multiple fronts, including the surveys that test the GVC governance framework developed by Gereffi et al. (2005) and the quantification of value capture in specific GVCs (Linden at al. 2007). Equally important is the ongoing stream of detailed field-based research on the functioning of GVCs, in particular industries and places (e.g., Kawakami and Sturgeon forthcoming). In the next section, we propose another approach: the collection of a broad range of economic data, such as employment, sourcing locations, and job characteristics according to an exclusive, exhaustive, parsimonious, and generic list of *business functions*.

COLLECTING NEW DATA ON BUSINESS FUNCTIONS

Vertical fragmentation and the growth of integrative trade—the very stuff of GVCs—has served to expand the arena of competition beyond final products to the vertical *business function* slices that can be offered (horizontally, to diverse customers) as generic goods and services within and across industries. This dynamic has raised the performance requirements for firms and workers that may have been insulated from global competition in the past. Workers, almost regardless of their role, can suddenly find themselves in competition with a range of consultants, vendors, suppliers, contractors, and affiliates from places both far and near. Global value chains raise, among other things, the possibility that entire societies can become highly specialized in specific sets of business functions, while others fail to develop or atrophy. Development paths that include heavy GVC engagement can have positive or negative consequences for wealth creation, employment, innovation, firm autonomy, social welfare, and economic development (Whittaker et al. forthcoming). Despite their growing importance as discrete realms of value creation, competition and industry evolution, we currently have no standard method for collecting data about business functions.

While there are a host of business functions that have long been disembodied from specific industries (e.g., from janitorial to IT to manufacturing services), qualitative research has shown that managers often experiment with a wide variety of “make” or “buy” choices and on- or offshore sourcing (Berger et al. 2005). Decisions about how to bundle and unbundle, combine and recombine, and locate and relocate business functions have become a central preoccupation of strategic decision-making. Because industry classification schemes typically describe only the main output or process of the firm, and input-output statistics refer only to those products the firm buys or sells, existing enterprise and establishment-level data resources are not well suited to capturing the dynamics of business function bundling or revealing the spatial and organizational patterns that result.

In our view, this data gap will become more important over time as the capabilities that reside in the domestic and global supply-bases continue to rise, increasing the potential for fragmenting, outsourcing and relocating a wide variety of business functions. A standardized list of exclusive and generic business functions is needed. An exclusive list will have no overlap between categories and will account for all of the functions of the firm. A generic list will be equally applicable to all firms and organizations, regardless of industry. The list should be extremely parsimonious at first, with detail collected only after the main categories have stabilized through field testing. While this is a difficult and time-consuming prospect, work to develop business function lists and deploy them in surveys is well under way.

Developing, Deploying, and Refining Business Function Lists: A Brief History

To our knowledge, the earliest use of a business function list to collect economic data was for the EMERGENCE Project (Huws and Dahlman 2004), funded by the European Commission. This research uses a less-than-generic list of seven business functions tailored to collect information about the outsourcing of information technology–related functions, such as software development and data processing. Industry-specific bias in business function lists can simplify data collection and focus research on specific questions, but the results cannot be easily compared to or aggregated with other data, and they increase the risk of creating nonexhaustive lists. When business function lists are nonexhaustive, they leave some functions unexamined and block our view of how specific business functions contribute to the *total* employment or output of a firm. Business function lists should seek to include the full range of activities that all establishments must either do in house or have done by others, regardless of industry.

In his 1985 book, *Competitive Advantage*, Michael Porter publishes a list of nine generic business functions: R&D, design, production, marketing and sales, distribution, customer service, firm infrastructure, human resources, and technology development. A list similar to Porter's was developed for the European Union (EU) Survey on International Sourcing (Neilsen 2008) and adopted by Statistics Canada for the Survey of Changing Business Practices in the Global Economy. This list, while not industry-specific in any way, was not fully exhaustive because it included an "other functions" category. Such categories are useful as checks on the exhaustiveness of the list used, but researchers should then combine them with an existing category or, if needed, define a new, exclusive category, rather than accepting an undefined category of data.

Firms, especially at the establishment level, typically have a main output, be it a product or service. The main operational function that produces this output is associated with the firm's standardized industrial code. Instead of counting all output and employment under this classification, as business censuses typically do, business function lists can be used to measure economic activity (e.g., employment, occupational mix, wages paid, etc.) in other functions as well. In business function frameworks, this main productive function has been designated variously as "production" (Porter 1985), the "core function" (Neilsen 2008), and "operations" (Brown 2008). In contrast, the EMRGENCE project list (Huws and Dahlman 2004) and a more recent list developed by the Offshoring Research Network for the purpose of detecting R&D offshoring (Lewin et al. 2009) did not include a category for the firm's main operational function. Instead it used a list of commonly outsourced functions (product development, IT services, back office functions, call centers, etc.). A business function list cannot be considered exhaustive unless it includes a category that captures the main productive function of the firm, a function that can be partially or even completely outsourced.

The Bureau of Labor Statistics' (BLS) Mass Layoff Statistics (MLS) program has developed a list to collect data on business functions fulfilled by workers who have been separated in large-scale layoffs in the United States (Brown 2008). In the 2007 MLS survey of establishments, respondents were asked a question about the primary and secondary roles, or "business functions," performed by laid-off workers. According to Brown (2008, p. 56), " 'Do not know' responses to the business function question remained low [less than 6 percent], indicating that the correct person is being reached for the interview and that most respondents in fact think in terms of business functions." In other words, the BLS found business function data to be highly collectable because company officials appear to recognize the business function concept. A tabulation of respondents' literal responses generated a very long, nonexclusive list of business functions that were then coded by BLS personnel to create detailed, mutually exclusive categories. This list was further coded to nine higher-level business functions (named "business processes" in the MLS) similar to the Porter list. It is the bottom up methodology used by the BLS—beginning with literal responses rather than using a list that researchers develop subjectively or iteratively with industry informants—along with its exhaustive, exclusive, and generic character, which gives us a high level of confidence in the BLS list.

A Proposed List of Business Functions

The growing use of business function lists in survey research suggests a need to delve within the firm to observe the details of organizational design, organizational change, outsourcing and industrial location. Clearly, new realities are spurring researchers to develop these new metrics. In our view, the sooner a business function classification scheme can be standardized and broadly deployed the better.

Table 3 presents a proposed list of 12 business functions, along with their definitions. The list adds four business functions to the 2007 BLS MLS list. First, there is a function called "strategic management." This reflects the common separation of the command, control, and strategy-setting activities of top management from more mundane managerial functions that can sometimes be located offshore and/or carried out in supplier firms. The most recent BLS MLS surveys distinguish strategic management from a set of "general management" functions. Second, because they typically occur at nearly opposite ends of the value chain, procurement has been separated from distribution, transportation, and logistics. Third, our list breaks out "intermediate input and materials production" from operations. This is meant to capture the very common practice of externally sourcing physical parts or blocks of services for inclusion in larger products and systems. In the BLS MLS list intermediate input production is considered part of operations. Fourth, because they contain very different activities, firm infrastructure has been broken out from general management (and corporate governance). Despite these differences, the lists are compatible since the functions in Table 3 can be combined to match the BLS MLS list.

Table 3. Twelve generic business functions and their definitions

Business function	Definitions
1) Strategic management	Activities that support the setting of product strategy (i.e., deciding what "new product development" works on), choosing when and where to make new investments and acquisitions, or sales of parts of the business, and choosing key business partners (e.g., suppliers and service providers).
2) Product or service development	Activities associated with bringing a new product or service to market, including research, marketing analysis, design, and engineering.
3) Marketing, sales, and account management	Activities to inform buyers including promotion, advertising, telemarketing, selling, retail management.
4) Intermediate input and materials production	The fabrication or transformation of materials and codification of information to render them suitable for use in operations.
5) Procurement	Activities associated with choosing and acquiring purchased inputs.
6) Operations (industry code)	Activities that transform inputs into final outputs, either goods or services. This includes the detailed management of such operations. (In most cases, operations will equate with the industry code of the establishment or the activity most directly associated with the industry code.)
7) Transportation, logistics, and distribution	Activities associated with transporting and storing inputs, and storing and transporting finished products to customers.
8) General management and corporate governance	Activities associated with the administration of the organization, including legal, finance, public affairs, government relations, accounting, and general management.
9) Human resource management	Activities associated with the recruiting, hiring, training, compensating, and dismissing personnel.
10) Technology and process development	Activities related to maintenance, automation, design/redesign of equipment, hardware, software, procedures, and technical knowledge.
11) Firm infrastructure (e.g., building maintenance. and IT systems)	Activities related to building maintenance, and ITC systems.
12) Customer and after-sales service	Support services to customers after purchase of good or service, including training, help desks, customer support for guarantees, and warranties.

Source: Adapted by the authors from Bureau of Labor Statistics, Mass Layoff Statistics Program.

Collecting Data on the Geography of Business Functions

Although business function data can be used to inform other research questions, as the BLS' MLS program does in identifying the functional role of laid-off workers, our main interest in using it to identify patterns of business function bundling (i.e., organizational design), and the locational characteristics of outsourcing and offshoring. Because business functions can be bundled and located differently, we can identify four nonexclusive quadrants for any given function: 1) domestic in house, 2) domestic outsourced, 3) offshore in house (i.e., the MNC affiliate), and 4) offshore outsourced. However, it is important that business function surveys that seek to capture data on global engagement are designed, not only to capture all four, but also the ways that firms combine them. Firms can, and typically do, combine internal and external sourcing of specific business functions. For example, some intermediate inputs may be produced in house while others are outsourced. Operations may be outsourced, but only when internal capacity is fully utilized. Firms might combine internal and external sourcing for strategic reasons (Bradach and Eccles 1989).

The same can be said of location. Managers can decide to locate business functions in proximate or distant locations, in high- or low-cost locations, near customers, suppliers, specialized labor markets, and so on, but most typically they combine these approaches and motives. This is why detailed information about the location of business functions is of great interest. Surveys that identify sourcing locations and either domestic or international are not very helpful. Outsourcing from the United States to Germany, for example, will likely involve different functions and have very different and motivations and implications than outsourcing from the United States to China. But even on the domestic front, outsourcing to a vendor in the same city is very different from outsourcing to a supplier located in a distant, rural location.

The surveys on international sourcing fielded by Eurostat, Statistics Canada, and the Offshoring Research Network collect no data on domestic locations and use predetermined lists of geographic locations to identify countries of great interest (e.g., India and China), but combine others into vast, amorphous groupings (e.g., “other Asia”). It is better, in our view, to ask respondents to provide geographic information according to city and country. In this way, a single question can begin to identify, with great precision, both domestic and international patterns of outsourcing and offshoring. Geographic aggregations can be made after the fact, and detailed locational coordinates can allow the use of geographic information system software to create and examine a host of potentially important variables (e.g., clustering, distances, travel times, prevailing labor market conditions).

Data collected according to business function can provide researchers and policymakers with a rough map of the value chain; reveal the roles that domestic establishments, firms, and industries play within GVCs; and offer a unique view of the competitive pressures facing domestic firms and industries. Over time, it will be possible to develop a hierarchy of business functions to provide information about business functions in greater detail, but in the shorter term a parsimonious, high-level list can provide important information, such as an at-a-glance perspective on how enterprises bundle value chain functions and a benchmark for how this is changing. As metrics for the key variables of GVC governance and the five GVC governance modes described earlier are developed, they can be used to characterize the internal and external linkages between specific business functions, testing our assumptions about the relationships between GVC governance and the “offshorability” and location of work. Nationally representative surveys can begin to characterize business function gaps and specializations in specific countries, while international surveys can develop comparisons between trading partners. When combined with existing data on employment, occupations, wages, worker career paths, firm performance, E-commerce, trade, etc., new data on business functions will open up important new avenues for research and policy analysis.

A New European Survey on Business Functions

To provide an example of the usefulness of business function data, we present some preliminary data from the EU Survey on International Sourcing. So far, the survey has been administered in 14 out of 27 EU member states, and 60,000 responses have been collected, but only the data from four Nordic countries have been tabulated (see Nielsen [2008] for details). Figure 3 and Table 4 and Table 5 show the results from Denmark, where the survey was carried out as a census for all 3,170 private sector nonagricultural enterprises with 50 or more employees.[21] Because a few of the core questions were mandatory, the response rate for this group of establishments was 97 percent. The questions about business functions on this survey were straightforward: Were business functions outsourced domestically or internationally in the 2001–2006 period (Table 4), and if so, what kind of business partner was used (Table 5), and (from a predetermined list) where were internationally sourced functions located (Figure 3)?

The data in Table 4 show that Danish firms sourced the majority of business functions in house. About 88 percent were not engaged in international sourcing of any kind. Facilities management was the most commonly outsourced function (37 percent), but because vendors provide these services on site, the source was invariably domestic. The business function that was sourced internationally the most frequently was the "core" function (10 percent of all firms), analogous to "operations" in Table 3, followed by information technology and communications (ITC) services. Twenty-nine percent of the 1,567 functions reported as internationally sourced were core functions, followed by ITC services (16 percent), distribution and logistics functions (13 percent), engineering functions (11 percent), administrative functions (10 percent), marketing and sales functions (10 percent), and research and development functions (9 percent).

These data support anecdotal evidence that international sourcing is most advanced in manufacturing (a "core" function for goods producing firms). This assumption gains further support when firms reporting their core function as manufacturing are compared to service-producing firms. Only 28 percent of service producing firms in Denmark reported international sourcing of their core function, while 70 percent of manufacturing firms did so (Nielsen 2008, p. 24). Table 5 shows that less than half of the reported international sourcing by Danish firms in the 2001–2006 period was to independent firms. The bulk of in-house international sourcing went to existing affiliates, as opposed to recently acquired or newly established "greenfield" affiliates.

Table 4. External and international sourcing of business functions by Danish firms, 2001–2006

Business Function	Not outsourced	Domestically outsourced	Internationally sourced
Core function	88%	4%	10%
ICT services	71%	24%	6%
Distribution and logistics	82%	15%	4%
Administrative functions	90%	7%	4%
Engineering	88%	9%	4%
Marketing, sales etc.	91%	6%	3%
R&D	94%	3%	3%
Other functions	96%	4%	1%
Facility management	63%	37%	0%

Source: Eurostat International Sourcing Survey, courtesy of Statistics Denmark (Nielsen 2008).
Notes: *n*=3,170 Danish enterprises with more than 50 employees. Rows may not add to 100 percent because a few firms reported more than one source for a given business function.

[21] The survey was also administered to 1,968 smaller Danish manufacturing and business services firms. For simplicity's sake, these data are not presented in this paper. In general, they show similar patterns but slightly less domestic and international outsourcing across business functions than the sample of larger firms.

Table 5. Internationally sourced business functions by Danish firms, by supplier type, 2001–2006

Business Function	Existing affiliate	Recently acquired affiliate	Recent greenfield affiliate	Independent firm (< than 50% owned)
Core function	29%	8%	18%	46%
Distribution and logistics	43%	5%	15%	37%
Marketing, sales etc.	48%	8%	14%	30%
ICT services	46%	3%	6%	44%
Administrative functions	50%	3%	13%	34%
Engineering	33%	6%	16%	45%
R&D	34%	8%	9%	49%
Facility management	NA	NA	NA	NA
Other functions	9%	9%	0%	81%

Source: Eurostat International Sourcing Survey, courtesy of Statistics Denmark (Nielsen 2008).
Notes: *n*= 611 Danish enterprises engaged international sourcing.

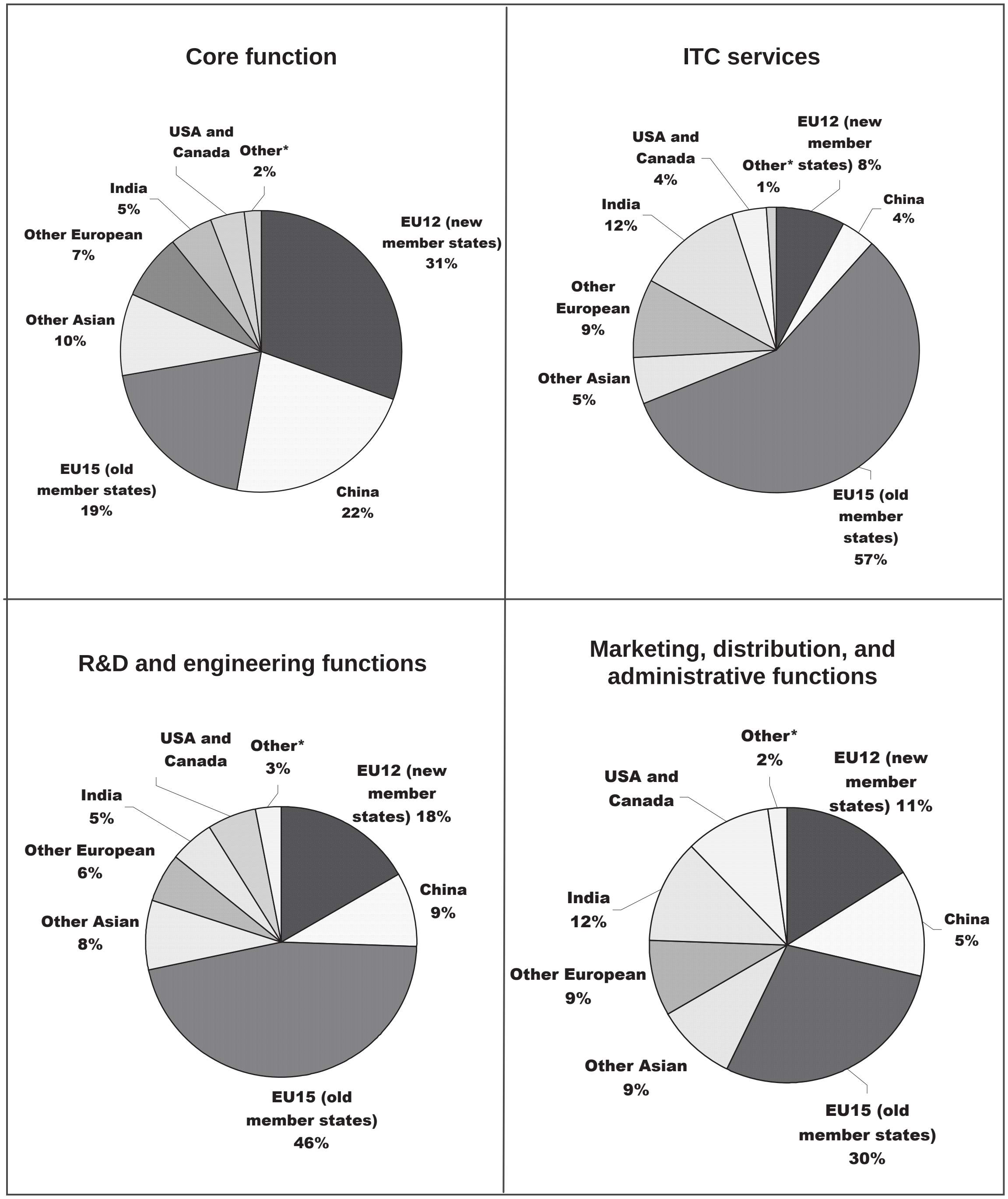
Figure 3 summarizes the geography of international sourcing by Danish firms. It shows that new European Union (EU) member states (mostly in Eastern Europe) account for 31 percent of the cases of international sourcing of core functions during the 2001–2006 period, followed by China (22 percent) and old EU member states (19 percent). When the focus is shifted to ITC services, the importance of the new member states falls to only 8 percent, while old member states account for 57 percent of the cases of international sourcing. India, a country typically identified as a destination for ITC outsourcing in the popular press and in qualitative research, is identified as a source country in 12 percent of the cases of ITC sourcing, in comparison with only 5 percent of the international sourcing cases for core functions. International outsourcing of R&D and engineering functions is also concentrated in Western Europe (42 percent), with China (9 percent) and "other Asian" countries (8 percent) playing a larger role than in ITC services. Interestingly, the role of India in R&D outsourcing is very small. The combined shares of marketing, distribution, and administrative functions show a more balanced pattern across locations.

The results presented here are largely unsurprising. They confirm both qualitative GVC research, and to some extent popular perceptions. Of the business functions that are sourced outside of Denmark, 30–50 percent are outsourced to independent suppliers, a substantial but not dominant share. Existing affiliates provide most of the in-house international sourcing, but international acquisitions and the establishment of new "greenfield" facilities are not unheard of. Core functions, mostly manufacturing, are most commonly outsourced and offshored, followed by ITC services. Functions based on tacit and local knowledge, such as marketing and sales, engineering, and R&D are less likely to be internationally outsourced or offshored. Most international sourcing by Danish firms is within Europe, but China is a popular location for sourcing core functions (mainly manufacturing). While India is more likely to be a source location for ITC service functions (12 percent of cases) than for core functions (5 percent of cases), it is notable that the majority (57 percent) of instances of international ITC services sourcing are to the original 12 member states of the European Union.

While it is important to have our impressions confirmed, the greater value of these data is that they establish a baseline for future research. Is the practice of outsourcing to independent suppliers becoming more prevalent? Will India grow as a location for ITC sourcing at the expense of old European Union member states? Will the outsourcing of engineering and R&D functions grow, and if so, where? Will service-producing firms increase the outsourcing and offshoring of core functions [operations]? If these are trends, then how quickly will they progress? Will Eastern Europe lose out to East Asia? Such questions comprise some of the most pressing policy questions of the day. When and if new rounds of business function data are collected, we will be in a much better position to provide answers.

What the Eurostat international sourcing survey did not collect was employment and wage data according to business function. Such data would begin to quantify the importance of specific business functions within firms, industries, and countries, and provide a benchmark for comparison with other countries that could reveal patterns of organizational design and national specialization within GVCs. It is our hope that future surveys will collect these data. One way could be to code census data that reveals performance metrics such as sales, employment and payroll according to a business function framework.

Figure 3. International sourcing of business function by Danish firms, 2001–2006



Source: Eurostat International Sourcing Survey, courtesy of Statistics Denmark (Nielson 2008).
Notes: Other is Latin and South America plus Africa. Other Europe is Switzerland, Norway, Turkey, Russia, Belo Russia, Ukraine, and the Balkan states. *n*=611 Danish enterprises engaged international sourcing.

CONCLUSIONS

In the mosaic of value chain specialization and intermediate goods flows that underlie the most recent trends in global integration, ownership and capability development cannot be so easily be linked to the domestic context, even if we allow that it is based in part on “borrowed” technology. The implications for policy are far reaching. How can workers, firms, and industries be provided with the best environment for engaging with the global economy? How can we be sure that enough wealth, employment, and innovative capacity are generated at home as global integration proceeds? How much national specialization—and by extension, interdependence with other societies—is too much? These are open questions. Even if policymakers seek few direct interventions in the areas of trade, industrial, or innovation policy, global integration can make the process of economic adjustment more difficult because it accelerates the pace of change.

Because the picture of global integration provided by current official statistics is incomplete, the causal links to economic welfare indicators such as employment and wages tend be weak and unconvincing. New thinking is required to develop useful insights into the character and implications of our increasingly globally integrated national economies. Perhaps the most pressing need is for new kinds of data to be collected, data that shed light on the position of domestic firms, establishments, and workers in GVCs. As a partial solution to this data gap, we advocate the collection of establishment-level economic data according to a standardized set of generic business functions. We share with Lall the desire to move beyond given industry and product classifications, and to create broad analytical frameworks and data collection tools to examine aspects of global integration that cut across specific industries and countries. The GVC framework, the business function scheme, and Lall’s technological classification of exports are all attempts to create intellectual tools and data classification schemes of exactly this sort.

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SESSION 2: MEASURING THE IMPACT OF OFFSHORING ON THE LABOR MARKET

CHAIR: Janet Norwood* (NAPA)

Addressing the Demand for Time Series and Longitudinal Data on Occupational Employment,
Katharine Abraham (University of Maryland) and
James R. Spletzer (Bureau of Labor Statistics)

Understanding the Domestic Labor Market Impact of Offshore Services Outsourcing: Measurement Issues, Lori Kletzer (University of California-Santa Cruz and
Peterson Institute for International Economics)

DISCUSSANT: Timothy Sturgeon (MIT)

* *National Academy Fellow*

Addressing the Demand for Time Series and Longitudinal Data on Occupational Employment*

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James R. Spletzer
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October 22, 2009
Revised February 26, 2010

* Without implicating them in any way, we are grateful to Laurie Salmon, Dixie Sommers, and George Stamas, Office of Employment and Unemployment Statistics, Bureau of Labor Statistics, for useful conversations and background information concerning the Occupational Employment Statistics survey.

Among the important potential effects of increased offshoring are changes in the occupational composition of U.S. employment. To the extent that firms choose to shift particular tasks to workers located overseas, domestic employment in the occupations that perform those tasks can be expected to decline or to grow less rapidly than would otherwise have been the case. It has been suggested that time-series data on occupational employment by industry could be useful for studying these effects in the aggregate. Similarly, longitudinal data on the mix of jobs at individual enterprises could be useful for better understanding the dynamics of outsourcing and offshoring at the level of the individual firm. The development of this sort of information has been recommended as part of a broader set of needed improvements in the data available for the study of off-shoring (see, for example, Sturgeon [2006] and National Academy for Public Administration [2006]).

Concerns about sample size and the accuracy with which household respondents report their occupations and industries, together with the fact that household survey data generally cannot be used to study the evolution of employment at individual firms, have led analysts interested in the effects of offshoring on domestic employment to focus on employer-provided employment data. The Occupational Employment Statistics (OES) survey conducted by the Bureau of Labor Statistics (BLS) is a large employer survey that, each year since 1988, has collected detailed information on employment by occupation.

The OES is designed to produce detailed point-in-time estimates of staffing patterns and wages, not to produce occupational employment time series or to support the analysis of changes in the occupational composition of employment at individual workplaces. For some applications, such as the use of OES employment data to determine weights in the BLS National Compensation Survey program or the use of OES wage data by the Employment and Training Administration to administer the H-1B visa program, having data that could be compared over time would not be especially valuable. Many users of OES survey data, however, clearly would benefit from data designed to support cross-year comparisons. For example, annual data designed to track trajectories in staffing patterns would be of great value to the BLS Occupational Employment Projections (OEP) program. Similarly, access to information on trends in occupational staffing patterns and wages would help those who use the data for workforce development, career counseling, and career planning purposes. Researchers studying organizational behavior, the sources of productivity growth, and other topics could benefit from data that allowed them to track staffing patterns at the level of the individual establishment or individual enterprise.

The purpose of this paper is to evaluate the OES survey as a source of time-series and/or longitudinal data on employment by occupation. This sort of information would be useful not only for identifying offshoring activity and study its impacts—topics that are the focus of the present conference—but for a variety of other purposes as well. In the next section we briefly describe the OES survey. We then discuss the feasibility of using the historical OES data to construct occupational employment time series or for longitudinal analysis at either the establishment or the enterprise level. Unfortunately, the existing survey design and the management approach dictated by current program objectives make the data poorly suited for the analysis of trends, especially over short time intervals. The fourth section considers how the OES survey might be reconfigured to produce reliable annual time-series data and support analysis at the individual establishment or enterprise level. A necessary step would be to collect data from some subset of establishments every year, rather than only once every three years as is the current practice, but other changes in the survey also would be required. Some concluding thoughts and observations are offered in the final section.

THE OES SURVEY

The OES survey is an ongoing mail survey conducted by the BLS in collaboration with its state partners. It covers all industries exclusive of agriculture. Prior to 1996, industries were surveyed on a three-year rotating cycle. Since 1996, each year's sample has covered establishments across all industries, but except for an annual enumeration of federal and state government establishments, it is still the case that even very large establishments are surveyed only once every three years.

The OES sample is designed to support cross-sectional estimates of staffing patterns developed from data collected over a three-year period. Through 2001, estimates were based on three annual panels, each consisting of approximately 400,000 establishments; within each panel, establishments were assigned an October, November, or December reference date. In 2002, the survey transitioned to a design in which estimates are based on six semiannual panels, with each panel consisting of approximately 200,000 establishments assigned either a May or a November reference date. The May 2008 published estimates, for example, rest on data collected for November 2005, May 2006, November 2006, May 2007, November 2007, and May 2008. Estimates are benchmarked to the average of the most recent May and November employment levels.

Since 1996, the OES has collected information on occupational wages in addition to occupational employment. Establishments selected for the OES are asked to report employment in each cell of a matrix in which the rows refer to different occupations and the columns to wage intervals. Generally, for firms with 20 or more employees, the survey forms contain between 50 and 225 occupations, depending on the industry of the establishment completing the form.   Prior to 2000, employers receiving these forms were asked to list numerically significant or new occupations that could not be reported in a detailed occupation and therefore were reported in an "all other" residual category. This information was used in revising the survey forms for later years. Beginning in 2000, employers have been asked to provide detailed occupational information for workers who cannot be placed in one of the listed occupations.

Since 1999, small employers have received a shorter unstructured form that contains no list of likely occupation titles; rather, the employer is asked to provide a brief description of each occupation represented in the establishment's workforce. The information on these forms is coded into occupational categories by survey staff in the state agencies.[22] Multiestablishment firms may request that their data be collected through the firm's corporate headquarters rather than directly from individual establishments. This is referred to as central office collection (COC). COC reporters provide the OES program with electronic records containing job title and

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[22]Prior to 1999, several states developed their own unstructured short forms that were used to collect data from some small employers, but this was not a part of the formal survey protocol. Beginning in 2004, states were given the discretion to send unstructured forms to establishments with up to 49 employees.

wage information for their employees. The OES staff then builds crosswalks for coding these firms' data into Standard Occupational Classification (SOC) occupations and OES wage intervals.

Approximately 80 percent of establishments sampled for the OES survey provide usable responses; on an employment-weighted basis, the survey response rate is approximately 75 percent. Nearest neighbor hot-deck procedures, which take data from another similar establishment, are used to impute missing employment information for establishments that do not respond. Missing wage distributions also are imputed using distributions for similar establishments.

OES survey data are published by occupation, industry, and area. Employment and wage estimates are produced for as many as about 800 occupations, both nationally and for states, metropolitan areas and other geographic areas. In addition, national occupational employment and wage estimates are available for specific industries. BLS does not publish occupation by industry data below the national level, and suppression of sparsely populated cells is common in both the national by-industry tables and the cross-industry tables for subnational areas. The OES program switched from its own survey-specific occupation coding system to the SOC system in 1999 and from the Standard Industrial Classification (SIC) system to the North American Industry Classification System (NAICS) in 2002.

CAN EXISTING OES DATA BE USED TO CONSTRUCT ANNUAL TIME SERIES?

Several features of the current OES design make it difficult to use the existing data to construct single-year estimates of employment by detailed occupation, even at the national level. The current design calls for estimates to be produced using three years of data, and the existing survey weights are not suitable for the production of annual estimates. It is possible to construct annual estimation weights, but because (except in federal government) even very large units are surveyed only once every three years, annual estimates tend to be quite variable, especially for smaller employment cells. The significant breaks in both occupation and industry classification caused by the adoption of the SOC and the NAICS are another problem. Finally, other changes in survey operations associated with the adoption of the SOC have affected the comparability of the OES estimates over time. To preview our conclusions, we believe that it is possible to use existing OES survey data to construct national occupational time series that are suitable for some analytic purposes, but that these estimates have serious limitations for studying offshoring and its effects.

Lack of Weights for Annual Estimates

The weights used to produce official OES estimates are constructed at the level of cells defined on the basis of industry, establishment size, and geography. As noted above, the sample units used to produce each set of estimates are divided into panels spread across three years of data collection. Each sampled establishment is assigned a current weight that reflects its probability of selection into a particular panel.[23] If every cell in a panel contained at least one establishment, the weighted sum of employment calculated for an industry using the current weights would be approximately equal to total national employment in the industry as of the panel reference date(s). There are, however, a very large number of OES sampling cells—as of 2004, the survey was stratified by 343 industries, seven establishment size classes, and 686 metropolitan or balance-of-state geographic areas—and individual panels contain a significant number of empty cells. Because employment in the cells that happen to be empty is not represented, using the current weights to estimate employment in an industry based on the responses to any single panel yields an estimate that lies significantly below the industry's true employment level.[24]

Working with OES data for the private sector over the period 1996–2004, Abraham and Spletzer (forthcoming) developed weight adjustment factors to be applied to the OES current weights that are calculated as follows:

$$(1)\qquad ADJFACTOR1_{jt} = \frac{E_{jt}^{CES}}{\sum_i CURRWT_{ijt}^{OES} E_{ijt}^{OES}},$$

where *ADJFACTOR*1 is the industry weight adjustment factor, *E* is employment from either the monthly Current Employment Statistics (CES) survey or the OES survey, *CURRWT* is the current weight from the OES data file, *i* indexes individual establishments, *j* indexes detailed industries, and *t* indexes years. Estimates produced from the OES microdata using weights equal to the product of *ADJFACTOR*1, and *CURRWT* reproduce CES national industry employment trends.

In all years, industry weight adjustment factors were calculated at the most detailed industry level for which sample data were available. The SIC classification structure in use through 2001 included 934 detailed industries. In 1996, taking that year as an example, weight adjustment factors were calculated at the four-digit (most detailed) level for 310 industries, representing 34.0 percent of employment; at the three-digit level for 383 industries, representing 37.6 percent of employment; at the two-digit level for 225 industries, representing 27.8 percent of employment; and at the one-digit level for 16 industries, representing 0.6 percent of employment. The NAICS structure adopted in 2002 includes 1,171 detailed industries. In 2004, weight adjustment factors were calculated at the five-digit (most detailed) level for 424 industries, representing 36.1 percent of employment; at the four-digit level for 520 industries, representing 47.1 percent of employment; at the three-digit level for 172 industries, representing 9.8 percent of employment; and at the two-digit level for 55 industries, representing 7.0 percent of employment.

A further weighting concern is that, although the true distribution of employment by size of establishment appears to have been very stable from 1996 through 2004, the distributions in the data collected for the OES vary considerably from year to year. Factors that appear to have contributed to this variability include the uneven distribution of the largest (certainty) units across panels; the effects of a 1999 experiment carried out in selected states to determine the

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[23] The current weights also incorporate adjustments for differences between the way a unit was sampled and the way it was reported (e.g., one establishment at a company sampled but data reported for several establishments together).
[24] In the official estimates, which are based on three years of data, this is not generally a problem because data at the detailed cell level are reweighted to account for the number of panels in which each cell is represented.

feasibility of collecting data from all certainty establishments every year; and the introduction of establishments with 1–4 employees into the survey sample in 1998 (these very small establishments previously had been represented by establishments with 5–9 employees). A second weight adjustment factor was developed to calibrate the share of employment in broad industries accounted for by each of nine establishment size classes to the average share for that size class across the OES benchmark data files for 1998, 2001, and 2004.[25]

$$(2) \qquad ADJFACTOR2_{kst} = \frac{AVESHARE_{ks}^{BMK}}{SHARE_{kst}^{OES}},$$

where *ADJFACTOR*2 is the size class weight adjustment factor, *AVESHARE* is the average share of employment accounted for by the designated size class in the benchmark data, *SHARE* is the current year share in the OES data, *k* indexes broad industry, *s* indexes establishment size class, and *t* indexes year. Applying both the industry and the size class adjustment factors yields

$$(3) \qquad FINALWT_{ijkst} = ADJFACTOR1_{jt} \; x \; ADJFACTOR2_{kst} \; x \; CURRWT_{ijkst}^{OES} .$$

Anyone interested in using the historical OES data to construct an annual time series would need to apply some similar procedure to produce weights suitable for annual estimates.

Variability in Annual Estimates

In cells defined at the national level using broad industries and occupations, employment estimates calculated using the adjusted weights just described seem generally to behave very sensibly (see Appendices C and D in Abraham and Spletzer forthcoming). Because even very large units in the private sector are surveyed only once every three years, however, annual estimates of employment for detailed occupations, estimates for subnational areas and/or estimates for occupation by industry are likely to behave more erratically. To illustrate the potential instability in estimates for small domains, we used the adjusted weights just described to construct annual time series for the 10 occupations identified by Jensen and Kletzer (forthcoming) as most offshorable. These are shown in Figure 1. Each of the 10 panels in the figure contains two employment series—one created from year-specific OES microdata with weights adjusted using the method just described, and one created from the November OES press releases posted to the BLS Web site.[26] We should note that using the published OES estimates in this way is not recommended by the BLS, which states on its Web site that it "does not use or encourage the use of OES data for time series analysis" (http://www.bls.gov/oes/oes_ques.htm#Ques29). Still, we believe that the comparisons shown in the figure are informative.

[25] The OES survey data are benchmarked to the quarterly Census of Employment and Wages. Our analysis rests on OES benchmark data files for the years 1998, 2001, and 2004. The size class distributions observed across these three years are very similar.

[26] Through 2001, all OES data were collected with a reference date in October, November or December. In 2002, the OES switched to May and November reference dates. For these later years, in an effort to avoid problems of comparability associated with seasonal differences in staffing patterns at different times of the year, we used only the data from the November panel. The 2003 and 2004 press releases report statistics benchmarked to average employment by industry for the most recent May and November and there may be an issue of comparability between the published estimates for these years as compared to earlier years.

The estimates in Figure 1 cover the years from 1999, the year that the SOC was adopted in the OES program, through 2004. One difference between the two series is that the microdata estimates cover only employment in the private sector, while the published estimates cover employment in federal, state, and local government, as well as the private sector. While this difference in coverage has a noticeable effect on the level of some of the series—most obviously, the series for statisticians and medical transcriptionists—it should not much affect their year-to-year variability. More importantly for the series' variability, the microdata estimates are based on establishments that, from 1999 through 2001, represented only about one-third of the full private sector OES sample and, from 2002 through 2004, only about one-sixth of the full private sector sample. The time series created with annual microdata are considerably more volatile than the time series created from the published data. Several of the occupational time series based on annual microdata—those for mathematical technicians; credit authorizers, checkers and clerks; biochemists and biophysicists; title examiners; weighers; and actuaries—show sharp changes from one year to the next that are not apparent in the published estimates based on multiple years of data. For 9 of the 10 occupations in Figure 1—excluding only statisticians—the variance of the series created from the annual microdata is higher than that for the published estimates. Figure 1 suggests that employment time series for detailed occupations that are created from single-year OES microdata are likely to be highly volatile, making them problematic for policy analysis of the effects of offshoring. Increases in the size of the OES sample would be needed to reduce the variance of annual employment estimates.

Breaks in Occupation and Industry Classification Systems

Breaks in both the occupation and industry classification structures are an additional barrier to using the historical OES data to produce detailed annual time series. As already noted, prior to 1999, the OES used its own classification structure; the Standard Occupational Classification (SOC) was introduced in 1999. The NAICS replaced the older SIC system in 2002. In both cases, the new classification structure was very different from the old. Of the 769 detailed occupations included in the SOC when it was introduced in 1999, only 374 could be cross-walked directly to occupations that previously existed in the old OES classification structure (BLS 2001a, pp. 24 and 175). During the transition to NAICS at the BLS, only about half of establishments could be assigned NAICS codes based on their SIC classification (Mikkelson, Morisi, and Stamas 2000).

Comparisons at an aggregated level seem more feasible across the classification structure breaks than do more disaggregated comparisons. Matthew Dey of the BLS, for example, has developed a concordance that links cells defined using 19 aggregated occupations and 13 aggregated industries that appear to be reasonably consistent across the breaks in classification system, and Abraham and Spletzer (forthcoming) use a modified version of the Dey concordance. There are detailed occupations within these larger groupings that are defined in the same way in the SOC as in the older OES classification structure, but as already noted there are also many detailed occupations for which no direct linkage is possible. The OES data were never dual coded using the SOC and OES occupational classification structures, so in cases where occupations are not comparable it is difficult to relate the new SOC occupations to the older OES occupations.

The best option for extending the OES annual estimates for detailed occupations back through time likely would be to plot the employment series for each of the occupations and retain those occupations for which there is no evidence of a discontinuity between 1998 and 1999 that might indicate a lack of comparability in how the occupation was defined. Where no direct match at the detailed occupation level exists, occupations formed by combining detailed occupations in an appropriate fashion could be evaluated similarly. Drawing clear conclusions could be difficult, however, because of the substantial underlying variability in annual estimates based on the OES microdata that has already been discussed. Moreover, since industries were surveyed on a three-year rotating cycle prior to 1996, even under the best-case scenario, it would be possible to extend true annual series by only three years, back to 1996.

Other Comparability Issues

In addition to a new coding structure, the SOC also introduced a set of principles intended to guide the classification of workers (OMB 2000). An important principle is that only individuals who devote at least 80 percent of their time to management activities are to be classified as managers. To implement this SOC guidance, the OES introduced new edit checks to flag establishments that reported employment in a management occupation (e.g., financial manager) without reporting employment in any of the expected subordinate occupations (e.g., financial specialists or clerks). A second set of edit checks was developed to flag establishments with an excessive number of managers. Both sets of edit checks were applied in a limited fashion in 1999 and phased in more fully over the following years.

Implementation of the SOC also included new training designed to explain its structure and coding principles to program staff. Staff who attended SOC training courses in 1999 and subsequent years were instructed that management jobs reported on establishment schedules that did not include an intervening layer of supervision generally would need to be recoded as something else. Management jobs recoded in accord with this advice typically were shifted either to one of the professional occupations or to a first-level supervisor occupation. Because survey program staff code all of the occupations reported on unstructured survey forms submitted by small establishments, the introduction of the unstructured forms as an option in 1999 may have amplified the effects of the SOC training on the OES management employment series. The “rule” that no job should be coded as a management position unless the schedule also includes a first-level supervisor position is easy to apply and seems to have been embraced as a guide to coding the unstructured schedules.

Our best assessment is that the combined effect of these changes was to reduce management employment by very roughly 2 million jobs between 1998 and 2001, with these jobs then assigned instead to other job categories. Although perhaps less important for the analysis of offshoring than for some other purposes, this is nonetheless an additional barrier to comparing OES estimates over time. In our earlier work (Abraham and Spletzer forthcoming), we developed a procedure for “reverse-engineering” the new coding rules that involved reclassifying a sufficient number of nonmanagement jobs in 1999 and later years as management positions to offset the sharp decline in management employment that is evident in the unadjusted data between 1999 and 2001. This effort was unavoidably crude. Further, going forward, insofar as it involves putting new OES data onto the old basis rather than putting old data on the new basis, the application of this procedure would inevitably become less and less appealing.[27]

New SOC training introduced in 2007 makes clear that someone might legitimately be performing management duties without there being an intervening layer of supervision between them and their subordinates. While this change was made to improve coding accuracy, going forward, it too may adversely affect the comparability of the OES data over time.

Problems with Coverage of Units Surveyed

A further limitation of the historical OES data is that the survey sample is not designed to support longitudinal analysis. As has been noted, establishments are asked to report on a three-year cycle. Large establishments responding to the survey in year *t* are likely also to have responded in year *t*-3. Because even large establishments are observed only once every three years, there may be a long lag before important changes in staffing patterns are captured. Further, the establishment is not the obvious unit of analysis for identifying and tracing the effects of offshoring. In a large corporation, sourcing decisions are likely to be made at the corporate level rather than the establishment level, and a decision to offshore work could take the form of shuttering an entire establishment, rather than transferring portions of the work performed at an individual establishment to another company. In this case, offshoring could not be identified through an establishment-level analysis, but only through an examination of changes in staffing patterns for the company as a whole.

To the extent that the appropriate level of analysis is the company rather than the establishment, the OES survey suffers from the further limitation that data generally are not collected for all of the establishments at a firm (National Academy of Public Administration 2006). Over the course of a three-year period, all establishments large enough to belong to the survey's certainty strata are asked to complete an OES questionnaire, but large firms include many small establishments, and only a fraction of these small establishments would be surveyed even once in a three-year cycle. Among firms in the United States with more than 10,000 employees, for example, in May 2006 there were 377,484 establishments with fewer than 250 employees, accounting for 53.6 percent of these firms' employment; 7,369 establishments with 250–499 employees, accounting for an additional 13.9 percent of the firms' employment; and 2,727 establishments with 500–999 employees, representing a further 10.1 percent of the very large firms' employment.[28]

[27] The specific jobs that formerly might have been categorized as management jobs were identified by looking for the highest-paid nonmanagement jobs in establishments with too few managers, based on historical patterns. This procedure took jobs from many different occupations and reclassified them as management positions (many to one). We were not able to devise a methodology for putting the old data on the new basis. That would have involved reassigning management positions to many different possible alternate occupations (one to many), and we did not believe we had a sound basis for making such assignments.

[28] These figures and others cited in the text are based on tabulations of the Business Employment Dynamics database, which is based on the Quarterly Census of Employment and Wages (QCEW) data file and are designed only to be illustrative.

REDESIGNING THE OES FOR TIME SERIES AND LONGITUDINAL ANALYSIS

To produce reliable annual time series, the OES sample would need to be augmented with units that are surveyed every year rather than only once every three years. Being able to track changes in staffing patterns at the establishment level might be of some interest, though as just discussed, important developments could be missed with an establishment-level focus. To the extent that analysts are interested in using enterprise-level data to study the effects of offshoring, it would be desirable for at least some firms to provide comprehensive data for all of their establishments. In addition to changes in the design of the survey sample to support time series and/or longitudinal analysis, other changes in the survey's focus also would be necessary.

Sample Redesign Options

We consider three possible options for augmenting the OES sample. The first is intended to be responsive to the demand for a sample that could support annual OES time series; the second suggests an approach to collecting data suitable for longitudinal analysis; and the third is a hybrid of the first two approaches. Many variations on these approaches can be imagined, and we do not mean to suggest that the specific options we describe are the only ones that are possible. Further, because it is the information we were able to access given our time constraints, we use data on number of firms and number of establishments from 2006 in our rough cost calculations, though since the size distribution of establishments is very stable over time and total employment has changed little on net between 2006 and the present, we do not believe our answers would have been much different had we been able to use 2009 data for these calculations. Our intent in any case is to stimulate thinking about sample design alternatives and the rough magnitude of the costs that might be associated with different choices, rather than to recommend a specific plan and attach a specific dollar cost figure to that plan. The rough dollar cost figures we present refer only to the direct costs of additional data collection and do not include the costs of other staffing necessary to edit and process the additional data collected. All of the options considered focus on increases in the size of the sample for the *private sector*, as that is where we would expect the effects of offshoring to be manifested.

Option 1: Survey all large private sector establishments every year. One way to increase the stability of annual OES estimates over time would be to survey all establishments with more than some threshold level of employment every year. Suppose, for example, that the survey were redesigned to collect data from all establishments with 250 or more employees every year. As of May 2006, the universe of private sector establishments eligible for inclusion in the OES included 30,639 establishments with 250–499 employees, 10,894 establishments with 500–999 employees, and 5,470 establishments with 1,000 or more employees. Since even units included in the current certainty strata are surveyed only once every three years, surveying all units with 250 or more employees every year would represent a significant increase in the annual survey sample.

Most of the work of collecting OES data is done by the states. Payments to the states for their work on the OES program totaled $21.5 million in FY2009 (the fiscal year in which the 2008 estimates were published). This figure includes some state overhead expenses and excludes some modest expenses for data collection work performed by the BLS national office staff, but for present purposes, we treat the payments made to the states as the cost of OES data collection.

The money awarded to states is allocated using a formula that takes into account the number of establishments surveyed in the state, the size distribution of those establishments, the number of publication areas in the state, and the average wages of state employees. In this allocation formula, establishments with 250–499 employees are treated as equivalent to two units, establishments with 500–999 employees as equivalent to three units and establishments with 1,000 or more employees as equivalent to four units.[29] By our calculations, as a very rough approximation, the current allocation formula implies a cost of $50 per establishment of size up to 249 employees, $100 per establishment of size 250–499 employees, $150 per establishment of size 500–999 employees, and $200 per establishment of size 1,000 or more employees. Applying these cost estimates, to survey all private sector establishments with 250 or more employees every year would have added roughly $3.9 million dollars to the cost of data collection for the OES program.[30]

Without a more detailed analysis that would be beyond the scope of the present exercise, we cannot say precisely how collecting data from all private sector establishments with 250 or more employees every year would affect the variance of annual estimates, but the number of employees for whom data were collected each year clearly would increase significantly. The current sample includes establishments with total employment of approximately 20.0 million per year over the three years of the survey cycle; the sample augmentation just described would add establishments with employment of approximately 19.6 million each year, close to doubling the employment covered.

Option 2: Survey all private sector establishments in large firms every year. Adoption of the preceding option for redesign of the OES sample would reduce the variance of annual OES estimates. Under this plan, however, only large establishments could be followed over time and, in most cases, data collected in a particular year still would cover only a portion of a firm's establishments, making it difficult to use the data for firm-level analysis. If longitudinal analysis at the firm level is a priority, surveying all of the establishments in *firms* with more than a threshold level of employment every year might be an appealing strategy. To the extent that large firms were willing to provide electronic data files containing information on the job classifications of all of their employees, collecting data in this way also could yield significant economies of scale. Indeed, without such economies, this data collection strategy would be prohibitively expensive.

Turning again to the May 2006 universe listing, using EIN as the firm identifier, we found 322,525 establishments that belonged to the 8,295 firms with 1,000–4,999 employees, 148,211 establishments that belonged to the 964 firms with 5,000–9,999 employees, and 429,140 establishments that belonged to the 677 firms with 10,000 or more employees. Using the per-establishment cost figures cited above, even restricting attention to establishments belonging to firms with 10,000 or more employees, the costs of data collection would be projected to rise by

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[29] This information was provided in a personal communication from OES program staff member Laurie Salmon on September 9, 2009.

[30] We should emphasize that the program does not receive a budget based on the number of units included in the survey sample. Rather, the program receives a total dollar amount of funding that then must be allocated to cover the various costs of program operation. Similar to other surveys, however, the amount of money needed to maintain program operations can be expected to grow over time because of growth in wages, salaries and other expenses and growth in the number of certainty units.

$18.7 million dollars per year, an amount that comes close to equaling the program's entire current data collection budget.

It seems likely, however, that economies of scale could be realized if data were collected for entire companies rather than separately for each establishment in the sample. So-called central office collection (COC) is already in place for some companies who prefer to submit their data in this way. Estimates of the staffing required to complete the current COC workload compiled by BLS national and regional office staff (NCS-OES Data Collection and Processing Cost Team 2008) suggest that a reasonable estimate might be that it costs approximately $6,000 per firm to process these submissions. If COC collection were mandated for all large firms, the per-firm cost likely would be higher. One reason is that firms for which this is not necessarily the preferred reporting method would have to be convinced to report in this way. The need to process all of the firms' establishments, rather than only selected establishments as at present, also would raise per-firm costs. To the extent that firms use common job classification systems across all of their establishments, the effort to assign SOC codes to job titles might not vary a great deal with the number of included establishments, but there could be other complications. For example, past experience suggests that there can be problems with matching establishments listed in the firm records to establishments on the BLS business list and with assigning appropriate industry and geographic identifiers.

For the purpose of producing a rough data collection budget estimate, suppose that it would cost $8,000 per COC firm to process electronically submitted data. If the COC universe were restricted to firms with 10,000 or more employees, this per-firm cost figure implies that total data collection costs would rise by $3.5 million per year, rather than the $18.7 million implied by the establishment-by-establishment collection cost model. If we instead assumed a higher figure of $10,000 per firm, the projected budget increment for added data collection work would be $4.8 million.

Compared to the previous sample redesign option, this option likely would do less to reduce the variance of annual OES estimates. As of May 2006, 14.0 million people were employed by establishments that would have been added under this strategy, compared to the 19.6 million employed by the establishments added under the previous strategy. In addition, to the extent that establishments of a given firm tend to be similar with respect to their staffing patterns, their addition to the sample will do less to improve the precision of the aggregate estimates than would the addition of a similar number of unaffiliated establishments. A major advantage of this approach is that, because information for all of the establishments at the identified firms would be collected, the data would be well suited for studying occupational employment trends at the firm level for the covered firms.

Option 3: Survey all private sector establishments in large firms and all other large private sector establishments every year. If a larger amount of money were available, a third option for augmenting the OES sample would be to combine the first two options. Under this option, data would be collected annually for all establishments that belong to firms with 10,000 or more employees and for all other establishments with 250 or more employees. To estimate the cost of this option, we assume that the incremental costs of data collection for establishments belonging to large firms would be $8,000–$10,000 per firm and that collecting data for any remaining establishments with 250 or more employees would cost $100–$200 per establishment, depending on establishment size, the same assumptions used to estimate the costs of option 1 and option 2. At $8,000 per firm for COC collections, this option would raise the cost of the OES program by $6.4 million dollars per year; if we instead assume a cost of $10,000 per firm for COC collections, the cost increment would be $7.7 million. These figures are about $1.0 million less than the sum of the incremental costs for option 1 and option 2, due to the overlap between the two covered groups, consisting of large establishments that belong to large firms.

Option 3 would reduce the variance of annual OES estimates by a larger amount than either option 1 or option 2. In total, it would add establishments with 27.8 million jobs to the sample each year. Firm-level analysis also would be supported under this sample design option, at least for the set of large firms for which comprehensive data were collected.

Other options. The options outlined above are of course not an exhaustive set of possibilities. One might, for example, want to modify option 1 by collecting data each year not only for large establishments but also for a subsample of smaller establishments. Option 2 might be modified by focusing collection efforts on firms doing business primarily in sectors that, according to some yet-to-be specified criterion, are likely to be affected by offshoring activity. Even assuming a cost of no more than $8,000–$10,000 per firm, reductions in the firm size threshold for data collection that were applied economy-wide would be very expensive. For example, lowering the firm size threshold to include all firms with employment of 5,000 or more would raise the cost of option 2 to between $10.5 million and $13.8 million. A lower firm size threshold might be more feasible, however, if its application were restricted to certain sectors. Other variants of the sampling options we have outlined also could be devised, but all would have in common the designation of some significant sample of establishments for annual collection.

One question that needs to be asked about the survey redesign options we have suggested is whether businesses would in fact be willing to respond to the survey every year. The results of a test conducted in 2000 are at least somewhat encouraging. In this test, staff in 25 states attempted to collect data from all of the certainty units in their states, and 12 states provided data on their collection experience that could be analyzed. These data show roughly comparable response rates for the certainty units originally scheduled to participate in the OES in 2000 and the added units originally scheduled to report only in another year of the three-year collection cycle. On the negative side, collecting data from both groups was difficult and the combined response rate was lower than would be hoped. An important factor in the response rate obtained appears to have been the amount of staff time available for follow-up with the surveyed units (BLS 2001b).

Another question is whether large companies would be willing to submit electronic records for all of their establishments centrally, as is assumed in our cost estimates for option 2 and option 3. Some large companies already do this and, depending on how their records are kept, others might be willing to do so. But if a significant number of large companies cannot or will not agree to central office collection, response rates for options that envision such collection could be adversely affected and the data collection costs for these options could be substantially higher than our rough figures suggest.

Other Changes in Survey Management Practices and Philosophy

In addition to the changes in sample design discussed above, converting the OES from a survey designed only to produce detailed cross-sectional estimates to a survey that also produced usable time series would require a number of other changes to the way in which the survey was managed. These would include changes in editing and imputation procedures, plans for dealing with future changes in the industry and occupation classification structures, and overarching changes in the philosophy governing other management decisions. Making these changes almost certainly would require additional staffing, and it should be emphasized that the costs of this added staffing are not reflected in the data collection cost estimates cited above.

Consider the process for editing the survey responses that are submitted. Under the current program structure, responses submitted by establishments are reviewed in isolation. Edit checks examine whether the combination of occupations reported seems sensible according to a specified set of criteria, but there are no edit checks that examine whether the information reported by an establishment in the current year is consistent with that reported by the same establishment in previous years. Checking the consistency of establishment reports across years would be more important in a program designed to produce time-series data. For example, inconsistencies in occupational coding across years might be identified through edit checks that flagged shifts of large blocks of employment from one occupation to another.

Similarly, under the current survey design, data for establishments that do not respond are imputed using information for other establishments that are deemed to be similar. In a program designed to produce time-series data, however, given idiosyncratic variation in staffing patterns across establishments, it would be desirable to develop an imputation methodology that relied more heavily on data reported by the missing establishments in previous time periods.

A recurring issue for a program designed to produce time-series estimates of employment by occupation would be dealing with future changes to the SOC and NAICS. The next scheduled NAICS revision is set for 2017, and the next scheduled SOC revision for 2018. From that point forward, current plans call for NAICS revisions approximately once every 5 years and SOC revisions approximately once every 10 years. It seems likely that SOC revisions will pose the most serious challenges for the OES program. Having a set of dual-coded records containing both the old and the new SOC code could allow the OES staff to reconstruct historical occupational employment series on the new SOC basis, but dual coding is expensive and would need to be built in to the OES budget plans.

Less tangible, OES management and staff would need to reorient themselves toward a new set of survey objectives, which in turn would drive subsequent decisions. There is always a tension between making changes designed to improve survey estimates and preserving the continuity of historical series. In the current OES program, the program’s stated objectives have dictated that, when data improvements are possible, they should be introduced, even when that makes the data less comparable over time. In a program that had as one of its stated objectives the production of annual time series, this balance would need to be set differently.

CONCLUSION

Because the annual sample for the OES survey is large, it is reasonable to think about using the historical OES data to produce annual time-series estimates. In practice, however, while useful for certain purposes, the annual times series that the historical data will support have significant limitations for studying the effects of offshoring. Reflecting the fact that certainty units are surveyed only once every three years, annual estimates for detailed occupations can be expected to have high variance. Breaks in occupation and industry classification systems and other changes in survey practices further complicate any trend analysis based on the OES data. Further, the existing data are not well suited to support longitudinal analysis.

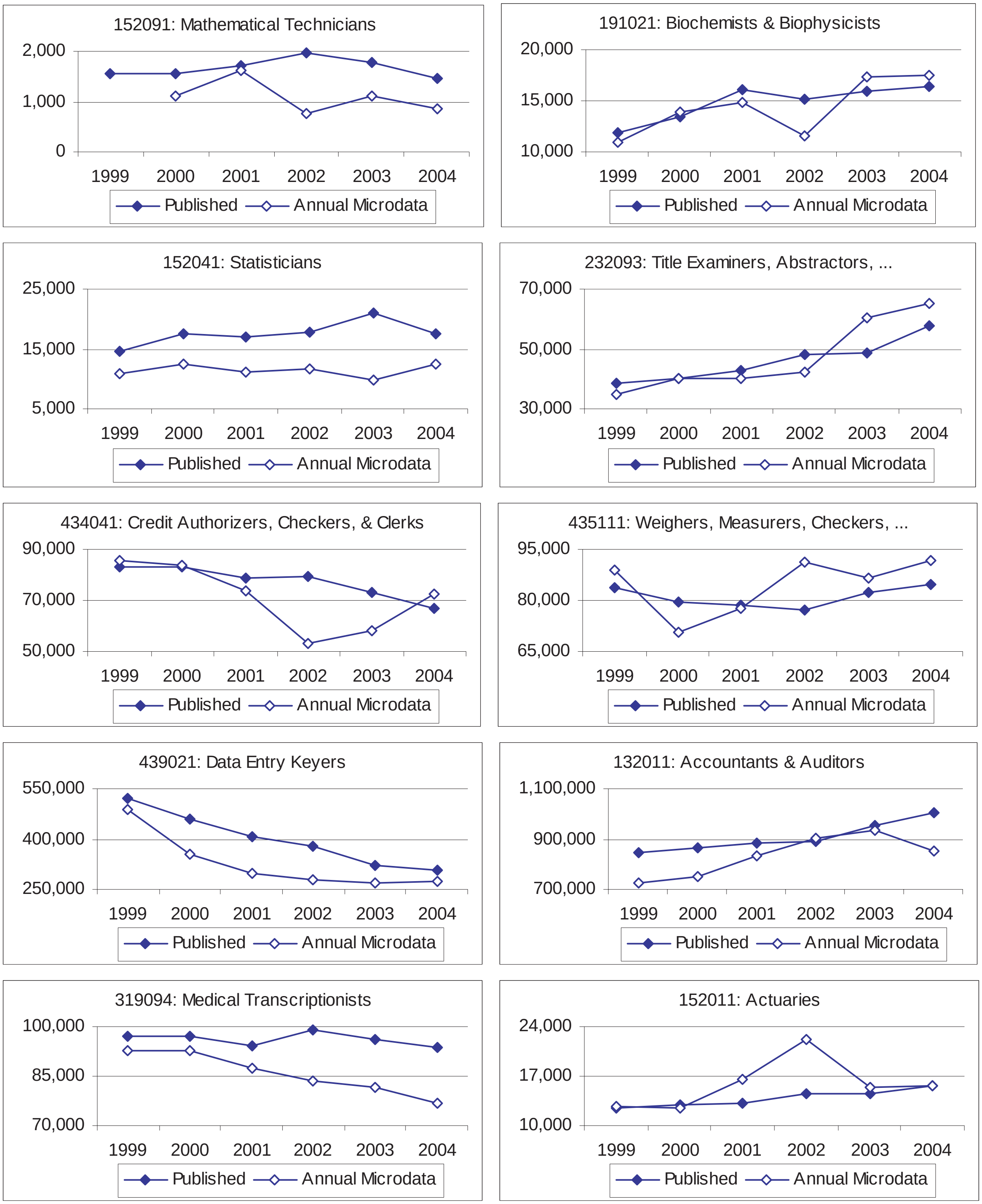
Any redesign of the OES program to produce reliable annual estimates and/or support longitudinal analysis should address each of these factors. We have suggested several options for redesigning the survey sample that would involve the collection of data from all large private sector establishments each year and/or the collection of data from all of the establishments at selected large firms each year. Ballpark cost estimates for the sample expansions associated with these options range from $3.5 to $7.7 million per year, though we should emphasize both that these estimates are very rough and that they cover only the direct costs of data collection. If the OES survey were to be redesigned along the lines we have suggested, funding also would be required to support new data editing procedures, dual coding of survey records at the time of future changes to the SOC, and other survey management activities, though data collection likely would account for the largest share of the total new funding that would be needed.

A significant complication we have not addressed is whether and how annual published estimates would be reconciled with more detailed cross-sectional estimates produced using data from multiple waves of data collection. The existing OES customer base cares a great deal about geographically disaggregated estimates and our guess is that, even with an expanded sample, the needs of this customer base could not be satisfied by purely annual data. This is, however, at least partly an empirical matter that remains to be addressed. Even with the full sample of approximately 1,200,000 establishments currently collected over three years, the BLS does not publish occupational data for industries disaggregated by geographic area, and, if we have understood correctly what is being recommended, it seems unrealistic to call for ". . . the BLS to make the changes to the OES methodology necessary to create time series data on all 820 occupations in the SOC by industry and geographic areas" (Sturgeon 2006). Further work would be required to determine the level of detail in occupational employment estimates—whether by industry or by geographic area, but almost certainly not by both simultaneously—that could be supported by different sample redesign options.

Finally, in thinking about a possible OES redesign, it will be important to consider carefully the value of data to support firm-level longitudinal analysis as compared to the value of improved annual time series. Without a doubt, a longitudinal occupational employment database could support interesting research, including useful research on the effects of offshoring. Further, there may be significant economies associated with the collection of data from all establishments of large firms. On the other hand, adding establishments from a small number of firms can be expected to do less to reduce the variability of annual time-series estimates than adding a similar number of establishments representing a larger number of firms. In addition, unless new modalities for researcher access to confidential microdata are developed, the number of researchers who would in practice end up working with firm-level data from the OES seems likely to be limited. Those charged with making a decision about the survey's future will need to be clear about the relative importance of different survey objectives as they choose among possible redesign options.

Figure 1: OES Employment of Ten Occupations Identified by Jensen and Kletzer (forthcoming)

As Most Off-Shorable, 1999-2004



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Understanding the Domestic Labor Market Impact of Offshore Services Outsourcing: Measurement Issues

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Over a remarkably short time frame, thinking about the production of services and services employment has changed dramatically. For a sector once considerable “nontradable,” measuring services trade is now a task of considerable energy and importance. The possible domestic employment implications of rising services trade—that is, services offshoring—attract significant attention and political interest.[31] The literature on services offshoring is expanding, although the activity remains “an elusive phenomenon.”[32] Much of that elusiveness springs from data limitations and measurement concerns, the subject of this conference. The increasing role of multinational corporations (MNCs), technology transfer, and increasing trade in services are just three activities associated with globalization where statistical and measurement limitations are widely acknowledged. Scholars interested in the labor market implications of increasing trade in services add one more area to this (partial) list: detailed time-series occupational data. Understanding the relocation of work, but not the workers doing the work, and more broadly, understanding the nature of work that is potentially offshorable, requires consistent detailed occupational data.

Before turning to the current data limitations and ongoing efforts to address the limitations, it is useful to establish definitions and provide context. For the vein of research focusing on domestic employment, one research goal is to understand and measure the magnitude and significance of shifting of business operations to offshore (foreign) locations and impact on American workforce (employment and earnings). The labor market impact questions include estimates of jobs moved offshore; estimates of lost potential job growth (because jobs moved offshore); jobs added due to foreign work located in the United States; jobs added due to efficiency gains; shifts in occupations; changes in earnings and the distribution of earnings; job displacement (numbers, worker characteristics, unemployment durations, UI receipt, reemployment).

Stated this way, it becomes clearer that the offshoring questions are not new, in that similar questions have been asked about and for the manufacturing sector for decades. These questions have, however, taken on heightened awareness with growth of services trade. This heightened awareness arises in part from the manufacturing/production worker focus becoming business and professional services/“white-collar” and professionals. This does not imply that everything is the same and nothing is new. Rather, the potential for services offshoring highlights tasks and occupations in a way that manufacturing import competition did not (and does not). Also, the implications for educational attainment may be different, as a result of the different impact on occupations.

One focused avenue in the literature on services offshoring attempts to address directly the occupational or task nature of the activity. Papers by Jensen and Kletzer (2006, 2008); Blinder (2006, 2007); van Welsum and Reif (2009); and Moncarz, Wolf, and Wright (2008) share a general approach to measuring potential offshorability by looking at the task and activity content of jobs. Although these papers differ in methodology and details, they share a common starting

[31] Services offshoring refers to the (potential) migration of jobs (but not the people performing them) across national borders, mostly from rich countries to poor ones, with imported products and activities flowing back to the United States.
[32] See Jensen and Kletzer (2008) for citations to the literature. The phrase “elusive phenomenon” appears in NAPA (2006a). Interested readers are directed to the set of three NAPA publications on offshoring (2006a,b; 2007).

point that movable jobs are those with little face-to-face customer contact; high information content, work process is Internet enabled and/or telecommutable (see Bardhan and Kroll [2003]; Dossani and Kenney [2003], and Blinder [2006]). More informally, it is commonly believed that if "it can be sent down a wire (or wireless)," it is offshorable. These papers have all yielded sets of occupations varying in their "potential offshorability." One possible next step, as noted in Chapter 4 of NAPA (2006b), is to consider that the offshoring of services should produce changes in the occupational structure of firms and establishments. In other words, shifts in certain (potentially "movable") occupations may be consistent with offshoring. Shifts in these occupations, within industries with (intermediate) services trade, may be more compelling evidence.

This paper proceeds with some thoughts on possible enhanced links between studies of (domestic) outsourcing and (international) offshore outsourcing. After that I describe the basic principles of offshorability and the data on the content and context of jobs (O*Net), together with occupational employment and earnings (Occupational Employment Statistics [OES]). The next section considers the preliminary evidence of shifts of the occupational employment distribution, followed by a concluding section.

HOW STUDIES OF OFFSHORING MAY BENEFIT FROM LITERATURE ON OUTSOURCING

Over the past five years, the potential for services offshoring has generated remarkable attention for an internal-to-the-firm economic activity, and area of research, historically undertaken behind-the-scenes and not in the spotlight. These behind-the-scenes activities are the "make-or-buy" points—the decisions to use in-house (own) employees versus purchasing completed tasks from other establishments.

Interest in domestic contracting out surged in the 1990s, with attention paid to temporary help agencies. Katharine Abraham's research led the way, with her 1988 and 1990 papers on market-mediated work arrangements. Then, as now, research progress was slowed by data limitations. The still-small literature on domestic outsourcing now reveals significant growth in the activity over the past 25 years (see papers by Segal and Sullivan [1997], Houseman [2001], and Dey, Houseman, and Polivka [forthcoming]).

To date, research on offshore outsourcing has proceeded without much of a link to the domestic outsourcing literature. Interestingly, perspectives from international trade have dominated the offshore outsourcing literature, in a services version of "does trade cost jobs?" Yet the domestic outsourcing literature has implications for offshore outsourcing research. Domestic outsourcing can produce shifts in the industry structure of employment. Contractual production workers are employees of temporary help agencies (or more broadly, firms in the business services sector). In-house production workers are (usually) employed by manufacturing firms. Simply put, as stated by Dey, Houseman, and Polivka (forthcoming), ". . . the number and occupational distribution of workers classified in the manufacturing sector changes, even if the number and occupational distribution of workers performing the tasks does not" (p. 2). Thus, the domestic outsourcing literature looks at shifts in the pattern of occupational employment across industries.[33] Following the logic that offshore outsourcing involves the reallocation of production tasks within establishments, firms, and industries, we might expect to see shifts in the pattern of occupations within industries, and most specifically for "potentially movable" occupations within industries where business and professional services imports have increased. Investigating this (weakly formed) hypothesis involves bringing together data on (potentially movable) occupations, occupational employment, and services trade.

MEASURING TASK CONTENT OF POTENTIALLY MOVABLE SERVICES OCCUPATIONS[34]

The literature on offshoring posits that movable jobs are those with little face-to-face customer contact, those with high information content, and those whose work processes are Internet enabled and/or telecommutable.[35] A great deal of attention is paid to Internet-enabled: the expansion of broadband and wireless (and the broad use of "off the shelf" software programs) having greatly reduced the "transportation costs" of information. Having developed a set of tradable services occupations, the next step is to consider the detailed characteristics of these jobs and whether the characteristics fit a description of offshorability.

The use here of Occupational Information Network (O*Net) is in the spirit of Autor, Levy, and Murnane (2003), who explore the spread of computerization, using the *Dictionary of Occupational Titles* (DOT) to measure the routine vs. nonroutine, and cognitive vs. noncognitive aspects of occupations. The O*Net was developed by the U.S. Department of Labor as a replacement for the DOT.[36] Similar in theme to the DOT as a source of occupational information, O*Net reflects the expanded possibilities of contemporary information technology in that it is a database, with information on job characteristics and worker attributes. Unlike the vast job-specific detail provided on 12,000+ occupations in the DOT, O*Net provides information on 1100+ occupations, using language and assessment common across jobs. Unlike DOT, where professional analysts are the primary source of information, job incumbents provide the information, which is gathered by survey questionnaire. Occupations are organized at the Standard Occupational Classification level.[37] O*Net is used in a variety of fields studying work and occupations, such as organizational behavior, applied psychology, career assessment, human resource management, and occupational psychology.[38] O*Net is relatively foreign to research in economics. Blinder (2007) takes an approach similar in spirit to our discussion here.

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[33] In fairness to the domestic outsourcing literature, it considers a broader range of questions from industrial relations to labor demand, including job security, wages, compensation and benefits costs, job training, hiring, firing, and search costs.
[34] This section borrows heavily from Jensen and Kletzer (2008).
[35] See Bardhan and Kroll (2003) for a list of attributes.
[36] See Peterson and Mumford et al. (1999) for a history of the development of O*Net.
[37] Importantly, the level of SOC detail used in O*Net (6-digit plus) is deeper than the 6-digit SOC codes used in OES.
[38] See http://online.onetcenter.org/ for information on acquiring the data.

The O*Net Content model identifies the most important types of information about work, jobs, and workers, and integrates the information into a structured system of six major categories:[39]

1) Worker characteristics (abilities, occupational interests, work values, work styles);
2) Worker requirements (skills and knowledge, education);
3) Experience requirements (experience and training, skills and entry requirements, licensing);
4) Occupational requirements (generalized and detailed work activities, organizational context, work context)
5) Labor market characteristics (labor market information, occupational outlook); and
6) Occupation-specific information (tasks, tools and technology).

The first three categories (Worker characteristics, Worker requirements, Experience requirements) are worker oriented. The second three are work- (or job-) oriented categories, with Occupational requirements as the focus of interest here. Occupational requirements are meant to identify requisite tasks, and are designed to cross occupations, at both a general and detailed level, while Occupation-specific information is meant to be quite detailed and literally occupation specific.

The domain/category Occupational requirements is designed to provide ". . . a comprehensive set of variables or detailed elements that describe what various occupations require" (National Center for O*Net Development 2006, p. 20). The focus is on typical activities required across occupations. Within the Generalized and detailed work activities subdomain, 11 measures to construct an index of offshorability/potential tradability. The sign in parentheses [(+) or (-)] denotes a prior on whether the characteristic is positively related to offshorability or negatively related.

On information content:

Getting information (+)

Processing information (+)

Analyzing data or information (+)

Documenting/recording information (+)

On Internet-enabled:

Interacting with computers (+)

On face-to-face contact:

[39] The idea behind the six content areas is to provide "multiple windows" on the world of work. Information on the O*Net Context Model comes from National Center for O*Net Development (2006). For a comprehensive discussion of O*Net from the practical and research perspectives, see Peterson and Mumford et, al. (2001).

Assisting or caring for others (-)

Performing or working directly with the public (-)

Establishing or maintaining interpersonal relationships (-)

On working together or supervising the work of others:

Communicating with supervisors, peers, subordinates (-)

Training and teaching others (-)

Performing administrative duties (-)

Coordinating work and activities of others (-)

On the "on-site" nature of work:

Inspecting equipment, structures, or material (-)

Monitoring processes, materials, and/or surroundings (-)

Rating scales are used to quantify these characteristics. Multiple scales are provided, with "importance" and "level" as the predominant pair. "Importance" is the rating of answers to the question, "How important is this skill to performance on the job?" Answers vary from "not important" to "extremely important," on a scale of 1 to 5. "Level" is the rating of "What level of this skill is needed to perform this job?" ranging from low (level) to high (level), on a scale of 1 to 7.[40] An illustration might be useful, normalizing the two different scale ranges to 0 to 100. For the attribute "Performing or working directly with the public," data entry keyers are assigned importance (I) =43, and level (L) = 33. For Security Guards, I=74 and L=62. Compared to data entry keyers, working with the public is more important to performance on the job for security guards, along with a higher level of the "skill" of working with the public. See Jensen and Kletzer (2008) for a more complete description of the rating scheme and a presentation of summary statistics on the work activities.

The composite index of offshorability is the weighted sum of the 14 components, using priors on the sign of the attribute in regard to offshoring potential. Higher values of the index indicate more offshorability potential, yielding a ranking of all occupations for which the attributes are available.[41] The usefulness of the index is ordinal, not cardinal. Occupations are judged on their offshorability relative to each other, not compared to some absolute standard. Tables 1 and 2 report the top-30 and bottom-30 occupations.[42] Occupations at the top of the list seem unsurprising: credit authorizers, data entry keyers, accountants, medical transcriptionists, market research analysts, bookkeeping, and account clerks.

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[40] See Peterson and Mumford et al. (1999, 2001). Level allows a "not relevant to performance" rating, coded as 0.

[41] In constructing an index, it is not obvious how to weight importance and level. Starting from the observation that importance varies more than level across occupations, an index was created using a weight of three-quarters to importance and one-quarter to level. The ranking is robust to different weights.

[42] The full listing of 799 occupations, ranked by job-task content, takes up 28 printed pages, and is available upon request.

Tables 1 and 2 list employment and median annual earnings for each occupation, for May 2003 and May 2008, obtained from the OES program. The OES program, operated by the U.S. Bureau of Labor Statistics (BLS), generates employment and earnings estimates for over 800 detailed occupations, derived from a semiannual mail survey of establishments. Although the OES survey methodology is designed to create detailed cross-sectional employment and wage estimates for the U.S. and smaller geographic units, across and by industry, it is less useful for comparisons of two or more points in time. Changes in the procedures for collecting data, along with changes in occupational and industry codes may it complicated to create a time series. A great deal of detail must be suppressed to create a consistent time series, as noted by Abraham and Spletzer (2009). Dey, Houseman, and Polivka (forthcoming) create a time series for 15–18 broad occupational aggregates (at the major occupation level) and 6 narrow occupational groups. This level of aggregation loses the movability characteristics available from O*Net. For this paper's preliminary analysis, changes in employment and earnings are considered at just two data points, May 2003 and May 2008.

To date, I have located three other analyses that order occupations by an assessment of offshorability. Consistent with its organizational interest in occupational growth projections, the BLS has developed a list of 40 detailed occupations deemed "susceptible to a significant risk of offshoring" (BLS 2006, p. 12). Of these 40 occupations, 39 are services occupations (the exception is aircraft mechanics and service technicians). With varying degrees of "fit," 38 of these 39 occupations are noted for their offshorability by the index reported here. Graphic designers and switchboard operators are included in the BLS list, with my index ranking these two occupations close to the middle of the 457. All the rest of the BLS occupations are fairly highly ranked by my index. The BLS list is not ranked; it is simply offered as a list of susceptible occupations, presumably with some more susceptible than others.[43]

Moncarz, Wolf, and Wright (2008) present a more comprehensive analysis of offshoring and occupations, from work performed for the BLS Employment Projections Program. Starting with 515 service-providing occupations, BLS economists who study occupations identified those occupations "that had insurmountable barriers to offshoring" (p. 73).[44] After eliminating occupations "considered not at all susceptible to offshoring" (p. 73), the analysis was confined to 160 occupations. The analysts considered four characteristics: 1) inputs and outputs that can travel easily across long distances (such as electronically), 2) work that requires little interaction with other types of workers, 3) work that requires little knowledge of the social or cultural idiosyncrasies of the target market, and 4) work that is routine in nature (p. 73). Occupations were scored on this characteristics (very low to very high, a four-point scale), and assigned a susceptibility score. A preliminary comparison of the resulting ranking suggests considerable difference between the BLS analysis and the analysis reported here.

[43] The BLS methodology is similar in spirit to ours, considering characteristics of digital transmission, repetitive tasks, little face-to-face interaction. Occupational analysts provided judgments on these characteristics. Further refinements included excluding occupations where technology or automation could account for a dampening of employment growth. See BLS (2006).

[44] Examples include physical therapists and barbers, security guards, correctional officers.

Blinder (2007) explores a subjective index based on two characteristics: 1) can the work be delivered to a remote location, and 2) must the job be performed at a specific (U.S.) location? In his subjective measure, Blinder concentrates on one characteristic of the delivery of services, the separation of customer and supplier that he labels “impersonally delivered services.” Basically, impersonally delivered services can be delivered electronically, incorporating the vast improvement in ICT. His measure does not incorporate any attributes related to the kind of work sent down the wire, such as information context or internet enabling. Most importantly, in terms of the area of traditional US comparative advantage, Blinder does not consider the creativity or routineness of work.[45] In an area that needs more exploration, there are many high-skill and high-value (creative) services, that while transmittable electronically, pose opportunities for American workers and firms to penetrate foreign markets.

Using both production and nonproduction occupations, Blinder estimates that 30–40 million workers are currently in potentially tradable jobs, based on May 2005 employment levels. Objective measures may well be preferred, given the number of occupations (less than 450) and desire for replication.

RISING SERVICES TRADE AND SHIFTS IN THE OCCUPATIONAL DISTRIBUTION OF EMPLOYMENT

Taking up the approach followed in National Academy of Public Administration (NAPA 2006b), this section examines shifts in the occupational distribution of employment within service sector industries where imports (trade) have expanded. The idea is to look for evidence consistent with offshoring, within industries where services trade has expanded: Do high potential movability occupations decline (relative to national trends) in industries coincident with rising imports?[46] How does the occupational employment share within a “rising import” industry relate to potential movability?

NAPA (2006b) examines a limited set of industries that were “significant in size, potentially vulnerable to off-shoring, sufficiently diverse, well integrated into the overall economy, and likely to continue expanding.” Four industries were selected:

1) pharmaceutical and medicine manufacturing [3254];

2) architectural, engineering, and related services [5413];

3) computer systems design and related services [5415]; and

4) business support services [5614].

The NAPA analysis developed additional and more extensive measures of offshoring than tackled here (to date). The approach here is in the spirit of NAPA’s analysis, of considering service industries with a high-tech component with increasing trade flows, yet with a considerably larger set of detailed industries. Appendix Table A.1 reports changes in

[45] The routineness of work, or the codification of tasks, is a characteristic emphasized by Autor, Levy, and Murnane (2003).
[46] This framing ignores the question of whether the appropriate “trade” measure is the level of trade or the change.

occupational employment, within 6-digit NAICS industries and across industries, for NAICS sectors 51 (Information), 54 (Professional, scientific, and technical services) and 56 (Administrative and support services).[47]

Before turning to the occupational employment data, Figure 1 shows the rise in trade in the overall category of Other private services, where these NAICS sectors reside. There is a trade surplus in this category that has grown since the early 2000s. Table 3 presents more detailed trade data, for the period 2002–2007, for a subset of Other private services that includes a number of the industries examined here. The services trade surplus is broadly in evidence, although it is also clear that imports have increased substantially.

Returning to Appendix Table A.1, for each industry, the subset of occupations charted starts with the "Ten largest occupations for each industry" featured on the BLS Web site, drawn from the May 2008 OES (BLS 2009). Given the difficulties of using the OES data as a time series, and the desire to examine very detailed occupations, the analysis to date compares just two points in time, May 2003 and May 2008.

Table 1.1 is sufficiently detailed to make summary statistics complicated. Offering the most summary of summary statistics, the movability index is negatively correlated with changes in the share of industry employment accounted for by an occupation (if an occupation's share of industry employment rose from 2003 to 2008, that occupation was lower ranked in terms of potential movability).[48] A general observation from the table: the majority of the most populous occupations in these industries grew faster than the corresponding national occupational average (that is, a comparison of Columns 2 and 4).

CONCLUSIONS

This paper offers a measure of potential movability of occupations, built from common notions of job characteristics related to "offshorability." The calculated index of offshorability offers strong potential for understanding jobs (tasks) at risk. Preliminary analysis of how these occupations have changed in importance, measured as by employment share and earnings change, is ongoing. A natural question arises as to whether business, professional, and technical services industries with rising imports show evidence of shifts in occupational employment that are consistent with offshoring.

[47] NAICS sector 56 also includes Waste management and Remediation services, but those detailed industries are not included here.
[48] Correlation = –0.25 for sectors 54 and 56.

Table 1: Top 30 Occupations for Potential Movability

				May 2008		May 2003		Change, 2003–2008	
SOC code	Occupation title	Movability index	Rank	Employment	Median annual earnings	Employment	Median annual earnings	Employment	Real median earnings
15-2091	Mathematical technicians	1.274	1	1,100	$38,400	2,180	$36,540	-0.495	-0.102
15-2021	Mathematicians	0.118	2	2,770	$95,150	2,470	$78,290	0.121	0.039
17-3013	Mechanical drafters	-0.171	3	77,070	$46,640	74,010	$41,520	0.041	-0.040
13-2041	Credit analysts	-0.173	4	74,400	$55,250	68,910	$45,020	0.080	0.049
15-2031	Operations research analysts	-0.289	5	60,860	$69,000	58,080	$58,300	0.048	0.012
19-2011	Astronomers	-0.358	6	1,280	$101,300	770	$88,310	0.662	-0.020
15-2041	Statisticians	-0.391	7	20,680	$72,610	18,370	$59,560	0.126	0.042
17-3012	Electrical and electronics drafters	-0.395	8	32,710	$51,320	33,720	$41,730	-0.030	0.051
15-1051	Computer systems analysts	-0.443	9	489,890	$75,500	474,780	$64,160	0.032	0.006
19-3011	Economists	-0.454	10	12,600	$83,590	12,300	$70,250	0.024	0.017
19-3021	Market research analysts	-0.457	11	230,070	$61,070	142,190	$54,670	0.618	-0.045
15-2011	Actuaries	-0.486	13	18,220	$84,810	14,680	$72,520	0.241	0.000
15-1031	Computer software engineers, applications	-0.506	14	494,160	$85,430	392,140	$72,530	0.260	0.007
17-2072	Electronics engineers, except computer	-0.539	15	139,930	$86,370	137,320	$71,370	0.019	0.034
13-2031	Budget analysts	-0.564	16	62,630	$65,320	55,560	$54,520	0.127	0.024
15-1061	Database administrators	-0.571	17	115,770	$69,740	100,890	$58,200	0.147	0.024
13-2011	Accountants and auditors	-0.577	18	1,133,580	$59,430	924,640	$49,060	0.226	0.035
43-9021	Data entry keyers	-0.644	19	272,810	$26,120	339,010	$22,600	-0.195	-0.012
13-2052	Personal financial advisors	-0.668	20	146,690	$69,050	85,670	$58,700	0.712	0.005
23-2093	Title examiners, abstractors, and searchers	-0.669	21	59,390	$38,300	47,840	$34,080	0.241	-0.039
17-2071	Electrical engineers	-0.671	22	154,670	$82,160	146,150	$69,640	0.058	0.008
31-9094	Medical transcriptionists	-0.677	23	86,200	$32,060	97,810	$27,590	-0.119	-0.007
17-2011	Aerospace engineers	-0.679	24	67,800	$92,520	70,740	$74,520	-0.042	0.061
17-1021	Cartographers and photogrammetrists	-0.741	25	11,690	$51,180	8,940	$44,170	0.308	-0.010
19-3041	Sociologists	-0.754	26	4,390	$68,570	3,060	$54,410	0.435	0.077
43-9111	Statistical assistants	-0.760	27	16,900	$34,850	20,970	$29,890	-0.194	-0.003
43-3031	Bookkeeping, accounting, and auditing clerks	-0.763	28	1,855,010	$32,510	1,750,680	$27,760	0.060	0.001
15-1011	Computer and informa-tion scientists, research	-0.785	29	26,610	$97,970	23,210	$81,600	0.146	0.026
13-2051	Financial analysts	-0.833	30	236,720	$73,150	165,420	$60,050	0.431	0.041

Table 2: Bottom 30 Occupations for Potential Movability

SOC code	Occupation title	Movability Index	Rank	May 2008 Employment	May 2008 Median annual earnings	May 2003 Employment	May 2003 Median annual earnings	Change, 2003 -2008 Employment	Change, 2003 -2008 Real median earnings
31-9091	Dental assistants	-3.228	768	293,090	$32,380	272,030	$27,700	0.077	-0.001
53-6021	Parking lot attendants	-3.241	769	136,470	$18,790	113,490	$16,630	0.202	-0.034
29-1061	Anesthesiologists	-3.247	770	34,230	#	23,790	#	0.439	
39-5093	Shampooers	-3.257	771	15,570	$17,300	15,300	$14,360	0.018	0.030
29-1081	Podiatrists	-3.272	772	9,670	$113,560	7,800	$94,060	0.240	0.032
47-5061	Roof bolters, mining	-3.284	773	4,950	$45,210	3,980	$38,550	0.244	0.002
25-2011	Preschool teachers, except special education	-3.288	774	392,170	$23,870	368,870	$19,820	0.063	0.029
27-2032	Choreographers	-3.301	775	13,860	$38,520	14,810	$31,030	-0.064	0.061
29-9091	Athletic trainers	-3.316	777	15,070	$39,640	11,750	$32,850	0.283	0.031
29-2055	Surgical technologists	-3.317	778	89,600	$38,740	73,250	$32,130	0.223	0.031
53-3011	Ambulance drivers and attendants, except emergency medical technicians	-3.324	779	21,790	$22,410	17,650	$19,000	0.235	0.008
33-9032	Security guards	-3.334	780	1,046,760	$23,460	964,260	$19,660	0.086	0.020
39-1021	First-line supervisors/managers of personal service workers	-3.340	781	129,070	$34,910	110,630	$29,500	0.167	0.011
21-2011	Clergy	-3.351	782	42,040	$41,730	38,170	$33,800	0.101	0.055
27-2021	Athletes and sports competitors	-3.362	783	13,960	$40,480	11,840	$45,780	0.179	-0.244
39-3091	Amusement and recreation attendants	-3.366	784	258,820	$17,470	236,070	$15,030	0.096	-0.007
31-9011	Massage therapists	-3.379	785	51,250	$34,900	29,940	$28,670	0.712	0.040
39-3011	Gaming dealers	-3.381	786	91,130	$16,310	76,120	$14,200	0.197	-0.018
49-9051	Electrical power-line installers and repairers	-3.427	787	111,580	$55,100	95,190	$48,960	0.172	-0.038
47-2022	Stonemasons	-3.446	788	18,910	$37,800	13,710	$34,000	0.379	-0.050
47-4091	Segmental pavers	-3.480	789	1,170	$27,400	1,710	$26,530	-0.316	-0.117
27-2041	Music directors and composers	-3.488	790	9,120	$41,270	9,000	$32,530	0.013	0.084
37-3013	Tree trimmers and pruners	-3.497	791	35,420	$29,970	40,710	$25,630	-0.130	-0.001
11-9031	Education administrators, preschool and child care center/program	-3.528	792	49,630	$39,940	56,030	$34,500	-0.114	-0.011
29-2054	Respiratory therapy technicians	-3.533	793	16,210	$42,430	25,470	$34,850	-0.364	0.041
39-6031	Flight attendants	-3.609	794	99,480	$35,930	107,100	***	-0.071	
39-9031	Fitness trainers and aerobics instructors	-3.623	796	229,030	$29,210	177,790	$24,510	0.288	0.019
33-1021	First-line supervisors/managers of fire fighting and prevention workers	-3.680	797	53,300	$67,440	59,000	$57,000	-0.097	0.011
27-2022	Coaches and scouts	-3.844	798	175,720	$28,340	105,070	$26,950	0.672	-0.101
49-9095	Manufactured building and mobile home installers	-4.131	799	8,290	$28,250	13,160	$23,360	-0.370	0.034

Table 3: International Trade in Business, Professional and Technical Services (millions of dollars)

	2002	2003	2004	2005	2006	2007
Total						
Imports	34185	37458	40992	46924	61068	68763
Exports	60177	62958	69568	76487	89692	107675
Advertising						
Imports	786	864	931	876	1845	1977
Exports	466	517	581	896	3163	4030
Computer and Information Services						
Imports	6495	7617	8639	10596	13085	14815
Exports	7079	8213	8693	9434	10341	12798
Research, Development and Testing Services						
Imports	4063	5071	5778	7239	9429	11437
Exports	8678	9467	9563	10431	12821	14698
Management Consulting and Public Relations Services						
Imports	11028	10770	12076	14905	19361	20475
Exports	14339	14309	16372	19242	22058	24699
Legal Services						
Imports	820	874	899	894	1222	1561
Exports	3099	3377	3997	4225	5294	6424
Construction, Architectural and Engineering Services						
Imports	316	303	580	434	1751	1851
Exports	2247	2564	3294	3791	5369	6469
Industrial Engineering						
Imports	183	176	164	169	1035	1504
Exports	806	877	828	2303	3836	3872
Installation, Maintenance and Repair of Equipment						
Imports	668	670	720	956	3780	4180
Exports	5287	4995	4948	6494	7667	8966
Operational Leasing						
Imports	1060	841	1142	1316	1161	1046
Exports	7552	8062	8634	9555	10389	11664
Other (1)						
Imports	8768	10267	9994	9538	7880	9917
Exports	10622	10575	12656	10116	8754	14124

(1) Other includes accounting, auditing, and bookkeeping services; medical services; mining services; sports, and performing arts; trade-related services; training services.

Source: Bureau of Economic Analysis, U.S. International Services Cross-Border Trade

Accessed at: http://www.bea.gov/international/intlserv.htm

Figure 4

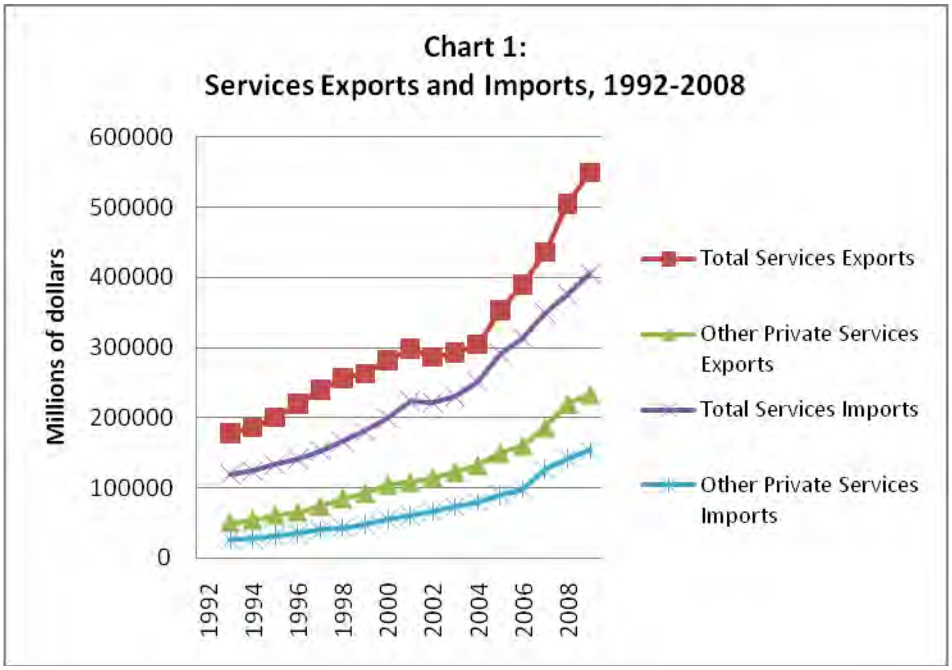
Chart 1:
Services Exports and Imports, 1992-2008
Millions of dollars
600000
500000
400000
300000
200000
100000
0
1992
1994
1996
1998
2000
2002
2004
2006
2008
Total Services Exports
Other Private Services Exports
Total Services Imports
Other Private Services Imports

Table A.1 Top 10 Occupations (by employment), by Industry, 2003 and 2008

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
Legal Services	541100	All	00-0000	0.032		0.060	
		Lawyers	23-1011	0.046	0.004	0.073	180
		Paralegals and legal assistants	23-2011	0.226	0.025	0.224	41
		Title examiners, abstractors, and searchers	23-2093	0.580	0.008	0.241	21
		Bookkeeping, accounting, and auditing clerks	43-3031	-0.015	-0.001	0.060	28
		File clerks	43-4071	0.099	0.001	-0.179	186
		Receptionists and information clerks	43-4171	0.077	0.001	0.037	208
		Executive secretaries and administrative assistants	43-6011	-0.264	-0.007	0.051	293
		Legal Secretaries	43-6012	-0.023	-0.011	-0.024	148
		Secretaries, except legal, medical, and executive	43-6014	-0.290	-0.017	0.014	273
		Office clerks, general	43-9061	0.031	0.000	-0.007	209
Accounting & Bookkeeping Services	541200	All	00-0000	0.113		0.060	
	541200	Accountants and auditors	13-2011	0.279	0.042	0.226	40
	541200	Tax preparers	13-2082	0.279	0.009	0.250	70
	541200	First-line supervisors/managers of office and administrative support workers	43-1011	-0.063	-0.004	-0.006	556
	541200	Bill and account collectors	43-3011	1.114	0.010	-0.020	118
	541200	Billing and posting clerks and machine operators	43-3021	0.486	0.011	0.051	45
	541200	Bookkeeping, accounting, and auditing clerks	43-3031	0.154	0.004	0.060	28

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
	541200	Payroll and timekeeping clerks	43-3051	2.208	0.018	0.046	34
	541200	Executive secretaries and administrative assistants	43-6011	0.164	0.001	0.051	293
	541200	Secretaries, except legal, medical, and executive	43-6014	-0.001	-0.004	0.014	273
	541200	Office clerks, general	43-9061	0.029	-0.004	-0.007	209
Architectural & Engineering Services	541300	All	00-0000	0.172		0.060	
	541300	Engineering managers	11-9041	0.100	-0.002	-0.065	228
	541300	Architects, except landscape and naval	17-1011	0.267	0.005	0.220	258
	541300	Surveyors	17-1022	0.091	-0.002	0.083	261
	541300	Civil engineers	17-2051	0.356	0.013	0.267	363
	541300	Mechanical engineers	17-2141	0.371	0.005	0.124	93
	541300	Architectural and civil drafters	17-3011	0.276	0.005	0.175	104
	541300	Civil engineering technicians	17-3022	0.124	-0.001	-0.021	55
	541300	Surveying and mapping technicians	17-3031	0.337	0.004	0.246	67
	541300	Executive secretaries and administrative assistants	43-6011	0.350	0.004	0.051	293
	541300	Office clerks, general	43-9061	0.208	0.001	-0.007	209
Specialized Design Services	541400	All	00-0000	0.195	.	0.060	.
	541400	General and operations managers	11-1021	-0.081	-0.007	-0.103	650
	541400	Art directors	27-1011	0.178	0.000	0.403	131
	541400	Commercial and industrial designers	27-1021	0.394	0.003	-0.013	125

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
	541400	Graphic designers	27-1024	0.273	0.013	0.377	103
	541400	Interior designers	27-1025	0.541	0.034	0.152	326
	541400	Sales representatives, services, all other	41-3099	0.507	0.006	0.617	150
	541400	Bookkeeping, accounting, and auditing clerks	43-3031	0.077	-0.003	0.060	28
	541400	Executive secretaries and administrative assistants	43-6011	0.251	0.001	0.051	293
	541400	Secretaries, except legal, medical and executive	43-6014	0.384	0.003	0.014	273
	541400	Office clerks, general	43-9061	0.216	0.001	-0.007	209
Computer Systems Design & Related Services	541500	All	00-0000	0.284		0.060	.
	541500	Computer and information systems managers	11-3021	0.355	0.002	0.041	301
	541500	Management analysts	13-1111	0.404	0.002	0.264	223
	541500	**Computer programmers**	15-1021	0.268	-0.001	-0.087	59
	541500	Computer software engineers, applications	15-1031	0.325	0.004	0.260	14
	541500	Computer software engineers, systems software	15-1032	0.321	0.002	0.336	64
	541500	**Computer support specialists**	15-1041	0.212	-0.004	0.129	157
	541500	Computer systems analysts	15-1051	0.462	0.011	0.032	9
	541500	Network and computer systems administrators	15-1071	0.280	0.000	0.378	87
	541500	Network systems and data communications analysts	15-1081	0.461	0.003	0.557	348
	541500	**Customer service representatives**	43-4051	-0.016	-0.007	0.174	161

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
Management & Technical Consulting Services	541600	All	00-0000	0.292	.	0.060	.
	541600	General and operations managers	11-1021	0.119	-0.005	-0.103	650
	541600	Management analysts	13-1111	0.534	-0.001	0.264	223
	541600	Business operations specialists, all other	13-1199	0.897	0.011	0.216	225
	541600	Market research analysts	19-3021	0.791	0.008	0.618	11
	541600	Sales representatives, services, all other	41-3099	0.929	0.008	0.617	150
	541600	Bookkeeping, accounting, and auditing clerks	43-3031	0.184	-0.003	0.060	28
	541600	Customer service representatives	43-4051	0.041	-0.001	0.174	161
	541600	Executive secretaries and admin. Assistants	43-6011	0.334	-0.001	0.051	293
	541600	Secretaries, except legal, medical, and executive	43-6014	0.281	-0.006	0.014	273
	541600	Office clerks, general	43-9061	0.142	-0.015	-0.007	209
Office administrative services	561100	All	00-0000	0.338	0.000	.	.
	561100	General and operations managers	11-1021	0.446	0.004	-0.103	650
	561100	Management analysts	13-1111	0.195	-0.004	0.264	223
	561100	Accountants and auditors	13-2011	0.855	0.011	0.226	40
	561100	First-line supervisors/managers of office and administrative support workers	43-1011	0.551	0.005	-0.006	556
	561100	Billing and posting clerks and machine operators	43-3021	0.529	0.003	0.051	37

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
	561100	Bookkeeping, accounting, and auditing clerks	43-3031	0.652	0.010	0.060	28
	561100	Customer service representatives	43-4051	0.950	0.022	0.174	161
	561100	Executive secretaries and administrative assistants	43-6011	0.350	0.000	0.051	293
	561100	Secretaries, except legal, medical, and executive	43-6014	0.753	0.007	0.014	273
	561100	Office clerks, general	43-9061	0.317	-0.001	-0.007	209
Employment Services	561300	All	00-0000	0.033	0.000	0.060	
	561300	Employment, recruitment, and placement specialists	13-1071	1.110	0.013	0.255	440
	561300	Registered nurses	29-1111	0.307	0.006	0.132	741
	561300	Customer service representatives	43-4051	0.471	0.009	0.174	161
	561300	Executive secretaries and administrative assistants	43-6011	0.109	0.001	0.051	293
	561300	Office clerks, general	43-9061	0.033	0.000	-0.007	209
	561300	Construction laborers	47-2061	0.687	0.012	0.218	567
	561300	Team assemblers	51-2092	1.613	0.031	-0.006	405
	561300	Helpers-production workers	51-9198	0.531	0.012	0.104	249
	561300	Laborers and freight, stock, and material movers, hand	53-7062	-0.189	-0.031	0.035	575
	561300	Packers and packagers, hand	53-7064	-0.048	-0.003	-0.138	585
Business Support Services	561400	All	00-0000	0.113	0.000	0.060	
	561400	General and operations managers	11-1021	-0.030	-0.003	-0.103	650
	561400	Medical transcriptionists	31-9094	0.094	0.000	-0.119	23
	561400	Telemarketers	41-9041	0.101	-0.002	-0.146	42

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
	561400	First-line supervisors/managers of office and administrative support workers	43-1011	0.206	0.003	-0.006	556
	561400	Switchboard operators, including answering service	43-2011	-0.221	-0.010	-0.293	233
	561400	Bill and account collectors	43-3011	0.316	0.020	-0.020	118
	561400	Customer service representatives	43-4051	0.517	0.055	0.174	161
	561400	Mail clerks and mail machine operators, except postal service	43-9051	0.244	0.002	-0.099	213
	561400	Office clerks, general	43-9061	0.011	-0.003	-0.007	209
	561400	Office machine operators, except computer	43-9071	0.088	-0.001	-0.122	537
Newspaper, book & directory publishers	511100	All	00-0000	-0.092	0.000	0.060	.
	511100	General and operations managers	11-1021	-0.103	0.000	-0.103	650
	511100	Graphic designers	27-1021	0.408	0.016	-0.013	125
	511100	Reporters and correspondents	27-3022	-0.036	0.003	-0.035	40
	511100	Editors	27-3041	0.051	0.014	0.009	147
	511100	Advertising sales agents	41-3011	0.137	0.017	0.143	251
	511100	Sales representatives, wholesale and manufacturing, except technical and scientific products	41-4012	-0.170	-0.002	0.051	231
	511100	Customer service representatives	43-4051	-0.143	-0.002	0.174	161

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	**(2)**	**(3)**	**(4)**	**(5)**
	511100	Mail clerks and mail machine operators, except postal service	43-9051	0.239	0.006	-0.099	213
	511100	Office clerks, general	43-9061	-0.112	-0.001	-0.007	209
	511100	Printing machine operators	51-5023	0.016	0.003	0.019	145
Software Publishers	511200	All	00-0000	0.074	0.000	0.060	.
	511200	Computer and information systems managers	11-3021	0.095	0.001	0.041	301
	511200	Computer programmers	15-1021	-0.015	-0.006	-0.087	59
	511200	Computer software engineers, applications	15-1031	-0.067	-0.022	0.160	14
	511200	Computer software engineers, systems software	15-1032	0.343	0.020	0.336	64
	511200	Computer support specialists	15-1041	-0.100	-0.014	0.129	157
	511200	Computer systems analysts	15-1051	0.342	0.009	0.032	9
	511200	Network and computer systems administrators	15-1071	0.493	0.007	0.378	65
	511200	Computer specialists, all other	15-1099	.	0.026	0.470	40
	511200	Sales representatives, wholesale and manufacturing, technical and scientific products	41-4011	0.386	0.009	0.064	149
	511200	Customer service representatives	43-4051	0.312	0.005	0.174	161
Motion picture & video industries	512100	All	00-0000	0.019	0.000	0.060	.
	512100	General and operations managers	11-1021	-0.161	-0.005	-0.103	650
	512100	Multi-media artists and animators	27-1014	0.574	0.009	-0.043	122

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
	512100	Actors	27-2011	-0.622	-0.051	-0.144	640
	512100	Producers and directors	27-2012	1.005	0.032	0.436	415
	512100	Film and video editors	27-4032	0.245	0.006	0.240	257
	512100	Counter attendants, cafeteria, food concession, and coffee shop	35-3022	0.017	0.000	0.143	521
	512100	Motion picture projectionists	39-3021	0.165	0.003	-0.024	518
	512100	Ushers, lobby attendants, and ticket takers	39-3031	-0.066	-0.009	-0.025	451
	512100	Cashiers	41-2011	0.001	-0.001	0.024	396
	512100	Executive secretaries and administrative assistants	43-6011	-0.022	-0.001	0.051	293
Sound recording industries	512200	All	00-0000	-0.229	0.000	0.060	.
	512200	General and operations managers	11-1021	-0.081	0.006	-0.103	650
	512200	Producers and directors	27-2012	0.622	0.019	0.436	415
	512200	Audio and video equipment technicians	27-4011	-0.017	0.006	0.210	420
	512200	Sound engineering technicians	27-4014	1.238	0.116	0.402	252
	512200	Sales representatives, services, all other	41-3099	0.645	0.013	0.617	175
	512200	Sales representatives, wholesale and manufacturing, except technical and scientific products	41-4012	-0.273	-0.002	0.051	231
	512200	Bookkeeping, accounting, and auditing clerks	43-3031	1.000	0.028	0.060	28
	512200	Executive secretaries and administrative assistants	43-6011	0.000	0.008	0.051	293

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
	512200	Secretaries, except legal, medical and executive	43-6014	0.000	0.008	0.014	273
	512200	Office clerks, general	43-9061	0.000	0.012	-0.007	209
Radio & Television Broadcasting	515100	All	00-0000	-0.016	0.000	0.060	.
	515100	General and operations managers	11-1021	-0.125	-0.003	-0.103	650
	515100	Producers and directors	27-2012	0.285	0.021	0.436	415
	515100	Radio and television announcers	27-3011	-0.105	-0.014	-0.100	204
	515100	Broadcast news analysts	27-3021	-0.014	0.000	-0.089	163
	515100	Reporters and correspondents	27-3022	-0.046	-0.001	-0.035	40
	515100	Broadcast technicians	27-4012	0.066	0.008	0.024	214
	515100	Camera operators, television, video, and motion picture	27-4031	-0.215	-0.008	-0.101	439
	515100	Advertising sales agents	41-3011	0.023	0.005	0.143	251
	515100	Executive secretaries and administrative assistants	43-6011	0.071	0.001	0.051	293
	515100	Office clerks, general	43-9061	0.151	0.004	-0.007	209
Cable & Other subscription programming	515200	All	00-0000	-0.074	0.000	0.060	.
	515200	Producers and directors	27-2012	0.275	0.021	0.436	415
	515200	Audio and video equipment technicians	27-4011	0.860	0.010	0.210	420
	515200	Broadcast technicians	27-4012	0.635	0.013	0.024	214
	515200	Advertising sales agents	41-3011	0.429	0.008	0.143	251

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
	515200	Sales representatives, services, all other	41-3099	0.206	0.009	0.617	175
	515200	Customer service representatives	43-4051	-0.443	-0.060	0.174	161
	515200	Executive secretaries and administrative assistants	43-6011	0.207	0.005	0.051	293
	515200	First-line supervisors/managers of mechanics, installers, and repairers	49-1011	-0.126	-0.001	-0.004	760
	515200	Telecommunications equipment installers and repairers, except line installers	49-2022	0.546	0.032	-0.002	359
	515200	Telecommunications line installers and repairers	49-9052	-0.016	0.008	0.135	523
Wired telecommunications carriers	517100	All	00-0000	0.133	0.000	0.060	.
	517100	Business operations specialists, all other	13-1199	0.259	0.002	0.216	225
	517100	Network and computer system administrators	15-1071	0.981	0.010	0.378	65
	517100	Network systems and data communications analysts	15-1081	4.900	0.028	0.557	348
	517100	Electronics engineers, except computer	17-2072	-0.038	-0.004	0.019	15
	517100	Sales representatives, services, all other	41-3099	0.471	0.014	0.617	175
	517100	Telephone operators	43-2021	-0.331	-0.014	-0.496	108
	517100	Customer service representatives	43-4051	0.260	0.010	0.174	161

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
	517100	First-line supervisors/managers of mechanics, installers, and repairers	49-1011	0.038	-0.002	-0.004	760
	517100	Telecommunications equipment installers and repairers, except line installers	49-2022	0.097	-0.005	-0.002	359
	517100	Telecommunications line installers and repairers	49-9052	1.118	0.062	0.135	523
Wireless telecommunications carriers	517200	All	00-0000	0.029	0.000	0.060	.
	517200	Business operations specialists, all other	13-1199	0.799	0.008	0.216	225
	517200	Computer support specialists	15-1041	0.700	0.007	0.129	157
	517200	Network systems and data communications analysts	15-1081	-0.049	-0.001	0.557	348
	517200	Electronics engineers, except computer	17-2072	0.340	0.006	0.019	15
	517200	First-line supervisors/managers of retail sales workers	41-1011	0.451	0.011	0.009	739
	517200	Retail salespersons	41-2031	1.138	0.088	0.109	460
	517200	Sales representatives, services, all other	41-3099	0.235	0.012	0.617	175
	517200	First-line supervisors/managers of office and administrative support workers	43-1011	-0.224	-0.007	-0.006	556
	517200	Customer service representatives	43-4051	0.387	0.066	0.174	161

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
	517200	Telecommunications equipment installers and repairers, except line installers	49-2022	-0.022	-0.002	-0.002	359
Satellite telecommunications	517400	All	00-0000	-0.259	0.000	0.060	.
	517400	Business operations specialists, all other	13-1199	1.071	0.015	0.216	225
	517400	Network systems and data communications analysts	15-1081	9.750	0.033	0.557	348
	517400	Electronics engineers, except computer	17-2072	0.933	0.015	0.019	15
	517400	Sales representatives, services, all other	41-3099	0.061	0.025	0.617	175
	517400	Telemarketers	41-9041	0.144	0.029	-0.146	42
	517400	Customer service representatives	43-4051	-0.356	-0.016	0.174	161
	517400	Order clerks	43-4151	-0.500	-0.019	-0.182	80
	517400	Telecommunications equipment installers and repairers, except line installers	49-2022	-0.663	-0.033	-0.002	359
	517400	Electrical and electronics repairers, commercial and industrial equipment	49-2094	1.583	0.018	-0.078	325
	517400	Telecommunications line installers and repairers	49-9052	-0.229	0.002	0.135	523
Other telecommunications	517900	All	00-0000	18.831	0.000	0.060	.
	517900	Business operations specialists, all other	13-1199	93.500	0.021	0.216	225
	517900	Computer support specialists	15-1041	80.250	0.017	0.129	157

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
	517900	Network systems and data communications analysts	15-1081	58.333	0.017	0.557	348
	517900	Electronics engineers, except computer	17-2072	9.364	-0.022	0.019	15
	517900	Retail salespersons	41-2031	.	.	0.109	460
	517900	Sales representatives, services, all other	41-3099	78.400	0.063	0.617	175
	517900	Sales representatives, wholesale and manufacturing, technical and scientific products	41-4011	95.000	0.021	0.064	149
	517900	Customer service representatives	43-4051	70.529	0.062	0.174	161
	517900	Telecommunications equipment installers and repairers, except line installers	49-2022	51.974	0.091	-0.002	359
	517900	Telecommunications line installers and repairers	49-9052	25.500	0.013	0.135	523
Data processing & related services	518200	All	00-0000	-0.081	0.000	0.060	
	518200	Computer and information systems managers	11-3021	0.108	0.006	0.041	301
	518200	Computer programmers	15-1021	-0.471	-0.028	-0.087	59
	518200	Computer software engineers, applications	15-1031	0.084	0.007	0.160	14
	518200	Computer software engineers, systems software	15-1032	0.539	0.022	0.336	64
	518200	Computer support specialists	15-1041	-0.076	0.000	0.129	157
	518200	Computer systems analysts	15-1051	0.008	0.006	0.032	9
	518200	Network and computer systems administrators	15-1071	0.062	0.005	0.378	65

Industry	NAICS	Occupation	SOC	Within NAICS employment change, 2003-2008	Change in share of NAICS employment	National-level employment change	Movability index ranking
			(1)	(2)	(3)	(4)	(5)
	518200	Customer service representatives	43-4051	-0.168	-0.006	0.174	161
	518200	Computer operators	43-9011	-0.088	0.000	-0.329	170
	518200	Data entry keyers	43-9021	-0.167	-0.007	-0.195	19
Other information services	519100	All	00-0000	1.730	0.900	0.060	
	519100	Computer programmers	15-1021	16.714	0.028	-0.087	59
	519100	Computer software engineers, applications	15-1031	18.227	0.031	0.160	14
	519100	Computer software engineers, systems software	15-1032	21.290	0.051	0.336	64
	519100	Network systems and data communications analysts	15-1081	16.381	0.027	0.557	348
	519100	Librarians	25-4021	0.178	0.041	-0.014	453
	519100	Library technicians	25-4031	-0.029	0.031	0.042	242
	519100	Editors	27-3041	2.712	0.036	0.009	147
	519100	Sales representatives, services, all other	41-3099	10.561	0.048	0.617	175
	519100	Customer service representatives	43-4051	1.958	0.039	0.174	161
	519100	Library assistants, clerical	43-4121	0.660	0.067	0.044	352

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SESSION 3: MEASUREMENT IMPLICATIONS OF TRANSFORMATION OFFSHORING AND IMPORTED INTERMEDIATE INPUTS

Chair: Ned Howenstein (Bureau of Economic Analysis)

Outsourcing, Offshoring, and Trade: Identifying Foreign Activity across Census Data Products,
Ron Jarmin, C. Krizan, and John Tang (U.S. Census Bureau)

Effects of Imported Intermediate Inputs on Productivity.
Lucy P. Eldridge and Michael J. Harper (Bureau of Labor Statistics)

Discussant: John Haltiwanger

Outsourcing, Offshoring, and Trade: Identifying Foreign Activity across Census Data Products

Ron Jarmin, C.J. Krizan, and John Tang*
U.S. Census Bureau

May 2010

Abstract

The 2007 Economic Census asked establishments to identify if they engaged in domestic outsourcing or foreign offshoring for manufacturing and wholesaling. These novel data can be linked to existing longitudinal business microdata that include information on such variables as employment, firm structure, and revenue. In this paper, we describe the collected responses, their distribution across sectors, and some business activity patterns with reference to the U.S. economy as a whole. We find that the majority of establishments do not offshore but those that do are likely to belong to larger firms; furthermore, most offshorers can be linked to at least one import transaction. Interestingly, less than a third of manufacturing activity occurs among "traditional manufacturers"—firms that design and produce their own good and whose primary activity is the production of their own goods. We observe additional differences in employment shares and growth between offshorers and own producers. Finally, we find the special inquiry data are a valuable complement to other Census Bureau microdata on trade transactions and firm dynamics. While there is still more work needed to develop a fully integrated data infrastructure, this paper demonstrates that analytic utility of that infrastructure will likely be very high.

* Center for Economic Studies, U.S. Census Bureau, 4600 Silver Hill Road, Washington, DC 20233. Any opinions and conclusions expressed herein are those of the authors and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed. We would like to thank Susan Houseman, Ken Ryder, Dennis Shoemaker, John Murphy, and participants in the National Academy of Public Administration preconference workshop on measurement and globalization.

INTRODUCTION

Generally speaking, the practice by which firms transfer all or part their production to another company is called "outsourcing" if the partner business is domestic and "offshoring" if foreign.49 While offshoring and outsourcing have been controversial topics in the public discourse, some have noted that these practices can impact many of the key measures we use to track the health of our economy. Houseman (2007, 2008) notes in particular that increased sourcing of imports, whose prices are poorly measured and biased upwards, is leading to mismeasurement of industry productivity statistics. In addition, the growing ease with which production activities can be moved around the globe to take advantage of factor price differentials has made the classification and measurement of activity at domestic business establishments and firms more difficult.

Our ability to quantify and examine how outsourcing and offshoring affect our statistics and economy has been severely limited by a lack of appropriate data.50 This paper is an exploratory study that utilizes a unique new dataset linking survey based offshoring data from the 2007 Economic Census with administrative import and export transactions files. With these data, we are able to conduct a number of exercises aimed at assessing our ability to identify firms engaging in these practices and to appropriately classify their activities in official statistics. Moreover, the data we use are part of a broader effort under way at the Center for Economic Studies (CES) to link import, export, outsourcing, and longitudinal firm data. The CES maintains and updates an innovative dataset of the universe of transaction-level foreign trade data linked to firm-level data from the longitudinal business database (LBD), the economic censuses and other data sources. The new file is called the longitudinal firm trade transactions database or (LFTTD). 51

In this paper, we describe and evaluate the new census 2007 questions on outsourcing. For example, we break down the responses by industry sector and firm size and identify some intuitively appealing stylized facts. We observe, for example, that although most offshoring firms are small, offshoring firms are overrepresented among the largest firms, i.e., those that employ more than 500 workers. To gauge the reliability of the offshoring responses, we match them to international trade data and find that, as expected, a disproportionate share of the firms that report outsourcing activities also can be linked to an import transaction. Finally, we more closely scrutinize differences in employment shares and growth among the three different types of manufacturing sourcing firms.

The paper proceeds as follows: the next two sections describe the new data we use and provide some basic statistics and various exercises that include data quality checks; disaggregation by major sector, size, and activity; linkage to trade data; comparisons at the establishment- and firm-

[49] Technically, this usage is imprecise as outsourcing can refer to both domestic and foreign, so offshoring is more accurately defined as foreign outsourcing. For ease of reference, this paper will follow the less precise, conventional usage.

[50] Helpman (2006) notes that while theoretical work on why firms outsource production or invest abroad for vertical integration is inconclusive, very few studies empirically test some model implications due to a lack of appropriate data.

[51] The LFFTD was developed primarily through the efforts of J. Bradford Jensen, an RDC researcher. See the data appendix in Bernard, Jensen, and Schott (2009) for details.

levels; and preliminary analyses of employment differences. The last section summarizes our findings.

DATA

Among other business microdata, the CES maintains and updates a novel dataset of the universe of transaction-level foreign trade data linked to firm-level data from the LBD, the business register, economic censuses, and other data sources. The transaction-level international trade files, also known as the foreign merchandise trade (FMT) data, underlie the census bureau's published foreign trade statistics, which are the official source of data on U.S. international trade.[52] The export data come from exporters' electronic filings on the census bureau's automated export system and also through a data-sharing arrangement with the Canadian government. Each filing represents a shipment of one or more kinds of merchandise from one exporter to one importer on a single carrier. Similarly, the import data come from the U.S. Customs' Automated Commercial System, which collects information on imports from import entry forms, warehouse withdrawal forms, and foreign trade zone documents.

These data contain information for each transaction, including the 10-digit harmonized schedule code, value, quantity, entry or exit port, date of transaction, mode of transportation, and related-party status. Data are collected for every import transaction with a value greater than $2,000 and every export transaction with a value greater than $2,500. In addition, the employer identification number of the importer or exporter is collected. This is the primary variable used to link the records to other census data products like the business register.[53]

The business register is the primary file used to assign firm identifications to transaction-level trade data. In particular, it contains establishment-level data including employer identification number, firm name, firm identification, address and industry affiliation. Matching transaction-level import data to firm identifications is relatively straightforward. Because most export and all import transaction data contain a field for the employer identification number, observations can be linked directly to the business register. The match rates of import transactions to the business registerare typically in the 80 percent range and the share of matched import value is typically above 80 percent. The linked trade transaction data with firm identifiers are the key components of the LFTTD.[54]

For this exercise, we link the LFFTD files to the special inquiries data on offshoring and outsourcing in the 2007 economic census. The questions were originally designed to help census more accurately describe firms' supply chains and to aide in the classification of the increasingly

[52] Tang (2009) describes the FMT in detail and provides useful information including variable definitions, codebooks, and variable coverage over time. The data cleaning performed to construct the FMT include, for example, assigning time-consistent variable names.
[53] The EIN variable is not present on records of exports to Canada due to a bilateral data exchange program; instead, name and address are used. Because of differences in matching methodologies as well as the sheer number of records (20 million per year), it has taken several years for researchers to develop matching algorithms that can be rapidly and reliably applied to new years of data.
[54] The description of the matching procedure for imports and exports draws heavily on the data appendix in Bernard, Jensen, and Schott (2009).

complex web of manufacturing activities. In particular, they ask manufacturing and wholesaling plants whether they designed the goods they sell, their primary activity was manufacturing (for themselves or others) or re-sales, and if they purchased contract-manufacturing services from either foreign or domestic companies.[55] For all establishments that received a form, about 72 percent of wholesale establishments and 66 percent of manufacturing plants responded to the questions, which is roughly comparable to the 72 percent and 73 percent response rates for employment.[56] Although the questions were not officially pretested, our results indicate that the responses make intuitive sense.

EXPLORATORY EXERCISES

Special Inquiry Cross-Tabulations, by Activity, Count, and Size

We begin our analysis with a few basic tabulations. Table 1 presents establishment-level breakdowns for each part of the special inquiry, while Table 2 contains analogous figures for employment.[57] From these basic summary statistics, a number of interesting patterns quickly emerge. Almost 60 percent of establishments responding to this part of the manufacturing form indicate that they design their own goods (row 2, column 1), while only 15 percent of responding wholesale establishments state the same. For part 2 of the special inquiry, the majority of responses to both forms are consistent with the expected industry definition of the establishments. For example, roughly 81 percent of the manufacturing establishments (and about 86 percent of their employment) is accounted for by establishments that reported their major activity as either "production" or "contracting." Similarly, about 68 percent of establishments (and 66 percent by employment) that answered the wholesale forms reported their major activity as "resales."[58] Note that although the first row indicates the total number of establishments or their associated employment, not all establishments necessarily answered each part of the inquiry, which is why the subtotals for each part may sum to less than the total responses.

Interestingly, 5 percent of tabbed manufacturing establishments report that their primary activity is resales and 7 percent of tabbed wholesale establishments report their major activity is production. While the special inquiry data were not used for classification purposes, the Economic Census is the most reliable source of industry codes available to the Census Bureau and quinquennial collection results in a substantial number of corrections to establishment

[55] 2007 Economic Census, Forms MC-313XX through 315XX, Question 26. Although the question was asked in the Census of Manufacturers, respondents included both manufacturers and wholesalers. See Appendix A at the end of this paper for the specific questions (under "Special Inquiries"). Note that the language used in these questions was not pretested.

[56] These include all long-form manufacturing cases and all wholesale establishments except for Miscellaneous wholesale and Agents and brokers. Furthermore, note that establishments receiving forms represent less than half of the universe of establishments. We thank Dennis Shoemaker in the Census Bureau's Economic Planning and Coordination Division for providing the background information.

[57] Since this categorization is based on which forms the establishments responded to and not on a comprehensive measurement of the overall firms' activities, one should interpret the table accordingly. That is, it may be that the establishment is classified as "wholesale" but report doing their own production because they are part of a larger firm that has manufacturing activities.

[58] We should note that this sample conditions on the establishments answering all three questions and also excludes wholesale establishments that are known to act primarily as manufacturers' sales offices.

industry codes. In fact, about 5 percent of the manufacturing establishments (nonbank) were classified in different (nonmanufacturing) sectors after the 2007 Economic Census form was received and the share of wholesalers that switched sectors was roughly twice that. These numbers are typical during Economic Census operations. Thus, the findings from the special inquiries are in line with typical reclassification rates.

In light of recent research on the effects of professional employer organizations on industry statistics, it is worthwhile to note that in separate calculations, we found these shares to have been relatively stable since at least 1997.[59] That is, it seems unlikely that the share of manufacturers reporting that they engage in other activities is due to them reclassifying themselves because they use professional employer organizations. Instead, it seems like a normal part of the classification process. Furthermore, most establishments indicated that they neither outsource nor offshore any activity. For manufacturing, the offshorer, outsourcer, and own-producer shares were roughly 2, 26, and 69 percent, respectively. For wholesale establishments, the analogous shares were 4, 11, and 82 percent.

The employment breakdowns in Table 2 are qualitatively similar to the figures in Table 1, with employees concentrated in each sector's primary functions (manufacturing and reselling). However, note that establishments that offshore production—bidparticularly manufacturers—represent twice their share of manufacturing employment (4 percent) than they do of establishments (2 percent). Thus, establishments reporting offshoring activity are larger, on average, than nonoffshorers.[60]

The decision to outsource or offshore production activities is better thought of as a firm-level rather than establishment-level choice. For the exercises that follow, we will shift our unit of analysis to the firm-level. In order to do this we need a protocol for aggregating the establishment-based questions from the Economic Census. Our approach is to classify a firm as an offshorer if it operates at least one establishment that reports offshoring activity, and as an outsourcer if it has no offshoring establishments and at least one outsourcing establishment. Firms with no contracts make up the balance.

One important firm characteristic that is likely related to the propensity to engage in outsourcing and offshoring activity is size. Table 3 shows the number of firms grouped by size and primary sourcing activity. While small firms (those with 50 or fewer employees) dominate each category of firm, a greater proportion of offshoring firms (8 percent) employ more than 500 employees compared to firms with no contracts (1 percent) or those using domestic suppliers (5 percent). That is, while most offshoring firms are small, the greatest share of offshoring activity can be found among large firms.

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[59] Dey, Houseman, and Polivka (2009).

[60] The relative share of domestically outsourced employment in manufacturing (35.0 percent) reported here is comparable to that found using the 2005 Contingent Worker Supplement (CWS) collected by the Bureau of Labor Statistics (38.7 percent) (Dey, Houseman, and Polivka (2009, Table 3).

Matching to the Trade Transactions Files

A natural quality control check on the validity of the offshoring responses was to look at differences in observed importing activities among the three firm production types. As shown in Table 4, the overwhelming majority (78 percent) of firms that reported offshoring activity on the 2007 Economic Census form can be matched to at least one import transaction in 2007. We cannot conclude that most of the remaining firms that responded that they are offshorers but were not matched to an import transaction answered the form incorrectly because 1) our matching methodology between firms and import transactions is still under development, and 2) not all firms that outsource their production will necessarily reimport the good. Clearly many of these firms are multinational corporations that sell goods and services in many different countries, and it may be that the majority of their offshore production is aimed at foreign markets. Finally, 3) many firms use third-party wholesale firms to handle their foreign trade activity.

Interestingly, Table 4 also shows that while the shares of total import value are fairly similar across the production categories, if one considers the much smaller number of offshoring firms it is clear that offshorers import far more than other types of producers. We also corroborated this hierarchy of import activity by firm production type by focusing on two specific industries: vehicle manufacturing and electronics, where we found even stronger results.[61] Additional breakdowns by each census form type are presented in Tables 5 and 6, which also present the number of firms and their employment associated with the responding establishments. We in turn identify the number of manufacturing and wholesaling establishments owned by these firms, which may or may not have responded to the census forms, as well as how many of these firms can be identified in the import transaction data and what share of total U.S. imports those transactions represent. It is interesting to note the employment discrepancy among respondents to the wholesaling forms (Table 6), with both own producers and outsourcers having a larger share of their workers in wholesaling establishments (column 4) than in manufacturing, as one would expect; yet among offshorers this is not the case. These statistics hint at the complex structure of larger multinational companies. We're hopeful that the integrated data infrastructure discussed here and still under development will help researchers to get a better handle on how firms and value chain evolve and the role outsourcing and offshoring play in this evolution.

Comparing Manufacturing Types

In a recent federal register notice the Organization of Management and Budget's (OMB's) Economic Classification Policy Committee (ECPC) pointed out some of the difficulties involved in defining what a manufacturing establishment is in the presence of outsourcing and offshoring (OMB 2009). They define three general types of manufacturing units: 1) traditional or integrated manufacturing, 2) manufacturing service providers, and 3) factoryless goods providers. They define the major characteristics of each as follows:

[61] Results are withheld due to potential disclosure of confidential information.

1) Traditional manufacturers

- Perform transformation activities
- Own the rights to the product they manufacture
- Control and facilitate the production process
- Sell the final good

2) Manufacturing service providers

- Performs transformation activities
- Receives contracts to perform transformation activities
- Does not own intellectual property or design of the final product
- Does not own the final product
- Controls the production facility but not the production process
- Does not sell the final product

3) Factoryless goods providers

- Does not perform transformation activities
- Contracts with manufacturing service providers
- Owns the intellectual rights to the final product
- Owns the final product
- Sells the final product

We make use of the new questions on the 2007 Economic Census to approximate these categories using the following definitions:

1) Traditional manufacturers

- Establishment does not contract out for manufacturing services from other companies or other establishments of its company
- Establishment's primary activity is manufacturing
- Establishment designs, engineers, or formulates the manufactured products it sold, produced or shipped

2) Manufacturing service providers

- Establishment does not contract out for manufacturing services from other companies or other establishments of it's company
- Establishment's primary activity is providing contract services for others
- Establishment does not design, engineer, or formulate the manufactured products it produced or shipped

3) Factoryless goods provider

- Establishment contracts out for manufacturing services from other companies or other establishments of its company (both in and outside of the United States
- Establishment's primary activity is resales
- Establishment designs, engineers, or formulates the manufactured products it sold, produced or shipped

Table 7 displays the shares of activity accounted for by each establishment type. The denominator is the sample of total activity accounted for by the establishments that answered all three questions. While traditional manufacturers dominate the three categories of producer types, they represent less than a third of total manufacturing activity by establishment count and employment.

Of course, it may be that traditional manufacturers are more (or less) common in certain industries. We investigate this possibility by calculating the employment shares accounted for by these producers for a subset of NAICS industries. Due to disclosure concerns, we limit the analysis to only those industries with a relatively large number of firms; results are displayed in Figure 1.[62]

Clearly, there is wide variability in the shares of activity accounted for by traditional manufacturers across industry subgroups. The range of activity starts at about 8 percent for printing and ranges to almost half for textile mills. Interestingly, computer manufacturing, an industry one would normally associate with outsourcing, is only slightly above the average share of employment at traditional manufacturers. This unexpected finding for computer manufacturing suggests that as outsourcing and offshoring become more common, firms may become less manufacturing intensive over time. That is, firms that previously had a large share of manufacturing employment may begin to specialize more heavily in other activities and it may affect their manufacturing employment, overall employment or both.

To explore this issue further, we identified firms that existed in both 1990 and 2007 and categorized them according to whether or not they outsourced, offshored, or did not contract out for manufacturing services. Next we calculated the firms' shares of manufacturing employment in both years as well as the changes in total employment for each group; these are shown in Figures 2 and 3, respectively.

Both figures show an ordering to the changes in employment. The firms without contracts decline less or grow more than either outsourcers or offshorers. In Figure 2 noncontracting firms' manufacturing shares (weighted means) declined about 13 percent, similar to outsourcers (14 percent) but visibly less than offshorers (18 percent). Similarly, in Figure 3 we see that own producers had much stronger growth than did either outsourcing or offshoring firms. In fact, employment actually declined at offshoring firms.

[62] We find similar results for establishment shares but omit them here for brevity.

Multivariate Analysis of Employment Trends

The above findings do not control for any of the many other factors that are known to affect firm growth rates, such as age, size, and geography. While a rigorous treatment of these factors is beyond the scope of this exploratory paper, we begin by running linear regressions of changes in manufacturing shares and total employment on a set of basic firm controls, as well as firm type. The results are reported in Table 8.

In both specifications, the omitted firm type is non-contractors so the results should be interpreted accordingly. Interestingly, the regression results do not completely support our preliminary observations from the earlier figures. Controlling for other major factors, both outsourcers and offshorers are associated with a more negative change in their shares of manufacturing employment (column 1, rows 5 and 6) relative to own producers. On the other hand, with growth in total manufacturing employment as the dependent variable (column 2), it appears that outsourcers may have had more employment growth than own producers, and substantially more than offshorers. These discrepant findings suggest that substantial care must be taken in any interpretation and that much more work is necessary before we are fully confident in the results.

CONCLUSION

This paper takes advantage of a unique new dataset linking offshoring data from the 2007 Economic Census with import and export transactions files to examine the prevalence of outsourcing and offshoring and how these activities are correlated with firm productivity. We performed a number of preliminary quality control and exploratory exercises and obtained the following six results:

1) The majority of establishments do not report either outsourcing or offshoring activity.

2) Most establishments' activity is consistent with their industry definitions. That is, most wholesalers report resales as their primary activity and most manufacturers report either manufacturing or contracting as their primary activity. Differences from these norms are in-line with historical industry changes that normally occur during economic censuses.

3) The majority of offshoring firms are small but large firms are more likely to engage in offshoring.

4) We are able to match 78 percent of the firms that reported engaging in offshoring activity to at least one import transaction. This is encouraging given that there is some noise in our linking variable and that a firm that offshores does not necessarily need to reimport the good.

5) Less than a third of manufacturing activity occurs at traditional manufacturing plants that design and produce their own goods and whose primary activity is manufacturing for themselves.

a. A further 11 percent occurs at manufacturing service providers.

b. Less than 1 percent is accounted for by factoryless goods providers

c. There are substantial differences in these shares across industries.

6) As a group, noncontractors grew more and stayed more manufacturing intensive than both outsourcers and offshorers, but when we controlled for key firm characteristics we found that outsourcing firms grew more than noncontractors.

Additional areas for study that can usefully exploit these data include examining the role of outsourcing and offshoring in firm and productivity dynamics. Combing the data infrastructure described in this paper with Bureau of Economic Analysis data on trade in services and foreign direct investment would greatly enhance the analytic capability of both permitting the analysis of, for example, changes in the distribution of manufacturing and wholesaling activities across establishments within domestic-only and multinational firms, and investment patterns by sector and firm type.[63] Discussions about bringing these rich data sources together are ongoing.

Table 1: Special Inquiry Response Breakdown, by Form Type: Establishment

	Manufacturing	Wholesaling
Total establishment count[a]	106,550	153,147
Own design		
Yes	63,017	22,554
No	41,266	127,942
Primary function		
Production	57,371	10,061
Contracting	28,725	4,169
Reselling	5,326	104,900
Other	10,725	20,627
Primary sourcing		
No contracts	74,030	126,100
Domestic outsourcing	28,173	16,762
Foreign offshoring	2,269	5,397

[*]Includes all establishments that answered any part to special inquiry.

[63] Data on foreign direct investment are collected by the Bureau of Economic Analysis; see Mataloni (1995), Quijano (1990), and.Bureau of Economic Analysis (2004, 2006).

Table 2: Importing, Offshoring, and Outsourcing

	2007 EC respondent firms	2007 import data matches	% Total value of imports (2007)
No contracts	154,961	40,827	19%
Domestic outsourcing	33,313	10,250	16%
Foreign offshoring	6,055	4,750	14%

Table 3: Special Inquiry Response Breakdown, by Form Type: Employment

	Manufacturing	Wholesaling
Total employee count	9,215,356	2,805,397
Own design		
Yes	6,129,012	547,211
No	2,937,883	2,209,371
Primary function		
Production	6,211,181	291,188
Contracting	1,790,786	63,166
Reselling	198,641	1,847,761
Other	603,521	422,633
Primary sourcing		
No contracts	5,486,210	2,195,630
Domestic outsourcing	3,161,254	380,445
Foreign offshoring	361,009	143,767

Table 4: Number of Firms by Employment Size

	≤50	51-500	>500
No contracts	122,139	21,401	2,007
Domestic outsourcing	23,899	7,699	1,551
Foreign offshoring	4,402	1,122	506

Table 5: Special Inquiry Part 3 Breakdown: Primary Sourcing in Manufacturing Responses

	Estab.	Firms	*Affiliated mfg. estab.*	*Affiliated wholesale estab.*	Matched to import data	Import value* ($ bil)
Total						
Count	104,472	75,677	113,084	39,442	20,738	$855.7
Employees	9,008,473	19,575,864	10,472,662	1,371,578	16,070,271	
No contracts						
Count	74,030	52,629	65,520	13,306	11,932	$205.9
Employees	5,486,210	7,602,322	3,872,270	479,717	5,135,543	
Outsourcing						
Count	28,173	20,991	37,021	14,806	7,088	$356.3
Employees	3,161,254	7,579,528	4,276,430	499,135	6,588,885	
Offshoring						
Count	2,269	2,057	10,543	11,330	1,718	$293.5
employees	361,009	4,394,014	2,323,962	392,726	4,345,843	

*Note: total U.S. import value in 2007 = $2,344.6 billion

Table 6: Special Inquiry Part 3 Breakdown: Primary Sourcing in Wholesaling Responses

	Estab.	Firms	*Affiliated mfg. estab.*	*Affiliated wholesale estab.*	Matched to import data	Import value[a] ($ bil)
Total						
Count	148,259	122,227	24,966	194,312	37,586	$987.3
Employees	2,719,842	16,431,116	4,746,349	3,839,155	14,316,785	
No contracts						
Count	126,100	104,087	6,631	148,036	29,910	$387.9
Employees	2,195,630	7,527,531	779,450	1,604,389	5,775,482	
Outsourcing						
Count	16,762	13,700	10,634	29,948	4,223	$298.5
Employees	380,445	4,728,984	2,015,647	749,150	4,413,939	
Offshoring						
Count	5,397	4,440	7,701	16,328	3,453	$300.9
Employees	143,767	4,174,601	1,951,252	485,616	4,127,364	

[*]Note: Total U.S. import value in 2007 = $2,344.6 billion

Table 7: Activity Shares of Manufacturing Types

	Establishment share (%)	Employment share (%)
Traditional manufacturers	28.1	30.3
Manufacturing service providers	11.0	6.0
Factoryless manufacturers	0.9	0.5
All other manufacturing types	60.0	63.2

Table 8: OLS Regression Results

DV:	(1) Δ share of mfg. employment	(2) % Δ in total mfg. employment
Firm age	-0.013*** (0.000)	-0.044*** (0.001)
# States	-0.009*** (0.001)	0.018*** (0.001)
1990 Firm employees (1,000)	-0.000 (0.001)	-0.011*** (0.001)
1990 Estab. count (1,000)	0.065*** (0.022)	0.072* (0.042)
Outsourcer	-0.023*** (0.004)	0.048*** (0.008)
Offshorer	-0.049*** (0.011)	-0.075*** (0.022)
Intercept	0.287*** (0.004)	0.684*** (0.008)
Observations	34,667	34,667
Adjusted R-squared	0.055	0.110

Significance levels: *10 percent **5 percent ***1 percent
Standard errors in parentheses.

Figure 1

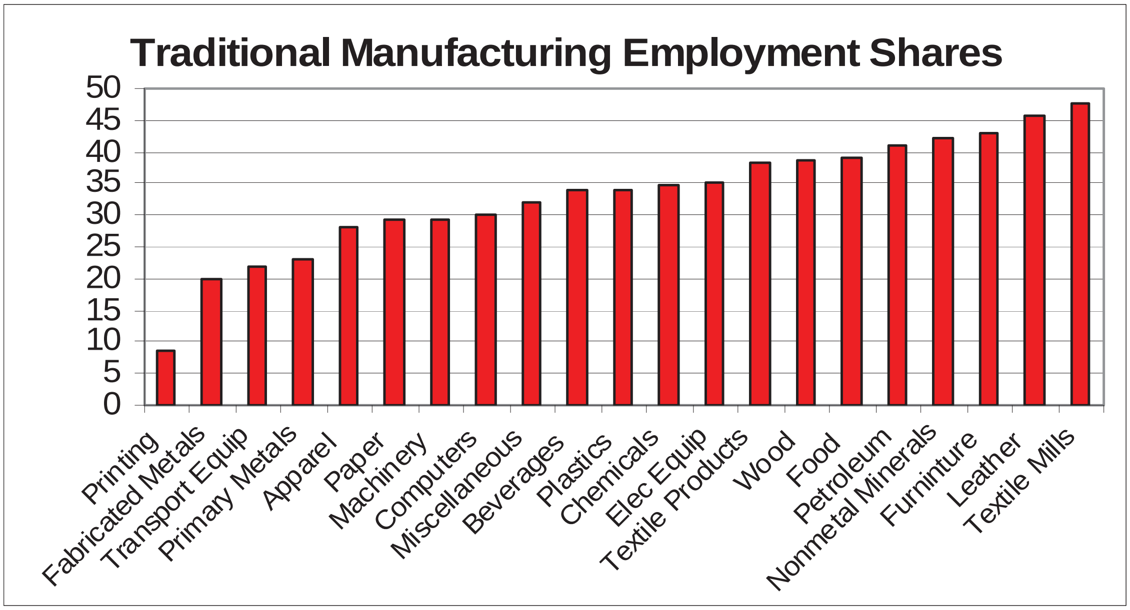


Figure 2

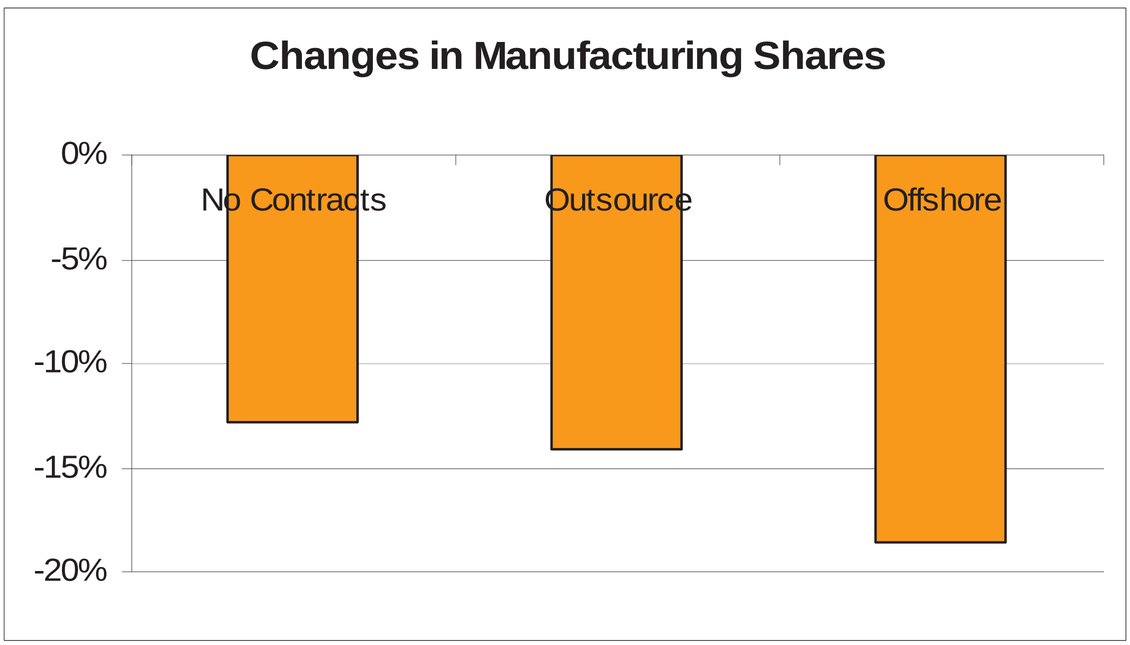
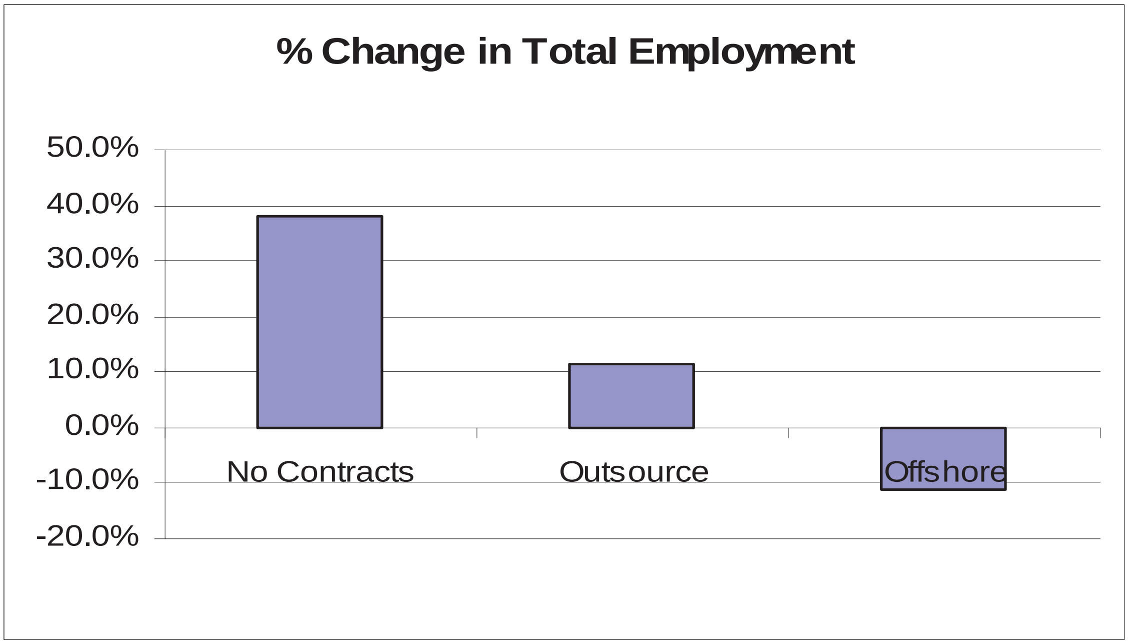


Figure 3


% Change in Total Employment
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
-10.0%
-20.0%
No Contracts
Outsource
Offshore

Appendix A

DETAIL OF SALES, SHIPMENTS, RECEIPTS, OR REVENUE - Continued

Line No.	Products and services (0734)	Census product code (0730)	Products shipped and other receipts — Value, f.o.b. plant: $ Bil. (0731)	Mil.	Thou.
41		42			
42		59			
43		67			
44	Contract work - Receipts for work done for others on their materials *(Specify products worked on and kind of work.)*	930000 0000			
45	Resales - Sales of products bought and sold without further manufacture, processing, or assembly *(The cost of such items should be reported in ●, line A2.)*	999890 0000			
46	Other miscellaneous receipts (including receipts for repair work, etc.)	999809 8000			
47	**TOTAL** *(Should equal total reported in ●)*	770000 0000			

●-● Not Applicable.

● SPECIAL INQUIRIES

OTHER ESTABLISHMENT ACTIVITIES

1. Did this establishment design, engineer, or formulate the manufactured products that it sold, produced, or shipped?

0318 ☐ Yes

0319 ☐ No

2. Which of the following best describes this establishment's primary activity? *(Mark "X" only ONE box.)*

0362 ☐ Providing contract manufacturing services for others

0363 ☐ Transforming raw materials or components into new products that this establishment owns or controls

0364 ☐ Reselling goods manufactured by others (with or without minor final assembly)

0365 ☐ Other - *Specify*

0366 ______

3. Did this establishment purchase contract manufacturing services from other companies or other establishments of your company to process materials or components that this establishment owns or controls?

0496 ☐ Yes, primarily with establishments WITHIN the 50 States and the District of Columbia

0497 ☐ Yes, primarily with establishments OUTSIDE of the 50 States and the District of Columbia

0498 ☐ No

●-● Not Applicable.

33613126

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Effects of Imported Intermediate Inputs on Productivity*

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There is significant interest in determining the effects of offshoring on U.S. economic performance. Offshoring, or offshore outsourcing, is the substitution of imported intermediate inputs for domestic labor or domestically produced intermediate inputs. To assess the effects of imported intermediate inputs on Bureau of Labor Statistics (BLS) productivity statistics, it is essential to understand how imports enter into the measurement framework. The BLS Major Sector Productivity program develops measures of labor productivity for broad sectors of the economy: business, nonfarm business, manufacturing, and nonfinancial corporations. In addition, this program develops annual indexes of multifactor productivity (MFP) for the private business sector, the manufacturing sector, and for most manufacturing groups. This paper focuses on the BLS productivity measures for the private business sector, as well as the manufacturing sector. Productivity measures for these two sectors are constructed using different methodologies; the private business sector productivity measures use a value-added output concept, while the manufacturing sector measures use a sectoral output approach. This difference in methodology influences the effects of imported intermediates on the measures of productivity.

In this paper, we develop a framework for estimating the effects of imported intermediate inputs on U.S. major sector labor productivity. The production model used to calculate the BLS private business sector MFP measures is expanded to treat imported intermediate inputs as an input, rather than as a subtraction from output. The BLS framework for constructing manufacturing MFP is decomposed in order to isolate imported intermediate inputs. For both sectors, we use the Solow MFP equation to estimate the effects on labor productivity of substitution between imported intermediate inputs and U.S. hours worked (Solow 1957). The data reveal that the growth in imported intermediate inputs contributed 14 percent to the average annual growth of labor productivity for the private business sector from 1997 to 2006, and contributed 23 percent to the average annual growth in labor productivity in the manufacturing sector.[64]

The study also addresses the difficulties surrounding the deflation of the imported intermediate inputs, since the coverage of import price indexes is sparse. We show that any mismeasurement of import prices will impact measured productivity growth. However, the size of the effect will depend upon the share of imports relative to aggregate output, which range from 8–12 percent for the private business sector and 12–18 percent for the manufacturing sector.

DATA SOURCES

Output

Real output measures used by the BLS to construct major sector productivity statistics are produced by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. The most widely known measure of aggregate output for the U.S. economy is gross domestic product (GDP). GDP is the sum of 1) personal consumption expenditures, 2) gross private domestic investment, 3) government consumption expenditures and gross investment, 4) exports of goods and services, less 5) imports of goods and services. The BEA constructs nominal output

[64] We implement the analysis using BEA annual input-output tables, as well as data on imported intermediate inputs provided by the BEA. See Yuskavage, Strassner, and Medeiros (2008).

for detailed components of GDP from various data sources, converts them to real measures, and then aggregates them to calculate GDP.

As a fundamental part of the national accounts, the BEA also distinguishes three primary sectors of GDP: business, household, and government (Young and Tice 1985). The business sector accounts for the bulk of national output. The BEA calculates the measure of business sector output by removing from GDP the gross product of general government, private households, and nonprofit institutions.[65]

Ideally, BLS productivity statistics would measure productivity for the U.S. economy at the most aggregate level of domestic output, GDP. However, the BLS must exclude several activities from aggregate output in order to remove potential sources of bias specific to productivity measurement. The real gross products of general government, of private households, and of nonprofit institutions are estimated primarily using data on labor compensation. The trends in such output measures will, by definition, move with measures of input data and will tend to imply little or no labor productivity growth. Although these measures are the best available estimates of nonmarket components of GDP, including them in measures of aggregate productivity for the economy would bias labor productivity trends toward zero.

The BLS private business sector also excludes the gross product of owner-occupied housing and the rental value of buildings and equipment owned and used by nonprofit institutions serving individuals.[66] These components are excluded because no adequate corresponding labor input measures have been developed. To measure MFP, the BLS must further restrict output to the U.S. private business sector, excluding the output of government enterprises. Estimates of the appropriate weights for labor and capital in government enterprises are not made because subsidies account for a substantial portion of capital income; therefore, there is no adequate measure of government enterprise capital income in GDP. In 2006, the BLS measure of the U.S. private business sector output accounted for approximately 76 percent of the value of GDP.[67]

In the manufacturing sector, BLS measures output for productivity statistics differently. Output in the manufacturing sector is the deflated value of production shipped to purchasers outside of the domestic industry, not just production for final users as is used for the major sector MFP indexes. This is a sectoral output concept, defining output as gross output excluding intrasectoral transactions (sales or transfers between establishments within the sector)—sales to final demand plus the intermediate goods sent to other industries. The manufacturing MFP indexes are based on sectoral output in an effort to avoid the problem of double-counting that occurs when one establishment provides materials used by other establishments in the same industry.

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[65] The gross product of general government is the sum of government expenditures on compensation of general government employees and the general government consumption of fixed capital, which measures the services of general government fixed assets. Government expenditures on goods and services purchased from the private sector are not excluded from private business sector output. The gross product of private households is the compensation of paid employees of private households; the gross product of nonprofit institutions serving individuals is the compensation paid to employees of these institutions.

[66] This value is measured as the sum of consumption of fixed capital, indirect business taxes, and interest paid.

[67] Data in this paper originate in the MFP program and coverage differs from BLS quarterly labor productivity measures for business sector. MFP measures are available only on an annual basis and exclude government enterprises from sectoral coverage.

Labor Input

Labor input for the U.S. private business sector is measured as total hours actually worked by all persons multiplied by a labor composition index. The hours actually worked measure is based on the sources and methods used to measure quarterly business sector labor productivity. The BLS labor composition index estimates the effects that shifts in age, education, and gender have on labor input growth and MFP growth.

Labor input is based on a jobs concept. The Current Employment Statistics program (CES) is the primary source of data used to construct hours for the BLS productivity measures.[68] The CES average weekly hours paid data are adjusted to an hours-at-work concept using a ratio of hours-worked to hours-paid.[69] Current Population Survey (CPS) data on average weekly hours of nonproduction and supervisory workers are incorporated into the methodology to expand coverage to all employees.[70] To expand sectoral coverage, hours actually worked for employees of farms, proprietors, and unpaid family workers reported in the CPS are incorporated into the labor input measure; remaining data are obtained from various sources.[71]

Construction of the MFP labor composition measure begins with estimates of the number of hours worked by each type of worker based on CPS data. The assembles data on workers' hours classified by their educational attainment, age, and gender using actual wage averages for weights. The sum over all groups of the hour's growth rates multiplied by the labor cost shares gives the growth in adjusted labor input. Subtracting this from the growth in total (unweighted) hours yields the growth in labor composition.[72]

Labor input for the U.S. manufacturing sector is constructed using the same methods, except that no adjustment is made for labor composition (age, education, and gender of the work force). The labor composition adjustment is currently not included in manufacturing hours data due to limitations in the data available from the CPS at the industry detail.[73]

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[68] The CES, an establishment survey, sample is benchmarked annually to levels based on administrative records of employees covered by state unemployment insurance tax records. Hours data from establishments provide consistency with output data in the reporting and coding on industries and thus are well suited for producing industry-level measures. CES data on employment and average weekly hours paid for production workers in goods-producing industries and nonsupervisory workers in service-producing industries are the building blocks of labor input.

[69] The hours worked to hours paid ratio is constructed using information from the National Compensation Survey program; prior to 2000, the annual Hours at Work Survey was used.

[70] In August 2004, BLS introduced this new method of constructing estimates of hours for nonproduction and supervisory workers; see Eldridge, Manser, and Otto. (2004).

[71] Employment counts for employees in agricultural services, forestry, and fishing are reported from the BLS's 202 program, based on administrative records from the unemployment insurance system.

[72] Additional information concerning data sources and methods of measuring labor composition can be found at www.bls.gov/mfp/mprlabor.pdf and in BLS Bulletin 2426 Labor Composition and U.S. Productivity Growth, 1948-90 (December 1993).

[73] The BLS is currently investigating the possibility of constructing labor composition estimates for the manufacturing sector productivity measures.

Capital Inputs

Capital inputs for private business and manufacturing MFP measures are similar. The BLS capital input measures include assets that are owned and operated by a business within the sector; rented capital services are included in intermediate inputs. Capital input measures the services derived from the stock of physical assets and software. The assets included are fixed business equipment, structures, inventories, and land. Financial assets are excluded from capital input measures, as are owner-occupied residential structures. The aggregate capital input measures are obtained by Tornqvist aggregation of the capital stocks for each asset type within each of 60 NAICS industry groupings using estimated rental prices for each asset type. Rental prices reflect the nominal rates of return and rates of economic depreciation and revaluation for the specific asset types. Rental prices are adjusted for the effects of taxes; rental prices of capital are computed for 18 3-digit NAICS industries within manufacturing. Data on investments in physical assets are obtained from the BEA (see BLS [2009]).

Energy, Materials and Purchased Business Services

In the manufacturing sector, inputs include intermediate inputs, as well as capital and labor inputs. Intermediate inputs (energy, materials, and purchased business services) are obtained from BEA's annual input-output tables. Tornqvist indexes of each of these three input classes are derived at the 3-digit NAICS level and then aggregated to total manufacturing. For manufacturing, materials inputs are adjusted to exclude transactions between manufacturing establishments to maintain consistency with the sectoral output concept. [74]

Nominal values of materials, fuels, and electricity and quantities of electricity consumed are obtained from economic censuses and annual surveys of the Bureau of the Census, U.S. Department of Commerce. Purchased business services are estimated using benchmark input-output tables and other annual industry data from the BEA. Prices of many service inputs are based on the BLS price programs and are obtained from the national income and product accounts.

Imported Intermediate Inputs

The BEA produces import matrices as supplementary tables to the annual input-output (I-O) accounts. For each commodity, the import-matrix table shows the value of imports of that same commodity used by each industry. Because such information is not available from most businesses, the estimates must be imputed from data available in the annual I-O accounts. The imputed-import values are based on the assumption that each industry uses imports of a commodity in the same proportion as imports-to-domestic supply of the same commodity. (Domestic supply represents the total amount of a commodity available for consumption within the United States; it equals domestic output plus imports less exports.) The implication of using this assumption to calculate the estimates is that all variability of import usage across industries

[74] A nonprofit adjustment is made to intermediate inputs, but not to imported intermediates because it is doubtful that nonprofits are using a significant amount of imported intermediates. By not making a nonprofit adjustment to imported intermediates, we may overstate the importance of imports slightly.

reflects the assumption and is not based on industry-specific information (Strassner, Yuskavage, and Lee 2009).[75]

The BEA provided these detailed statistics to the BLS for this research study. These data are not included in the published tables because their quality is significantly less than that of the higher level aggregates in which they are included. Compared to these aggregates, the more detailed statistics are more likely to be either based on judgmental trends, on trends in the higher level aggregate, or on less reliable source data.[76]

Using this dataset we can observe trends in the shares of imported intermediate inputs. The share of intermediate inputs, used by all private industries, that is accounted for by imports grew from 7.6 percent in 1998 to almost 10 percent in 2006. Notice in Figure 1 that there was a decline in the share of imports used by private industries around the 2001 recession; however, beginning in 2002, they increased steadily. Purchased materials account for the majority of imported intermediates, and grew steadily, again with a slight dip around the 2001 recession. Imported material inputs accounted for 15 percent of total materials used by private industries in 1998 and grew to 21 percent by 2006.[77]

Although it was once thought that services were not off-shorable, we see evidence that service inputs are also being imported. Imported service inputs accounted for 1.4 percent of total intermediates used by private industries in 1998 and 1.7 percent in 2006. However, imported services inputs account for roughly 3 percent of all service inputs used by private industries, and this stayed relatively steady from 1998 to 2006. Interestingly, we observe growth in the share of energy inputs that are imported; 4 percent of all energy inputs used by private industries were imported in 1998, and we see 12 percent imported by 2006.[78] However, imported energy inputs are less than 0.4 percent of total intermediates used by the private industries.

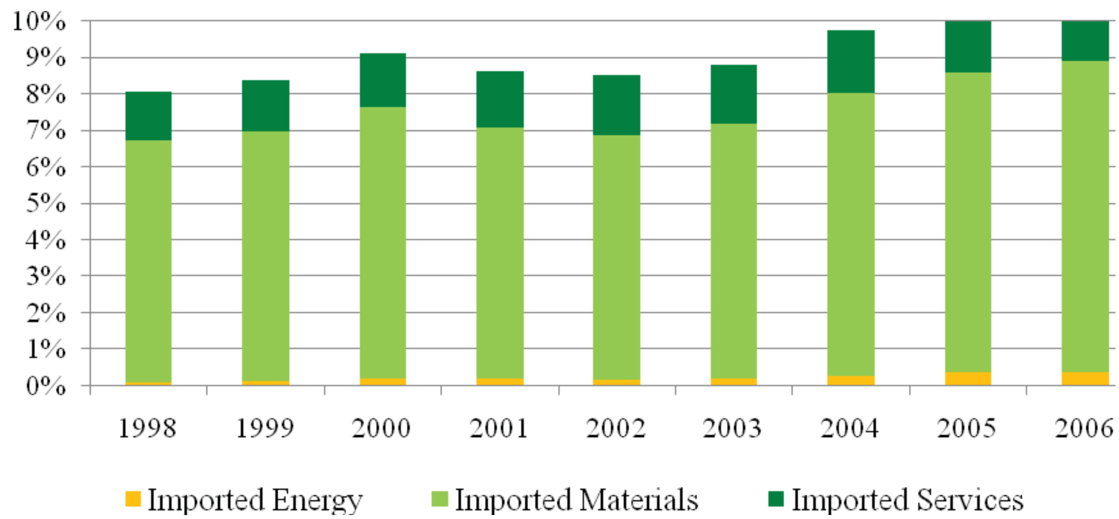
[75] This study uses BEA international transaction account data to assess the import comparability assumption. They find that real imported materials may be understated in the annual I-O accounts. However, they indicate that the comparability assumption provides reasonable results at the aggregate level. Feenstra and Jensen(2009) prepare alternative imported intermediates using an alternative method for allocating imported input across industries and compare the results with the BEA import matrix that uses the comparability assumption. They find that there are differences between the two approaches, and identify cells in the I-O table where the differences are greatest. Unfortunately, data limitations prevent them from resolving the differences

[76] Notes about the imported intermediate input data are from BEA documentation that accompanied the data.

[77] Imported materials inputs include crude petroleum as a raw material for the refining and coal products industry. The increase in crude petroleum prices over this time period could be responsible for the increase in imported materials share of intermediate inputs used by private industries, and more significantly the increase in imported materials share of intermediate inputs in the manufacturing sector.

[78] Crude oil is classified as a nonenergy material input to U.S. refineries, rather than an energy input.

Figure 1. Imported Intermediate Inputs Share of Total Intermediates, by type of input, private industries, 1998-2006



Source: Bureau of Economic Analysis

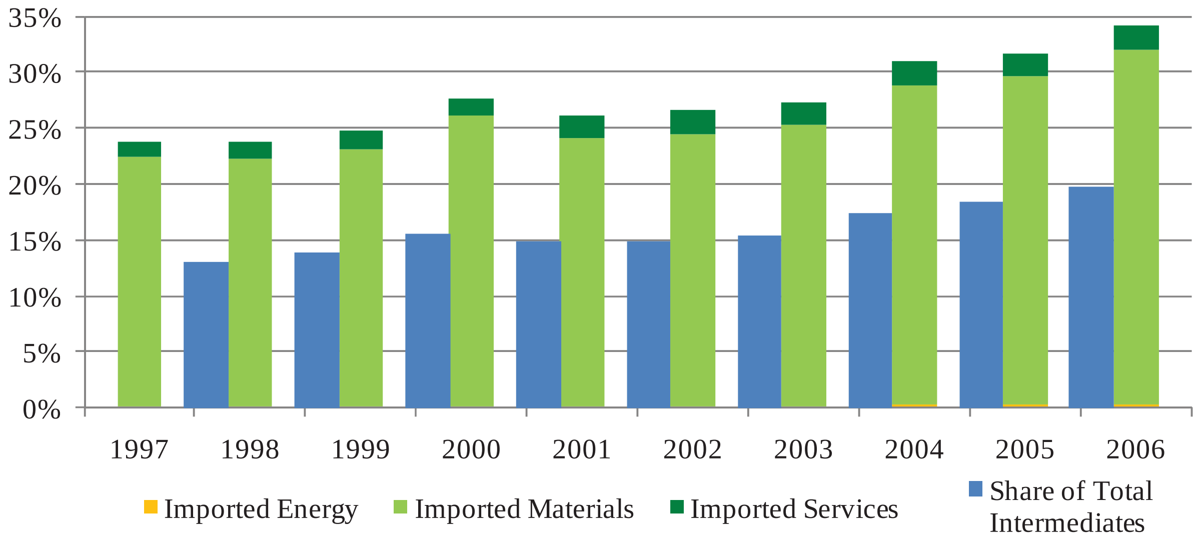
Looking at the imported intermediate data by industry, we see that the manufacturing sector consumes over 60 percent of all imported intermediate used by private industries. For the manufacturing sector, we observe that the share of intermediate inputs that is accounted for by imports is significantly larger than it is for all private industries and grew at a faster rate. Figure 2 shows imported intermediates share of "sectoral" intermediate inputs (total intermediates less domestically manufactured inputs), as well as the imports' share of total intermediates. The "sectoral" intermediate inputs for the BLS manufacturing sector are less than the total intermediates in the BEA annual I-O accounts because intermediates that are purchased from other firms within the U.S. manufacturing sector have been removed. Therefore, the imports' share of "sectoral" intermediates is greater than the imports' share of total intermediate inputs. The "sectoral" intermediate inputs for the manufacturing sector are 57 percent of the BEA total intermediates.

We observe that 24 percent of "sectoral" intermediates were imported in 1997; this grew to almost 35 percent in 2006. Notice in Figure 2 that beginning in 2002, there has been a steady increase in the share of imported intermediates used by U.S. manufacturing firms relative to "sectoral" and total intermediates.[79] As we observed for the private business sector, imported materials account for the majority of imported intermediate inputs. However, service inputs were also imported by the manufacturing sector. Imported services' share of "sectoral" intermediates in the manufacturing sector grew from 1.3 percent in 1997 to 2.1 percent in 2006, while imported energy's share grew from 0.1 percent in 1997 to 0.3 percent in 2006.

[79] In 2006, total materials imported by the petroleum industry accounted for 34 percent of material imports by the manufacturing sector. Over the 1997–2006 period, the price of imported intermediates for the petroleum industry grew 14 percent as compared to average growth of prices in the manufacturing sector as a whole of 4 percent.

Figure 2. Imports Share of Sectoral Intermediate Inputs, by type of input, U.S. Manufacturing, 1997–2006

(imports' share of total intermediates also shown)



Source: Bureau of Labor Statistics and Bureau of Economic Analysis

BLS MULTIFACTOR PRODUCTIVITY

Solow Model of Productivity

It is generally acknowledged that technical progress can best be captured using a total factor productivity concept. The most common model of total factor productivity is credited to Solow (1957). The Solow residual model evaluates technical progress as the difference between the time derivative of production and the weighted aggregate of the time derivatives for all factors of production. This measure of disembodied technological change evaluates the ability to expand the production possibilities frontier without the addition of resources. Given a production function $Y = f(X, t)$, the growth rate of total factor productivity, A, can be written as

(1) $$\frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - \sum_i \left(\omega_i \frac{\dot{X}_i}{X_i} \right)$$

where Δ represents a time derivative , Y denotes real aggregate output, X_i denotes the ith factor of production, and β_i represents the corresponding output elasticity. This productivity growth model requires well-defined concepts of output and inputs that correspond to a specified production process. To construct measures of productivity, we must make a discrete approximation for the time derivatives (Diewert 1976), and we must assume cost-minimizing behavior in order to measure the β_i with cost shares.

BLS Multifactor Productivity for the Private Business Sector

The BLS labor productivity measures for the private business sector compare output, measured as the real gross domestic product of U.S. businesses, to hours worked by all U.S. workers who contribute to the production of this output. Real GDP is measured by adding all exports and subtracting all imports from domestic final demand. Thus, imported intermediate inputs are excluded from the scope of the output measures, and as a result, the contribution of the labor hours worked overseas that produce the imported intermediate inputs are also absent from the analysis of U.S. productivity. The output measure used to construct the productivity measure for the private business sector removes the output of intermediate inputs produced and used within a sector, as well as all imported intermediate inputs and other domestic intermediate inputs produced outside the sector. Thus, BLS MFP, A_{BLS}, contains only two factor inputs, labor (L) and capital services (K), and can be written as

(2) $$\frac{\Delta A_{BLS}}{A_{BLS}} = \frac{\Delta Y_{BLS}}{Y_{BLS}} - w_L \frac{\Delta L}{L} - w_K \frac{\Delta K}{K}$$

Or

(3) $$d \ln A_{BLS} = d \ln Y_{BLS} - w_L \, d \ln L - w_K \, d \ln K$$

where the Y_{BLS} is the BLS real private business sector output, $d\ln A_{BLS}$ denotes the difference in logarithms of A_{BLS} for successive years ($lnA_{(BLS,t)} - lnA_{(BLS,t-1)}$) , and the weights for labor and capital, w_i, are the averages of each factor's nominal cost (C_i) relative to nominal output, $Y^N{}_{BLS}$, in two successive years:

(4) $$w_{i=L,K} = 1/2 * \left(\frac{C^N{}_{i,t}}{Y^N_{BLS,t}} + \frac{C^N{}_{i,t-1}}{Y^N_{BLS,t-1}} \right)$$

Because of this design it is impossible to observe the impact of offshoring intermediate inputs on production. To incorporate intermediate inputs into the model, we need to use a sectoral output concept.

Private Business Sector Multifactor Productivity Adjusted to Include Imports

Sectoral output removes from the value of output only those intermediate inputs that are produced elsewhere within the sector to eliminate double counting. Intermediate inputs, which are produced outside of the sector, (i.e., imported intermediates) remain in output (Domar 1961). To bring imported intermediate inputs inside the major sector model framework, we must not exclude them as a component of output, and they must be included as a factor input to production. Denoting the imported intermediate inputs as II, the production function becomes $Y_S = f\,(L, K, II, t)$. Using this output concept, we can write MFP as:

(5) $$d\ln A_S = d\ln Y_S - \theta\, w_L\, d\ln L - \theta\, w_K\, d\ln K - \sum_j \left[w_j\ d\ln II_j \right]$$

where the factor weights for imported intermediate inputs of energy (*IE*), materials (*IM*), and services (*IS*) are defined as

(6) $$w_{(j=IE,IM,IS)} = 1/2 * \left(\frac{C^N_{j,t}}{Y^N_{S,t}} + \frac{C^N_{j,t-1}}{Y^N_{S,t-1}} \right)$$

and an output adjustment ratio, θ, used to correct the weights on labor and capital, is written as a two-period average

(7) $$\theta = 1/2 * \left(\frac{Y^N_{BLS,t}}{Y^N_{S,t}} + \frac{Y^N_{BLS,t-1}}{Y^N_{S,t-1}} \right)$$

Algebraically working through the model, we derive an adjusted MFP measure that encompasses imported intermediate inputs in both the output and input indexes. Assuming that growth in sectoral output is a weighted average of growth in the BLS output measure and intermediate imports, the resulting MFP growth rate is a scalar of the existing BLS MFP growth:

(8) $$d\ln A_S = \theta\ \ d\ln A_{BLS}$$

Table 1. Growth of Components of Private Business Sector Multifactor Productivity, Alternative Output Concepts, 1997–2006

	Original Output	Sectoral Output	Labor	Capital	Imported Intermediates	Imported Energy	Imported Materials	Imported Services
annual growth from previous year								
1998	4.9%	5.3%	2.3%	6.3%	10.7%	3.8%	10.9%	10.3%
1999	5.2%	5.4%	2.7%	6.5%	8.5%	9.2%	8.3%	9.3%
2000	3.9%	4.4%	1.0%	6.3%	9.6%	11.2%	9.5%	9.7%
2001	0.5%	0.1%	-1.4%	4.6%	-3.8%	-1.9%	-5.4%	3.8%
2002	1.5%	1.4%	-1.4%	2.9%	-0.1%	-6.5%	-1.3%	5.5%
2003	3.1%	3.1%	-0.3%	2.3%	3.1%	3.4%	4.4%	-2.4%
2004	4.3%	4.9%	1.5%	2.3%	11.8%	27.3%	10.3%	16.4%
2005	3.7%	3.9%	1.8%	2.5%	5.7%	13.9%	5.6%	4.7%
2006	3.2%	3.4%	2.6%	2.7%	4.9%	2.8%	4.7%	6.8%
average annual growth								
1997-2006	3.4%	3.5%	1.0%	4.0%	5.5%	6.6%	5.1%	7.0%

Table 1 presents growth rates for the components of the MFP model for the private business sector.[80] Notice that the imported intermediates grow faster than labor and capital in most years, except around the 2001 recession. The growth of imported intermediate inputs has an impact on the growth of sectoral output trends as well, which grew somewhat faster than the published value-added output measure for all years except 2001 and 2002. The year-to-year growth rates of the imported intermediates fluctuate quite a bit. Over the 1997–2006 period, energy and service imports grew faster than imported materials. However due to their small size, imported materials growth is driving the growth in total imported intermediate inputs.

Using BEA estimates of imported intermediate inputs, we derived the adjustment scalar for the private business sector MFP measures. Table 2 shows the results of adjusting the published BLS MFP data. Notice that by incorporating the imported intermediate inputs into the MFP framework, the annual growth in private business sector MFP is reduced by 0.1–0.2 percentage points.

Table 2. Multifactor Productivity Growth for the Private Business Sector, by alternative treatment of imports, 1997–2006

	Excluding Imported Intermediate Inputs: BLS published data	Including Imported Intermediate Inputs	Difference
annual growth from previous year			
1998	1.30%	1.20%	-0.10%
1999	1.29%	1.19%	-0.10%
2000	1.28%	1.18%	-0.10%
2001	0.11%	0.10%	-0.01%
2002	1.65%	1.53%	-0.13%
2003	2.63%	2.43%	-0.20%
2004	2.49%	2.28%	-0.20%
2005	1.63%	1.48%	-0.15%
2006	0.54%	0.49%	-0.05%
annual average growth			
1997-2006	1.43%	1.32%	-0.12%

Substitution of Imported Intermediates for U.S. Labor in the Private Business Sector

Using the Solow MFP equation, we estimated the effects of substitution between imported intermediate inputs and U.S. hours worked on labor productivity. The growth in imported intermediate inputs, combined with growth in capital inputs and technical change, directly

[80] The time series does not cover the business cycles sufficiently to divide that data into subperiods that would allow a meaningful analysis of the data. We constructed subperiods of 1997–2000 and 2001–2006, as well as 1997–2002 and 2003–2006. The comparison of results between period 1 and period 2 was very sensitive to the year that the data was divided. Therefore, we will not present subperiod analysis in this paper.

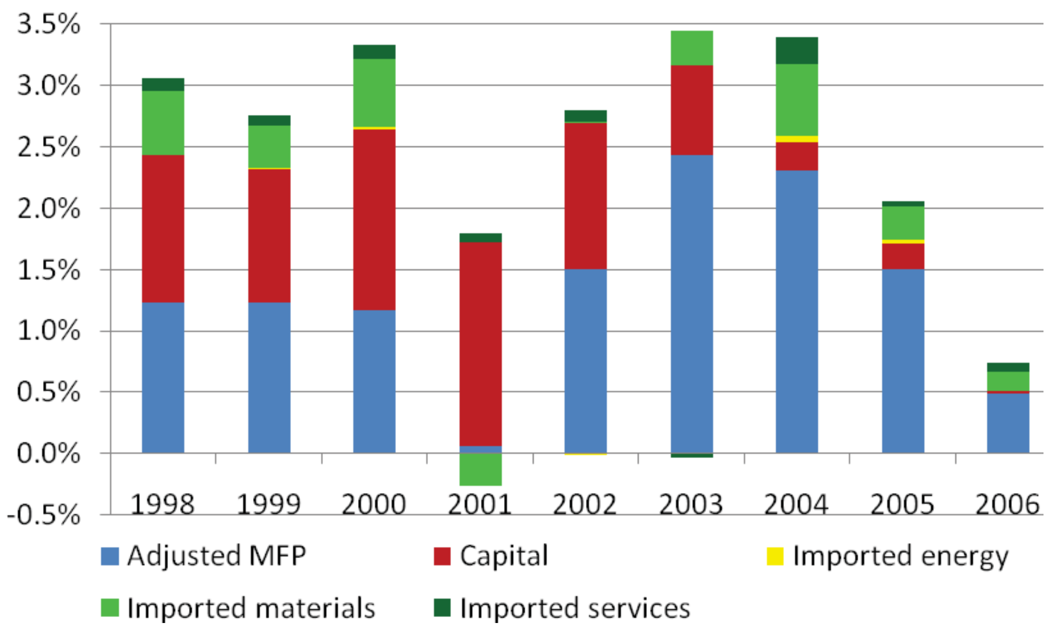
influence labor productivity. Thus, labor productivity can be written as the sum the intensity of each of the other input factors (increases in the factor's quantities relative to domestically employed labor):

$$(9) \qquad d\ln Y_s - d\ln L = d\ln A_s + \theta\, w_K \left(d\ln K - d\ln L\right) + \sum_j w_j \left(d\ln II_j - d\ln L \right)$$

Figure 3 shows the contributions to private business sector labor productivity of the remaining nonlabor factor inputs. From 1997 through 2002, growth in capital services contributed to the majority of labor productivity growth. Beginning in 2003, capital's contribution to labor productivity declined and was outpaced by MFP growth. Also, beginning in 2004 the contribution of imported intermediate inputs contributed more to labor productivity growth than capital growth. Again, we note that the influence of imported material inputs dominated the contribution of all imported intermediate inputs.

Figure 3. Labor Productivity Growth by Contributing Input Factors, Private Business Sector, 1997–2006

(annual growth rates from the previous year)



Sources: Bureau of Labor Statistics (using BEA unpublished import data)

Using the sectoral output approach, we observe (see Table 3) that for the 1997–2006 period, approximately 14 percent of labor productivity growth was attributed to growth in imported intermediate inputs (11 percent to materials, 3 percent to services, and less than 0.5 percent to energy).[81]

[81] Note that because output has been expanded to include imports, the labor productivity growth is 2.6 percent per year, rather than 2.4 percent per year.

Table 3. Labor Productivity Growth and the Contribution of Non-labor Inputs and Multifactor Productivity, U.S. Private Business Sector 1997–2006
(average annual growth rates)

Output per unit of labor (includes imports)	2.56%
Multifactor Productivity (includes imports)	1.31%
Contribution of capital intensity	0.88%
Contribution of imported intermediates	0.37%
Contribution of imported materials	0.27%
Contribution of imported services	0.08%
Contribution of imported energy	0.01%

BLS MULTIFACTOR PRODUCTIVITY FOR THE U.S. MANUFACTURING SECTOR

As mentioned earlier, BLS productivity measures for the manufacturing sector are constructed using a sectoral output concept. Therefore, imported intermediates are within the productivity model framework. For the MFP measures, imported intermediate inputs are a component of measured output and intermediate inputs. To identify the impact of imported intermediates on manufacturing productivity, we do not need to adjust the measures to include imports, but rather separate the intermediates into domestic and imported components. This demarcation is achieved using the BEA estimates of imported intermediates, which were provided to the BLS at the industry level of detail.

Table 4 presents the year-to-year growth rates and the average annual growth for the components of the manufacturing MFP model over the 1997–2006 period. Notice that in most years, labor inputs declined and imported intermediates grew faster than capital and domestic nonmanufactured intermediate inputs. Prior to the 2001 recession, there was strong growth in capital services, imported intermediates, and domestic nonmanufactured intermediates. However, note that domestic nonmanufactured intermediates were impacted by the recession sooner than the imported intermediates. Also notice that the imported intermediates were able to rebound after the recession, while domestic nonmanufactured inputs showed negative growth through 2004. Over the entire 1997–2006 period, labor and domestic nonmanufactured intermediates inputs declined, while capital services and imported intermediates grew.[82]

[82] Kurz and Lengermann (2008) construct a gross output productivity measure in order to keep U.S. manufactured intermediates in the model. This model allows an analysis of the shift from domestic to imported intermediate inputs.

Table 4. U.S. Manufacturing Sector Multifactor Productivity and Components, 1997–2006

	Sectoral Output	Labor	Capital	Domestic Intermediates	Imported Intermediates	MFP
Annual growth from previous year						
1998	5.2%	-0.2%	5.0%	2.3%	9.6%	2.30%
1999	3.8%	-0.7%	4.1%	4.2%	7.1%	0.80%
2000	2.7%	-1.3%	3.1%	-4.1%	5.5%	3.50%
2001	-5.1%	-6.5%	1.5%	-3.0%	-4.9%	-1.30%
2002	-0.7%	-7.1%	0.6%	-4.4%	-2.1%	3.70%
2003	1.0%	-4.9%	0.0%	-1.3%	2.6%	2.80%
2004	1.7%	-0.5%	-0.6%	-5.2%	8.7%	2.60%
2005	3.7%	-1.1%	0.0%	7.7%	4.9%	0.40%
2006	1.8%	0.6%	0.5%	-2.0%	4.3%	1.60%
Annual average growth						
1997-2006	1.53%	-2.44%	1.57%	-0.74%	3.88%	1.79%

* Combined intermediates constructed as a weighted aggregate of energy, materials, and purchased services.

Table 5 compares the growth of domestic nonmanufactured intermediate inputs and imported intermediates by type of input. In general, we note that imported intermediates showed stronger growth than domestically nonmanufactured inputs. It is interesting to note that domestic material inputs (excluding materials purchased from other manufacturing industries) were declining in most years, while imported materials grew.

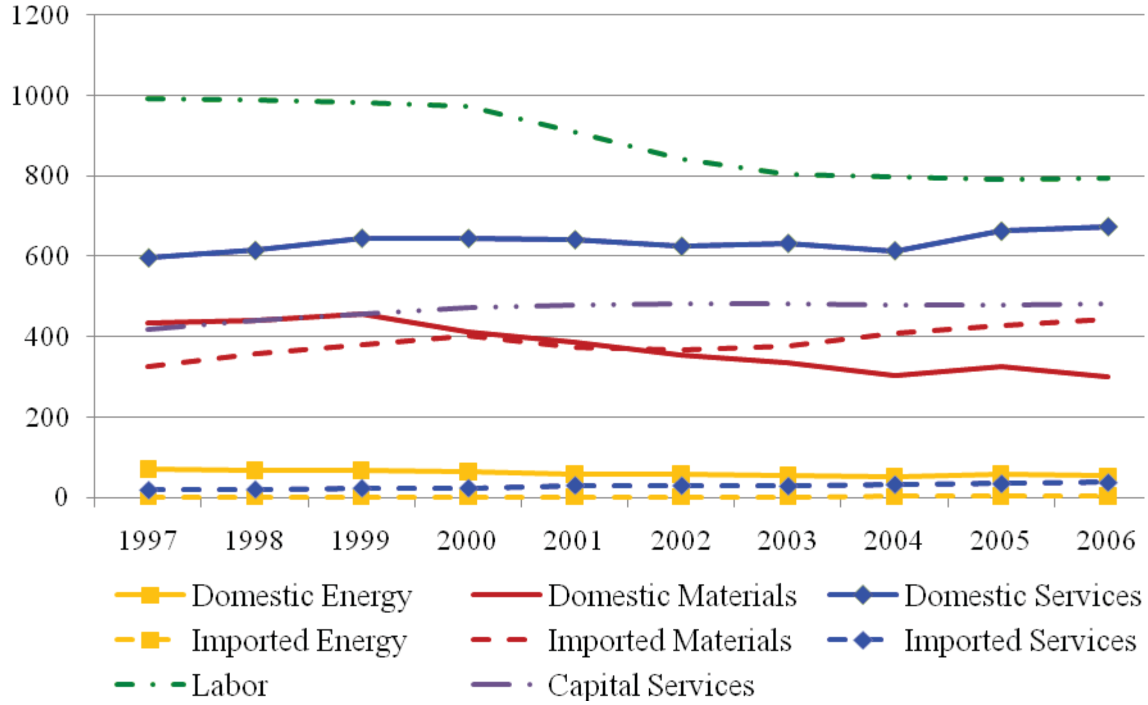
Table 5. Comparison of Imported and Domestic Intermediate Inputs by Type of Input, U.S. Manufacturing Sector, 1997–2006

	Total Intermediates		ENERGY		MATERIALS		SERVICES	
	Domestic	Imported	Domestic	Imported	Domestic	Imported	Domestic	Imported
Annual growth from previous year								
1998	2.25%	9.59%	-2.49%	-7.80%	1.94%	9.73%	3.02%	8.48%
1999	4.21%	7.12%	0.09%	0.39%	3.79%	6.57%	4.93%	15.76%
2000	-4.10%	5.52%	-5.04%	-11.12%	-10.12%	5.85%	-0.06%	1.54%
2001	-3.02%	-4.86%	-9.47%	-6.99%	-6.13%	-7.29%	-0.48%	28.48%
2002	-4.44%	-2.11%	-1.51%	-1.17%	-8.39%	-2.14%	-2.53%	-1.82%
2003	-1.25%	2.64%	-6.08%	12.96%	-4.87%	3.17%	1.14%	-4.19%
2004	-5.23%	8.71%	-2.15%	35.05%	-9.97%	8.12%	-2.89%	13.88%
2005	7.74%	4.93%	8.05%	25.06%	7.44%	4.63%	7.87%	6.38%
2006	-2.02%	4.25%	-6.81%	10.69%	-7.40%	3.91%	1.67%	8.20%
Average annual growth								
1997-2006	-0.74%	3.88%	-2.94%	5.34%	-3.93%	3.49%	1.36%	8.13%

*Combined intermediates constructed as a weighted aggregate of energy, materials, and purchased services

Figure 4 presents the trends in constant-dollar factor input costs for the U.S. manufacturing sector. Notice that labor represents the highest cost and was constant prior to the 2001 recession, when it declined with falling employment in manufacturing. Energy and imported services represent a very small portion of the overall factor costs in manufacturing and were relatively constant over the 1997–2006 period. Interestingly, the cost of imported materials increased over the period, while the cost of domestic nonmanufactured materials declined. The factor costs of capital services and purchased domestic services increased somewhat. We next estimate the effects of imported intermediate inputs on labor productivity by using the Solow MFP model.

Figure 4: Input Costs for the Manufacturing Sector, by type 1998–2006
Constant dollar, billions



Sources: Bureau of Labor Statistics (using BEA unpublished import data)

Substitution of Imported Intermediates for U.S. Labor in the Manufacturing Sector

The model used by BLS to measure MFP for the U.S. manufacturing sector can be written as

(10) $$d\ln A_G = d\ln Y_G - w_L\, d\ln L - w_K\, d\ln K$$

$$- w_E\, d\ln E - w_M\, d\ln M - w_S\, d\ln S$$

where Y_G is real sectoral output for the manufacturing sector, $d\ln A_G$ denotes the difference in logarithms of A_G for successive years ($lnA_{(G,t)} - lnA_{(G,t-1)}$), and the weights for labor, capital, energy, materials, and purchased business services, w_i, are the averages of each factor's nominal cost relative to nominal output, Y^N_G in two successive years:

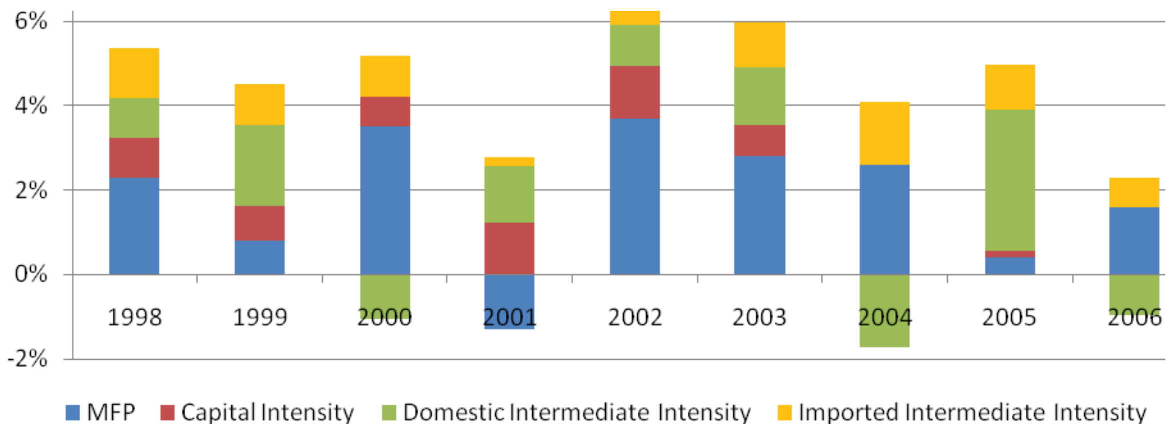
(11) $$w_{i=L,K,E,M,S} = 1/2 * \left(\frac{C_{i,t}}{Y^N_{G,t}} + \frac{C_{i,t-1}}{Y^N_{G,t-1}} \right)$$

The growth in imported intermediate inputs, combined with growth in capital inputs, domestic intermediate inputs, and technical change, directly influence labor productivity. Thus, labor productivity can be written as the sum the intensity of each of the other input factors (increases in the factor's quantities relative to domestically employed labor):

(12)
$$d\ln Y_G - d\ln L = d\ln A_G + w_K\left(d\ln K - d\ln L\right) +$$
$$\sum_j w_{DI_j}\left(d\ln DI_j - d\ln L\right) + \sum_j w_{II_j}\left(d\ln II_j - d\ln L\right)$$

where w_{DIj} denotes the weights on domestic intermediates $j = E,M,S$ and w_{IIj} denotes the weights on imported intermediates $j = E,M,S$.

Figure 5. Labor Productivity Growth by Contributing Input Factors, Manufacturing Sector, 1998–2006
(annual growth rates from previous year)



Sources: Bureau of Labor Statistics (using BEA unpublished import data)

Figure 5 shows the contributions of nonlabor factor inputs to year-to-year growth of manufacturing sector labor productivity, and Table 6 presents the contributions of nonlabor factor inputs on the average annual growth over the entire period from 1997 to 2006. From Figure 5, notice that in most years, MFP contributed the most to labor productivity growth. Also notice that growth in capital services contributed to labor productivity growth prior to 2004, but very little thereafter. Imported intermediate inputs made a relatively constant contribution to labor productivity growth in all years, with the exception of 2001. Over the period 1997–2006, MFP accounted for 45 percent of productivity growth and imported intermediate inputs accounted for 23 percent.

Table 6. Contributions to Labor Productivity in the U.S. Manufacturing Sector 1997–2006
(average annual growth)

Output per unit of labor	3.96%
Multifactor Productivity	1.79%
Contribution of capital intensity	0.64%
Contribution of domestic intermediates	0.65%
Contribution of imported intermediates	0.92%
Contribution of imported materials	0.80%
Contribution of imported services	0.10%
Contribution of imported energy	0.01%

INFLUENCE OF IMPORT PRICES

To assess the impact of possible bias in the price change of imports on productivity, we consider the difference between the growth of the BLS productivity measure, $d\ln A_{BLS}$, and the growth of a productivity measure that is constructed with more precise price indexes for imports, $d\ln A_{price*}$. Prices of imports enter the BLS private business sector productivity model when imports are removed from final demand in the construction of real GDP (which is further reduced to arrive at private business sector output, Y_{BLS}). To assess the impact of possible import price bias, we assume that domestic inputs and all other components of output are measured precisely.[83] Therefore, the possible bias in productivity growth equates to a difference in the growth of alternative output measures:

$$(13) \quad d\ln A_{BLS} - d\ln A_{Price*} = d\ln Y_{BLS} - d\ln Y_{Price*}$$

By assuming that all domestic components of output are measured precisely, the difference in the growth of measured output and an output measure that is constructed using alternate import prices becomes the difference in the growth of measured imports, I_{BEA}, and the alternate, $I_{\mathrm{Price*}}$, that is measured with alternative import prices. The growth of the differences in import measures must be weighted by imports' share, s_I, of output. Because the shares are calculated using nominal data, there is no difference in the weights. The difference in the growth of measured productivity relative to a productivity measures constructed with alternative prices of imports becomes

[83] Diewert and Nakamura (2009) present a new measure for the bias in an import price index due to outsourcing and show how the price index bias problems attributable to input source substitution can be represented theoretically. The authors suggest that outsourcing and the inability of price indexes to capture the effect of new firm entry and input substitution, have led to an upward bias in intermediate input and import price indexes.

(14) $$d\ln A_{BLS} - d\ln A_{Price*} = -s_I\left(d\ln I_{BEA} - d\ln I_{Price*}\right)$$

Where

(15) $$s_I = 1/2*\left(\frac{I^N_t}{Y^N_{BLS,t}} + \frac{I^N_{t-1}}{Y^N_{BLS,t-1}}\right)$$

Real growth in imports can be calculated as the difference between nominal growth and price growth. As there is no difference in nominal growth between the two concepts, the difference between the growth of measured productivity and a productivity measure constructed with alternative import prices becomes the weighted difference between the measured price growth of imports, P^I_{BEA}, and an alternative measure of price growth, P^I_{Price*}

(16) $$d\ln A_{BLS} - d\ln A_{Price*} = s_I\left(d\ln P^I_{BEA} - d\ln P^I_{Price*}\right)$$

Note that the value of aggregate imports is based upon many individual commodities that may or may not suffer from biased import prices. An individual commodity's impact on aggregate productivity growth will be determined by the bias in that commodity's price, P^I_i, growth, weighted by the imported commodity's share of output , c_i:

(17) $$c^I_i = 1/2*\left(\frac{I^N_{i,t}}{Y^N_{BLS,t}} + \frac{I^N_{i,t-1}}{Y^N_{BLS,t-1}}\right)$$

An individual commodity's impact on productivity growth can be estimated as

(18) $$c^I_i\left(d\ln P^I_{BEA,i} - d\ln P^I_{Price*,i}\right)$$

The size of the possible bias in aggregate productivity growth is

(19) $$\sum_i c^I_i\left(d\ln P^I_{BEA,i} - d\ln P^I_{Price*,i}\right)$$

When we modified the BLS private sector MFP model to include intermediate inputs in the model, we reduced the influence of possible price bias on the output component; however we introduced the possible price bias on the input side of the model. Again we consider the impact of import prices on productivity as the difference between the growth of the modified productivity measure, $d\ln A_S$, and the growth of a productivity measure that is constructed with more precise price indexes for imports, $d\ln A_{price*}$. Recalling the modified MFP Eq. (5), the difference between the growth of modified productivity and a productivity measure constructed with alternative import prices is the difference in output growth and the weighted difference the growth of imported intermediate inputs with existing import price indexes, II_{BEA}, and an alternative measure of price growth, II_{Price*}

(20) $$d\ln A_S - d\ln A_{Price*} = d\ln Y_S - d\ln Y_{Price*} - w_{II}\left(d\ln II_{BEA} - d\ln II_{Price*}\right)$$

In the modified MFP model, only imports used as intermediate inputs in production are added back into the model. Assuming they can be added back in the same manner as they were originally removed, the growth of real output can only be biased to the extent that price measures for imports that are destined for final demand are biased. The possible impact on productivity growth is estimated as the weighted difference between the measured price growth of imports, P^I_{BEA}, and an alternative measure of price growth, P^I_{Price*} over final demand products and intermediate inputs

(21) $$\sum_i^{final\_demand} w_i^I\left(d\ln P^I_{BEA,i} - d\ln P^I_{Price*,i}\right) + \sum_i^{intermediates} w^I{}_i\left(d\ln P^I_{BEA,i} - d\ln P^I_{Price*,i}\right).$$

Because the weights on the final demand components and the intermediate inputs are both that commodity's share of nominal output, the influence of mismeasured import prices on aggregate productivity is

(22) $$w^I\left(d\ln P^I_{BEA} - d\ln P^I_{Price*}\right)$$

where

(23) $$w^I = 1/2*\left(\frac{I_t^N}{Y_{S,t}^N} + \frac{I_{t-1}^N}{Y_{S,t-1}^N}\right)$$

By construction, w_j is less than s_j for all commodities; recall that $Y_S > Y_{BLS}$. Therefore, the impact of import prices on MFP is smaller under the modified MFP framework than in the BLS published MFP model.

Table 7: Imported Intermediate Inputs Share of Private Business Sector Output, 1998–2006

	1998	1999	2000	2001	2002	2003	2004	2005	2006
BLS Output Share, s^I	8.05%	8.07%	8.76%	8.84%	8.25%	8.25%	8.98%	10.03%	10.77%
Sectoral Output Share, w^I	7.45%	7.47%	8.05%	8.12%	7.62%	7.62%	8.23%	9.11%	9.72%

Because import prices are not used to construct real output measures for the BLS manufacturing productivity statistics, any possible price mismeasurement of imports does not affect labor productivity statistics for the manufacturing sector. However, prices of imports enter the BLS manufacturing sector MFP model when imports are included in the construction of purchased intermediate inputs. To assess the impact of possible import price bias, we assume that output and all domestic inputs are measured precisely. Therefore, the possible bias in productivity growth equates to a difference in the weighted growth of imported intermediate inputs

(24) $$d\ln A_S - d\ln A_{Price*} = -w_i \left(d\ln II_{BEA} - d\ln II_{Price*} \right)$$

(25) $$w_{i=IE,IM,IS} = 1/2 * \left(\frac{I_{i,t}}{Y^N_{G,t}} + \frac{I_{i,t-1}}{Y^N_{G,t-1}} \right)$$

Real growth in imports is calculated as the difference between nominal growth and price growth. As there is no difference in nominal growth between the two concepts, the difference between the growth of measured productivity and a productivity measure constructed with alternative import prices becomes the weighted difference between the measured price growth of imports, $P^I{}_{BEA}$, and an alternative measure of price growth, $P^I{}_{Price*}$

(26) $$\sum_i^I w_j^I \left(d\ln P^I{}_{BEA,j} - d\ln P^I{}_{Price*,j} \right)$$

Table 8: Imported Intermediate Factor Cost Shares, Manufacturing Sector, 1998-2006

	1998	1999	2000	2001	2002	2003	2004	2005	2006
BLS Output Share, w^I	12.24%	12.39%	13.53%	13.97%	13.57%	13.86%	15.24%	16.94%	18.33%

CONCLUSIONS

In this paper we develop a framework for estimating the effects of imported intermediate inputs on U.S. major sector labor productivity. The production model used to calculate the BLS private business sector MFP measures is expanded to treat imported intermediate inputs as an input rather than as a subtraction from output. Once the imported intermediate inputs are inside the framework, we use the Solow MFP equation to estimate the effects on labor productivity of substitution between imported intermediate inputs and U.S. hours worked. Separate effects are estimated for imported energy, materials, and services. The data show that imports increased as a share of total intermediates used by private industries from 8 percent in 1997 to 10 percent in 2006. By including imported intermediates in the MFP model, we find that private business sector MFP grew 0.1–0.2 percent per year slower than the BLS published series. Also, we estimated that the growth in imported intermediate inputs contributed 14 percent to the average annual growth of labor productivity for the private business sector from 1997 to 2006.

We do not believe that it would be a good idea to alter the labor productivity model to incorporate imported intermediates, as then the trend could be considered “biased” to the extent that output would reflect the growth in imported intermediates, while the labor input would not include the corresponding hours worked overseas. However, the role of imported intermediates can be meaningfully assessed in the MFP model. From the exercise above (see Table 2), we find that including imported intermediates in a sector output concept and as a factor input in production, MFP grew 0.1–0.2 percent per year slower than the BLS published series.

Because over 60 percent of imported intermediate inputs purchased by private industries are used by the manufacturing sector, we also evaluate the role of imported intermediates in the U.S. manufacturing sector. The BLS methods for constructing manufacturing MFP include intermediates in the model framework. Therefore, we isolate the imported components to assess their impact on labor productivity. The data reveal that over the 1997–2006 period, imported intermediate inputs grew as a share of total intermediate inputs. We find that labor inputs and domestic nonmanufactured inputs declined over the entire period, while capital services and imported intermediates grew. In addition, we estimate that growth in imported intermediate inputs contributed 23 percent to the average annual growth in labor productivity in the manufacturing sector.

Finally, we show that any mismeasurement of import prices impacts BLS productivity measures. However, the impact will be weighted by the share of imports relative to aggregate output, which ranged from 8–12 percent for the private business sector and 12–18 percent for the manufacturing sector.

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SESSION 4: OFFSHORING AND PRICE MEASUREMENT: INDUSTRY CASE STUDIES

CHAIR: Jon Steinsson (Columbia University)

Offshoring and Price Measurement in the Semiconductor Industry,
David Byrne (Federal Reserve Board), Brian Kovak (University of Michigan), and
Ryan Michaels (University of Michigan)

Measuring IT Software and Services: Implications for Real Trade Flows, Catherine Mann
(Brandeis University and Peterson Institute for International Economics)

Imports of Intermediate Parts in the Auto Industry—A Case Study, Thomas H. Klier (Federal
Reserve Bank of Chicago) and James M. Rubenstein (University of Miami, Ohio)

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Offshoring and Price Measurement in the Semiconductor Industry*

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Abstract

The recent growth in offshore outsourcing of intermediate input production makes it especially critical that statistical agencies are able to accurately measure quality-adjusted trade flows. This paper examines the implications of global production sharing for measuring the price of semiconductors, a critical input to high-end domestic manufacturing and U.S. productivity growth. We analyze new transaction-level data on semiconductor wafer fabrication around the world, including prices and detailed information on key physical attributes of semiconductor wafers. Semiconductor wafers are a high-value intermediate good in the production of final products in the semiconductor industry. Using this detailed information on wafer pricing and quantities by country, we study the price measurement implications of shifts in the pattern of international production sharing for this important stage in the value chain. We estimate that, after adjusting for changes in product characteristics, the average annual price decline in processed wafers was roughly 12.5 percent during the last five years. Our analysis also finds that shifts in the location of production to lower-cost countries can contribute an additional price decline of up to 0.8 percent per year.

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The recent growth in offshore outsourcing of intermediate input production has generated concern that standard government data collection methods are ill-suited to an increasingly international productive structure (Houseman 2007). This paper focuses on the semiconductor industry to estimate the effects of offshore outsourcing on input price measurement. We find that offshoring in this industry necessitates the collection of very detailed product data to adequately adjust prices for input quality, and that shifting sourcing patterns may cause standard price measures to understate price declines for processed semiconductor wafer inputs by as much as 0.8 percent per year.[84]

We choose to examine wafer fabrication, an intermediate stage in semiconductor production, for a number of reasons. First, semiconductor wafer production has moved offshore to a dramatic degree in the last forty years, with continual shifts in the geographic distribution of semiconductor manufacturing capacity. Second, China's entrance in the semiconductor manufacturing market in 2001 was much heralded in the media, and provides an interesting case study on the effects of growing Chinese economic strength on an important industry. Third, the discrete nature of technological progress in semiconductor wafer fabrication techniques makes careful quality adjustment feasible, as we describe in detail below. Finally, we have obtained a new dataset of semiconductor input prices with information on country of origin, making possible an empirical investigation of the effects of shifts in sourcing on input price measurement.

Offshoring poses a number of challenges for price measurement in the semiconductor manufacturing sector in particular. First, suppose a U.S.-based manufacturer contracts out all production to a firm overseas and that, prior to its decision to offshore, it had purchased final goods from an independent supplier here in the U.S. or had made the good itself. The one-time decline in the price level associated with the decision to offshore is not captured by current data-collection procedures. The Producer Price Index's universe does not include imports, so it does not reflect the price reduction. The Bureau of Labor Statistics (BLS) International Price Program (IPP) measures price changes beginning in the *second* month in which the imported good is observed, as it is not designed to measure the initial price decline that occurs when a domestic producer first off-shores a segment of production. A similar problem can arise if the firm has already contracted out production overseas but now sources from a low-cost supplier in China rather than from a producer in Taiwan.[85]

The problem posed by shifting sourcing arrangements is essentially equivalent to the problem of outlet substitution bias in the CPI, described in detail by the Boskin Commission Report (Boskin et al. 1996) and Diewert (1998). While those studies were concerned with consumers shifting their consumption toward low-cost retail outlets, this paper confronts the problem of semiconductor producers shifting their intermediate input sourcing toward low-cost suppliers located abroad. The bias is most acute whenever the inputs, as in our case, are approximately

[84] Semiconductor wafers are described in detail in the next section.

[85] In principle, the IPP would measure this change if the manufacturer imported the good itself or if it continued to work through the same intermediary that is surveyed by IPP. If, on the other hand, the manufacturer contracts with a different intermediary in order to access a new market overseas, the IPP will miss the price decline since it surveys the importer, which in this case was the original intermediary. Unfortunately, to the best of our knowledge, there is little information on the relative importance of intermediaries in the IPP.

identical, which implies that the unmeasured price change when production is shifted to a new location does in fact represent a genuine price decline for the same good.

The final significant challenge is quality adjustment. As a greater share of production is shifted abroad, the composition of imports becomes increasingly sophisticated. This is particularly true within the semiconductor industry, which imports many complex intermediate inputs at various stages in the production process. This process places much greater demands on quality adjustment procedures for import prices, as semiconductor technology changes so quickly. The challenge of quality adjustment in the semiconductor industry is well known and has been demonstrated in many previous studies.[86]

We address these concerns using new transaction-level data on semiconductor wafer purchases, collected by the Global Semiconductor Alliance (GSA). These data contain fine detail on product characteristics, allowing us to generate constant-quality price indexes. They also report the source country for each transaction, making it possible to examine the effects of shifting geographic production on price measurement. Our results demonstrate the importance of having such detailed data when constructing price indexes in industries with large amounts of offshoring. This need is likely to increase as more countries move up the technical ladder and begin exporting ever more complex products.

The paper proceeds as follows. The next section describes aspects of the semiconductor manufacturing process that are relevant to price measurement. We then describe the data we utilize to build input price measures, followed by a section that presents our price index calculations. We begin with a standard matched model index as a baseline and then follow Reinsdorf (1993) to bound the potential effect of outlet substitution bias due to shifting input sourcing across countries. This section concludes with comparisons to a hedonic index and a publicly available official semiconductor price index. The last section concludes.

SEMICONDUCTOR PRODUCTION

This section describes the semiconductor manufacturing process and recent changes in the business models employed by semiconductor firms, highlighting characteristics of the industry that are important for price measurement. Semiconductor production technology progresses in distinct measurable steps, allowing us to account for technological improvement when constructing price indexes in spite of rapid changes over time. The continuing movement to outsource semiconductor production to offshore firms raises the possibility of outlet-substitution bias in standard price indexes and motivates our choice to focus on foundry wafer fabrication.

Semiconductor Production Technology

Semiconductor fabrication involves creating networks of transistors on the surface of a thin piece of semiconducting material.[87] The process begins with the design and layout of a new chip. Semiconductor designers use suites of complex software to specify the functionality of the chip,

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[86] See, among others, Flamm (1993), Grimm(1998), and Aizcorbe, Corrado, and Doms (2003).
[87] Turley (2003) provides an accessible overview of semiconductor technology, manufacturing, and business.

convert that logic into the corresponding network of transistors, determine the physical layout of those transistors, and simulate the behavior of the proposed design for debugging purposes.

Semiconductors are manufactured in a facility called a fab. Transistors are created on the surface of the wafer through a photolithography process, in which successive layers of conducting and insulating materials are deposited on the surface of the wafer and chemically etched away in the appropriate places to form the desired pattern of transistors and necessary interconnections. The design layout software determines the etching pattern for each layer, which is projected onto the wafer through a mask containing the negative of the desired pattern, in a process similar to developing a photograph by projecting light through a negative. Each step of the etching process is repeated multiple times across the wafer, resulting in a grid pattern of many copies of the chip. Once all transistors and connection layers are complete, the chips are tested in a process called "wafer probe," and any faulty chips are marked to be discarded. The wafer is then cut up, leaving individual chips, called die. The die are then placed inside protective packages and connected to metal leads that allow the chip to be connected to other components.

Semiconductor fabrication technology has advanced over time in discrete steps, defined by wafer size and line width (also called feature size). Increases in wafer size allow larger numbers of chips to be produced on a wafer. Most fabs currently produce 150mm (roughly 6 inches), 200mm (8 inches), or 300mm (12 inches) diameter wafers. Although larger wafers cost more to produce, the move to a larger wafer has generally reduced the cost per die by approximately 30 percent per die (Kumar 2007).

Line width is the size of the smallest feature that can be reliably created on the wafer. Decreased line width means that individual transistors are smaller, and more functionality can be integrated into a given area of silicon. This makes chips of a given functionality smaller, lighter, and faster, and also makes it feasible to include more functions on a single chip. The number of transistors that can be produced on a chip has grown exponentially over time, following Moore's Law, the Intel cofounder's famous observation that the number of transistors on a chip doubled every eighteen months (Moore 1965).[88] Figure 1 shows the maximum number of transistors per chip and the minimum line width used to produce Intel processors over the last 40 years (both plotted on logarithmic scales).

Current line widths are measured in microns (μm) or nanometers (nm). The smallest line width currently being produced in volume is 25nm. As a rule of thumb, Kumar (2007) estimates that moving a given chip design to a 30 percent smaller line width will result in cost savings of approximately 40 percent, assuming the same number of defects in both processes. The primary drawback of smaller line widths is increased cost per wafer, particularly early in the technology's life span. Masks are much harder to produce when creating smaller features, and new process technologies often result in higher defect rates and lower yields, the fraction of chips on a wafer that function correctly. In spite of these challenges, the benefits of increased die per wafer and better performance outweigh the problems of decreased yields, particularly as the fabrication technology matures and yields increase. Given the benefits of smaller line widths, semiconductor manufacturers have steadily moved toward newer technology. This is apparent in Figure 1 for Intel processors and can be seen even more clearly in Figure 2, which plots the

[88] This regularity later slowed to doubling every two years.

technology composition of sales at Taiwan Semiconductor Manufacturing Company (TSMC), the largest semiconductor foundry.

There are a number of options regarding the chemicals used to create the transistors themselves and how the transistors are arranged to implement logical functions. The most common technology, called complementary metal-oxide semiconductor (CMOS), accounted for 97 percent of worldwide semiconductor production in 2008.[89] Other transistor arrangements, such as bipolar logic, and other chemical processes, such as Gallium Arsenide (GaAs) or Silicon Germanium (SiGe), generally focus on niche markets for high-frequency, high power, or aerospace devices, rather than the storage and computational logic products comprising the majority of the CMOS market. In the following analysis, we will refer to each combination of wafer size, line width, and logic family as a "process technology" (e.g., 200mm, 180nm, CMOS constitutes one process technology).

The price index calculations below require us to define the set of product characteristics that determine the performance, and hence the price, of a given wafer. To guide this choice, we have consulted pricing models used by engineers at fabless firms to estimate production costs when developing business plans. Kumar (2008) presents a wafer cost model based on wafer size, line width, and logic family. A commercial cost estimation firm, IC Knowledge, distinguishes wafer cost estimates by wafer size, line width, logic family, number of polysilicon layers, and number of metal layers. Given this potential importance of the number of layers in a given design, indicating the design's complexity, we calculate price per layer rather than price per wafer. These pricing models support the use of process technology (wafer size, line width, and logic family) to distinguish between goods in our price indexes, calculated in the section "Price Index Results."

Changing Semiconductor Business Models

In the early 1970s nearly all semiconductor producers were vertically integrated, with design, wafer fabrication, packaging, testing, and marketing performed within one company. By the mid-1970s, firms began moving packaging and test operations to East Asia to take advantage of lower input costs (Scott and Angel 1988, Brown and Linden 2005). In spite of outsourcing these relatively simple steps in the production process, firms maintained their complex wafer fabrication operations in house. Firms that perform both design and wafer fabrication are referred to as integrated device manufacturers (IDM). As wafer fabrication technology advanced, the cost of production facilities increased dramatically; the cost of a fabrication facility has risen from $6 million in 1970 (IC Knowledge 2000) to $4.2 billion in 2009 (Global Foundries 2009). This sharp increase in cost has made it ever more difficult to stay at the leading edge of process technology. In the mid 1980s, small semiconductor firms began producing some of their more advanced designs on the manufacturing lines of larger, more established semiconductor manufacturers that were better able to bear the capital costs of maintaining a state-of-the-art fab facility. Many Japanese semiconductor firms had substantial excess manufacturing capacity during this time period, making such production partnerships particularly attractive (Hurtarte, Wolsheimer, and Tafoya 2007).

[89] Share of actual wafer starts reported in SICAS Semiconductor International Capacity Statistics.

These production sharing arrangements led to the creation of a new business model through the emergence of wafer foundries that manufacture semiconductors designed by other firms. At first, foundries were used by IDMs as an alternative source of capacity for older process technologies (Kumar 2008). By the late 1980s a number of new semiconductor firms avoided wafer fabrication by doing all of their manufacturing through foundries. Semiconductor companies with little or no in-house wafer manufacturing capability are called "fabless" firms. In general, fabless firms perform chip design and layout, and use foundries and other contractors for mask production, wafer fabrication, packaging, and testing. The fabless business model has grown quickly over the last 30 years, accounting for 24 percent of total semiconductor industry revenue in 2009, as shown in Figure 3.[90] Since the largest foundries are located in Asia, and the largest fabless semiconductor producers are located in North America and Europe, the growth of the fabless model has increased the internationalization of semiconductor production.[91] Although the fabless share of the global semiconductor industry only edged up from 2006 to 2008, as new process technologies continue to raise the costs of fab facilities, the prominence of the fabless model may well increase even more. Indeed, AMD, the second largest microprocessor producer, spun off its manufacturing division as an independent foundry company in 2009, boosting the fabless share of the industry (Clendenin and Yoshida 2002).[92]

Implications for Price Measurement

The extremely fast pace of technological change in semiconductor manufacturing poses a large challenge to quality-adjusted price measurement. Aizcorbe (2002) demonstrates the difficulty government price indexes have had in tracking rapid price declines in finished semiconductors. However, as just described, technological advance in semiconductor production proceeds in discrete, measurable steps, in contrast to continuous and difficult to measure quality improvements seen in other industries (Flamm 1993). This discrete nature of technological advance in the semiconductor industry makes it possible to control for quality changes, given detailed enough data on product characteristics. In this study we construct constant-quality price indexes for wafer fabrication using quarterly pricing data that include the most relevant aspects of process technology: wafer size, line width, and logic family. We also control for the number of layers used in constructing the chip, a proxy for design complexity.

This section has also documented the increasing internationalization of the semiconductor supply chain coinciding with offshoring various steps in the production process and the growth of the fabless model of semiconductor production. Houseman (2007) describes the challenges faced by statistical agencies attempting to measure price changes when producers switch suppliers, particularly when the suppliers are located abroad. In particular, substitution toward low-cost suppliers is likely to be missed in standard price index calculations (see below for a more

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[90] Note that the shares in Figure 3 are likely to understate the extent of fabless production activity because companies must derive 75 percent or more of their semiconductor revenue from fabless production. Many companies not counted as fabless nevertheless rely heavily on foundries.
[91] In 2008, the 5 largest foundries (accounting for 84 percent of foundry revenue) were all located in Asia. Of the 25 largest fabless semiconductor companies (accounting for 75 percent of fabless revenue), 19 were located in North America or Europe. These figures were calculated from proprietary reports from iSuppli and GSA, respectively.
[92] A recent report (IC Insights) predicts that between 2008 and 2013, total foundry sales will grow at double the rate of the overall semiconductor industry. A recent report (IC Insights) predicts that between 2008 and 2013, total foundry sales will grow at double the rate of the overall semiconductor industry.

detailed discussion), understating the rate of input price decline. As semiconductor production technology advances and the fabless business model becomes more prominent, it is likely that these price measurement challenges will remain relevant in the foreseeable future.

In the remainder of this paper, we focus on foundry wafer production, leaving analysis of IDM production for future work. We make this choice for practical reasons. Our pricing data include only wafer purchases from foundries, though those purchases could have been made by fabless firms or IDMs choosing to use foundry suppliers. Also, the issue of within-firm transfer pricing raises a number of complications that are beyond the scope of this study and makes data collection essentially impossible.

DATA SOURCES AND DESCRIPTIVE RESULTS

To construct the price indexes used in our analysis, we require information on prices paid and quantities purchased for foundry services, specified by the characteristics relevant for pricing. We obtain prices from a survey conducted by the Global Semiconductor Alliance (GSA) and we calculate quantities by merging several different sources.[93] Observations are quarterly, and our data span the period 2004-2008. Descriptive results demonstrate the importance of controlling for process technology. They also reveal substantial shifting of production toward lower cost countries.

Wafer Pricing Survey

Our primary dataset consists of 7,455 individual responses to GSA's *Wafer Fabrication & Back-End Pricing Survey*, provided to us for 2004-2008.[94] The survey has been conducted quarterly since 2004 and provides extensive detail on contracts for foundry services, including key technological features, foundry location, price paid, and volume for a diverse set of foundry customers. The survey responses account for a representative sample of about 20 percent of the wafers processed by the foundry sector.

As shown in Table 1, we drop observations missing key variables. We also drop observations reporting prices for engineering runs, preliminary fabrication before volume production. To focus on substitution between onshore and offshore production, and between offshore locations, we retain only contracts for production at the major offshore locations (Taiwan, Singapore, and China), U.S. foundry contracts, and European contracts for comparison.[95] A small number of observations with internally inconsistent responses are dropped, as are the handful of observations on 100mm wafers–a very dated technology. All told, we use 5,464 observations for index construction.

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[93] GSA is a semiconductor trade association whose membership includes fabless producers and IDMs. Its survey is administered to members and nonmembers.
[94] Individual respondents are not identified in our data.
[95] Significant omissions from the global foundry industry are Japan and Korea. Our approach to estimating capacity, described below, does not allow us to assign reasonable weights on technologies in Korea. Our preliminary price index for Japan behaved erratically, and suggested that the product composition was changing in a way not captured by our data. We have obtained more detailed data extracts that may assist in alleviating this problem in subsequent versions.

Descriptive Price Results

Descriptive statistics for key variables in the resulting dataset are shown in Table 2. We observe 273 prices per quarter, on average. Wafer prices average $1,575 over the period covered. Interestingly, no substantial time trend is evident before adjusting for composition. The average contract was for 2,307 wafers, and the average contract size climbs over time. The number of layers per wafer also rose significantly over the period studied, from 23 in 2004 to 28 in 2008, reflecting a trend toward foundries handling increasingly complex products.

The changing technological characteristics of the fabrication process are evident in the statistics for wafer diameter and geometry. Pilot lines for 300 mm wafers were first introduced in 2000 and the share for this emerging technology rises from 3.5 percent of contracts to 20 percent of contracts over the survey. Similarly, new generations of lithography increase in penetration over time: 90 nanometer technology reached volume production in the overall semiconductor industry in 2004 and slowly gained share in the foundry market, ending at 7 percent in 2008; 65 nanometer contracts were just emerging in 2008.[96] Meanwhile, older technologies, with processes above 250 nanometers, dwindle in prominence from 45 percent in 2004 to 28 percent in 2008. 92 percent of contracts reported in the survey are for CMOS technology, but prices are available for other processes as well.

A challenge with the GSA pricing survey is sporadic reporting for some technologies in certain geographic regions, despite independent evidence that such production existed. For such cells where we believe there was production (based on our capacity database described in the next subsection) we linearly interpolate prices using values from surrounding periods or extrapolated based on higher-level prices.[97]

Quantities and the Shifting Geography of Production

To construct a price index, we need to weight individual price observations by quantity. Although the GSA survey includes information on the size of each order, some gaps in reporting remain. This makes weights based on the GSA data unstable at quarterly frequencies. As an alternative, we construct weights based on global foundry capacity. Although capacity is an imperfect proxy for actual production or purchases, we must choose between erratic sales measures and highly credible capacity estimates. Our baseline index uses the latter.

The Gartner *Semiconductor Fab Database* provided us with quarterly capacity data from 2004 to 2007. For specific fabs, key features are reported, including planned wafer start capacity, minimum line width, operating status, and whether the fab was operating as a foundry. We

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[96] 2004 and 2007 mark the years when volume production of DRAM began at 90nm and 65nm, respectively (*International Technology Roadmap for Semiconductors* 2007.

[97] Note that the alternative, dropping these periods for lack of directly observed prices, is not neutral, since it amounts to 1) assuming the product mix within the industry is different than we know it is, and 2) throwing out price information from this period for cells with similar technology or geography. See discussion of this approach in Gordon (2006).

extended these data with GSA's *2009 IC Foundry Almanac,* which provides a snapshot of capacity and technology by fab as of 2009.

Merging these datasets gives us a preliminary set of weights, but we address three remaining shortcomings. First, Gartner only reports planned capacity by fab and ramp-up status, leaving the contours of the ramp-up process unknown. Fortunately, many major foundries provide quarterly information on actual operational capacity, showing the actual path of capacity as equipment is added incrementally. We employ these directly reported capacities, when available, and add a comparable ramp-up period to fabs for companies without direct reporting.[98] Second, the data do not distinguish CMOS production quantitatively, though GSA does indicate whether a fab uses CMOS and other processes. Since CMOS prices behave rather differently than non-CMOS prices, we assigned a weighted average of the CMOS and non-CMOS prices to each fab for the technology in operation, using overall industry weights from the GSA. Third, in the Gartner fab database, we only observe the minimum line width in use at a fab, but we know that fabs often operate multiple geometries one time. This raises the possibility that we *overweight* leading edge technologies. On the other hand, it is important to bear in mind that we only observe capacity, not actual production. Since capacity utilization is higher for leading edge geometries, the application of capacity weights generates a bias in the opposite direction–toward *underweighting* these geometries.[99]

Table 3 compares two aggregate measures of foundry capacity, constructed as just described, to industry estimates from other sources. First, wafer fab capacity as reported to the SICAS survey suggests our wafer fab measure is not fully capturing the overall size of the sector. However, the growth rate from 2004 to 2008 for the measure constructed from our bottom-up approach is very close to the SICAS measure, suggesting we are catching the overall trend in industry capacity. Our measure of revenue is also somewhat lower than the measure of foundry company revenue published by the consultancy iSuppli. This may simply reflect that not all foundry revenues are for the services we are studying. Table 4 shows shifting revenue weights among the largest offshore foundry suppliers. While Taiwan's share falls somewhat, China and Singapore both gain revenue share, representing movement toward lower-cost foundry locations.

PRICE INDEX RESULTS

This section presents our price index calculations using the database just described. The level of detail in our data allows us to adjust for differences in physical product attributes. In addition, since our data also include foundry location, we are able to isolate the effect of shifting production across countries on the average wafer price. We find that substitution across countries may account for no more than a 0.8 percentage point per year decline in the average wafer price. Our findings also support the established importance of careful quality adjustment to capture the effects of rapid technological change on semiconductor prices.

[98] Ramping new capacity to volume production typically takes 12 months (Semiconductor Industry Association 2007).
[99] Utilization on fab lines using 90nm and smaller geometries was 94 percent in 2007, noticeably higher than the 86 percent utilization for larger geometries (SICAS 2008).

Fisher Matched Model Index

Our dataset includes price information by detailed semiconductor wafer type and source country at the quarterly frequency. As discussed in the "Semiconductor Production" section, a wafer's process technology (defined by wafer size, line width, and logic family) determines its performance, along with circuit design. Process technologies proceed in discrete steps, so our detailed data on prices by process technology yield a time series of price observations for each wafer type, with attributes held constant over time. This high level of detail allows us to construct a matched model price index tracking quarterly price changes for each wafer type.

The matched model index is calculated as a Fisher index of price relatives for each process technology and country pair. First we calculate Laspeyres and Paasche indexes, respectively, as

(1) $$P_L^t = \sum_i \sum_j s_{ij}^{t-1} \frac{p_{ij}^t}{p_{ij}^{t-1}}$$

(2) $$P_P^t = \left[\sum_i \sum_j s_{ij}^t \left(\frac{p_{ij}^t}{p_{ij}^{t-1}} \right)^{-1} \right]^{-1},$$

where *i* represents process technology, *j* represents source country, *t* is time (quarter), and *p* is the average price for a given process technology, country, and quarter in the GSA survey.[100] *s* is the share of total output value in time *t* accounted for by wafers in the relevant process technology and country cell, calculated using our capacity database. As the Laspeyres index overstates price changes and the Paasche understates them, it is advisable to construct the Fischer index, which is a geometric mean of the Laspeyres and Paasche indexes.

(3) $$P_F^t = \sqrt{P_L^t \cdot P_P^t}\ .$$

We normalize the index to 100 in the first quarter of 2004.

The procedure just described treats observations from different source countries as separate "models" by calculating separate price relatives by country. This parallels the treatment of prices across outlets in the U.S. CPI, and is subject to similar assumptions (Reinsdorf 1993). When a new process technology and country combination appears, it is assumed that any difference in the price *level* across countries for that process technology entirely reflects quality differences, where "quality" refers to any unmeasured attribute of the wafer or transaction that makes one production location more attractive than another. This is the "link-to-show-no-price-change" method in Triplett's (2006) classification of linking methods for matched model indexes. This linking strategy is based upon the assumption that the law-of-one-price holds for quality adjusted units across outlets. As we argue below, there is reason to believe that this

[100] Note that we use price per layer for the results presented here to account for the increased cost of producing more complex wafers containing more layers. As we expect, an index based on price per wafer falls somewhat more slowly, but the qualitative conclusions using price per wafer are the same as those presented here.

assumption does not hold in the semiconductor wafer fabrication industry, potentially leading the standard matched model index to understate the true rate of price decline.

As expected, entry and exit of products is a prominent feature of the data. As shown in Table 5, 27 cells are new entrants in the 2004–2008 period, and 23 cells are exits. This raises the challenge of estimating price changes for the first and last periods in the series for a large share of the data. However, because our data are high frequency (quarterly), the number of entrants or exits in any given quarter is small, at 2.5 on average. In addition, the weights on these periods are small as new technologies ramp up gradually.

Table 6 presents our price index calculations. Column (1) contains the Fisher matched model index just described. We present the quarterly index, yearly averages, and the average yearly change between 2004 and 2008. The index falls by 12.6 percent per year. As has been known since at least Flamm (1993), Grimm (1998), and more recently Aizcorbe (2002), quality adjustment of prices for semiconductors, and indeed for all high-tech products, is critical. In particular, bear in mind (see Table 2) that the average price change before adjusting for product composition was slightly positive. The substantial differences across countries points to the necessity of accurate weights by country.

Relaxing the Location as Quality Assumption

Our previous index maintained the assumption that price differences across countries for otherwise identical goods reflect unspecified differences in quality. We now make the opposite assumption: price differences reflect genuine price dispersion across goods of identical quality. Formally, this means that we calculate unit values by technology, averaging across observations from different countries. As a result, substitutions toward low-cost producers will be reflected in the average product price. These two assumptions bracket the truth, which likely lies in between.

We consider this alternative index because the location-as-quality assumption can lead to biased estimates of price changes under certain circumstances. Consider the convenient example of a situation in which two countries exhibit similar price trends for a given wafer type, but one has a consistently lower price level. Under the approach in the previous section, any shift toward the lower-cost country's foundries will have no effect on the aggregate price index, since the prices decline at the same rate in both countries. The linking procedure implicitly assumes that the savings accrued in shifting supplies are offset by lower quality of the goods being purchased. If, however, the goods are actually identical, then the shift to the lower-cost country represents a genuine price drop for the relevant customer. The standard matched model linking approach misses this price drop achieved in switching suppliers, and thus understates the true rate of price decline. This is the so-called "outlet substitution bias" discussed in the Boskin Commission report (Boskin et al. 1996).

To address this, we follow Reinsdorf (1993) and calculate an average price index across outlets.[101] This index is motivated by the opposite quality assumption of the index presented above. If models are very narrowly defined, one can assume that quality for a given model is

[101] Ideally, one would be able to directly observe particular buyers substituting between different outlets. Since our data do not include purchaser identifiers, directly observing substitution is not possible.

identical across outlets. In our context, this amounts to assuming that a given process technology is identical across foundries in different countries. If this assumption is correct, then there is no reason to distinguish price relatives by country. Instead, we calculate average prices across countries for each process technology.

(4) $$\overline{P_i^t} = \sum_j w_{ij}^t p_{ij}^t ,$$

where *w* is country *j*'s fraction of the total number units of process technology *i* produced at time *t*. We then generate price relatives of these average prices for each process technology and use them to generate a Fisher price index as described above. This approach is able to capture the effect of substitution toward low-cost countries as the weights on the lower prices increase with substitution.

If demand for wafers is shifting toward low-cost suppliers, and the matched model is missing this substitution effect, we expect to find that the average price index declines more quickly than the matched model index. The results are presented in Column (7) of Table 6. The index falls by 13.4 percent per year, which is 0.8 percentage points faster than the matched model index in Column (1). This result supports the notion that outlet substitution bias causes the standard measure to understate the price declines for wafer fabrication, suggesting an outlet substitution problem no bigger than 0.8 percentage points per year. Note, however, that the scale of quality change over time is much larger, as indicated by the sharp overall price declines.

This result should be interpreted with a number of caveats in mind. Both the law-of-one-price assumption and the alternative assumption of uniform quality across countries are extreme. The data likely reflect both quality differences across countries and some persistent quality-adjusted price differences. Thus, the two approaches bound the true quality-adjusted price change, and the difference between them is an upper bound on the effect of outlet substitution. This discussion raises the question of why quality-adjusted price differences should be able to occur in equilibrium. In the semiconductor fabrication market, a number of observations support the idea that quality-adjusted price differences can persist over time. There have been substantial shifts toward low-cost countries. This behavior suggests the presence of quality-adjusted discounts at the low-cost countries. Why might that be? Although Reinsdorf (1993) discusses the role of costly information gathering in generating real price dispersion, we think that this explanation is unlikely to hold in a market as concentrated as this one. Rather, we propose an alternative reason for price dispersion based on the particular characteristics of the wafer fabrication industry.

Very large fixed costs are incurred when getting a production line up to capacity with a given design. Discussions with engineers at a large U.S. fabless firm indicate that it takes a large number of sensitive calibrations to fabricate a particular design on a particular production line. This creates substantial start-up cost, such that semiconductor firms are very reluctant even to switch production lines within the same foundry, much less to move a product to a different foundry. This fact, coupled with the nature of new product introduction across countries leads us to a potential explanation for equilibrium price dispersion.

Consider the price plots presented in Figure 4. The top panel plots prices by country for a leading edge technology. Taiwan entered the market first, with a high price. Singapore and China each entered later, each at a lower price level. In spite of the increased competition from competitors entering the market, the Taiwanese price continued to decline at a steady rate, maintaining a roughly constant price differential relative to the others. A similar pattern for a more mature process technology is apparent in the bottom panel of Figure 4, in which a roughly constant price differential is maintained between the U.S. and Taiwan relative to Singapore and China.

To understand the implications of these observations, consider only Taiwanese and Chinese foundries for simplicity. If a given design requires the newest technology, it will have to be produced in Taiwan. In two years' time, when the Chinese foundry brings the same process technology on line, they charge a lower price in order to win market share away from their Taiwanese competitors. However, the lower wafer price in China does not outweigh the fixed cost of moving the existing products from Taiwan. The Taiwanese foundry can maintain a discretely higher price without losing its existing business, and only new products using the now year-old technology will go to the lower priced Chinese foundry. The Chinese foundry may adopt the new technology more slowly due to a relative lack of technical expertise or due to U.S. export license restraints on advanced semiconductor fabrication equipment going to China (*Electrical Engineering Times* 1998). In any case, the presence of large fixed costs of switching foundries coupled with staggered entry into a given technology makes persistent quality-adjusted price differences across countries possible.

Hedonic Price Index

To check the robustness of our results, we next generate a hedonic price index. Table 7 presents some information on the importance of the characteristics we observe. We regress log price per wafer on indicators for foundry location, technological characteristics, contract size, and quarter indicators using the 5,000 observations on contracts for CMOS technology.[102] All of these variables have a noticeable effect on prices and are estimated precisely. Collectively, they account for 88 percent of the variation in wafer prices.

The point estimates on foundry location and process technology appear to be reasonable. Controlling for technology, China has markedly lower prices than Taiwan, which serves as the baseline case in the regression. Singapore's prices are moderately lower than Taiwan's, while U.S. and European prices are substantially higher. Production using more advanced technologies clearly commands a higher price. Compared to the baseline case of production on 200 mm wafers with 180 nm geometry, production on larger (300 mm) wafers and production with narrower line widths is significantly more expensive. More overall layers per chip, and more metal layers in particular, both proxies for the complexity of the circuitry, also drive up the price. Finally, contracts involving a greater scale of production do appear to draw a volume discount;

[102] As mentioned above, non-CMOS technology is generally used in specialized niche markets. Although we do use non-CMOS prices when calculating industry price indexes, we omit them here for simplicity of exposition. Results for non-CMOS prices, not shown, indicate that location explains little of the variation in pricing, but technological characteristics do play a role.

other things equal, doubling contract size would be expected to reduce wafer costs by 5.5 percent.

Like the matched-model index, the hedonic index also falls rapidly, though the 11 percent average yearly rate of decline is 2 percentage points short of the rate for the matched model.[103] From this we conclude that our baseline results are fairly robust to choice of price index construction methodology. The hedonic specification also controls for characteristics not addressed in the matched model index, which suggest that contract size and the composition of layers contracted does affect pricing. The regression statistics indicate that these features explain over 80 percent of the variation in prices.

Official Indexes

For completeness, this section compares our results to the Bureau of Labor Statistics' (BLS) price series for imported semiconductors. The BLS' International Price Program (IPP) publishes a price index for Harmonized System code 8542, Electronic integrated circuits. These include microprocessors and memory, the final products of the semiconductor production chain.

IPP draws its sample from Customs lists at the more detailed 10-digit Harmonized System level.[104] For instance, until recently, IPP would draw a sample of establishments whose product(s) are recorded under the just phased-out HS classification 8542.21.80.05 for "unmounted chips, die, and wafers." Price indexes are calculated at this more disaggregated level and IPP then aggregates across the price relatives to produce the published index. Unfortunately, this more detailed data is sealed to outside researchers for confidentiality reasons.

Perhaps *the* measurement challenge for IPP is to control for quality improvements in ICs. We do this via a matched model price index that controls for several important performance-related characteristics of wafers. IPP does not necessarily observe as many characteristics of each IC, but it does have a potentially promising way to identify quality improvements. At least some respondents provide BLS staff with their own internal product code assigned to the surveyed item. It is likely that new, higher quality products would receive a new product code. If IPP observes that the product code attached to the surveyed item changes, it will follow up with the respondent to ask what the price of the new product would have been last month so that it can record the true price change for the quality-enhanced good. These follow-ups based on observed changes in firm product codes appear to be one of the principal ways by which IPP adjusts goods, at least in HS 8542, for quality improvements.[105]

The ICs observed by IPP are not directly comparable to the wafers studied in this paper. To see this more clearly, it is useful to recall that we can break up the production of ICs into four stages—design, wafer fabrication, test, and assembly. Our data pertain to the input produced in

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[103] Aizcorbe et al. (2003) find a similar result for microprocessors.
[104] This discussion draws on a number of conversations with Sonya Wahi-Miller of the IPP. We are very grateful for the time she spent educating us on the IPP's procedures. Any errors in our characterization of the IPP, however, are our own.
[105] Thus far, we have been unable to obtain information on how often this procedure is generally used in generating the HS 8542 index.

stage two whereas IPP measures the price of final output shipped at the conclusion of stage four. Nonetheless, it is instructive to ask how average price per wafer compares to the IPP estimate of the price of the finished product.

Table 6 Column (9) presents the IPP index by quarter over the period 2004-2008. Over this time period, the index falls on average 2.9 percent per year. Even though this is not directly comparable to our indexes, the discrepancy is quite large. It would imply that the prices in the remainder of the production chain (development, wafer test, and assembly) fall implausibly slowly. Consider, for instance, that recent research has found price declines that approach 40–50 percent per year for finished semiconductors sold in the United States (see, among others, Aizcorbe [2002, Table 1]). This work suggests that prices at other stages of the production chain, such as test and assembly, actually fall faster than the price of wafer fabrication, which contrasts starkly with the message sent by the IPP series. A critical task for future work is to dig deeper into the sources of these discrepancies. In particular, it seems worthwhile to investigate whether the IPP's follow-up procedure for product code changes does in fact effectively capture key quality improvements.

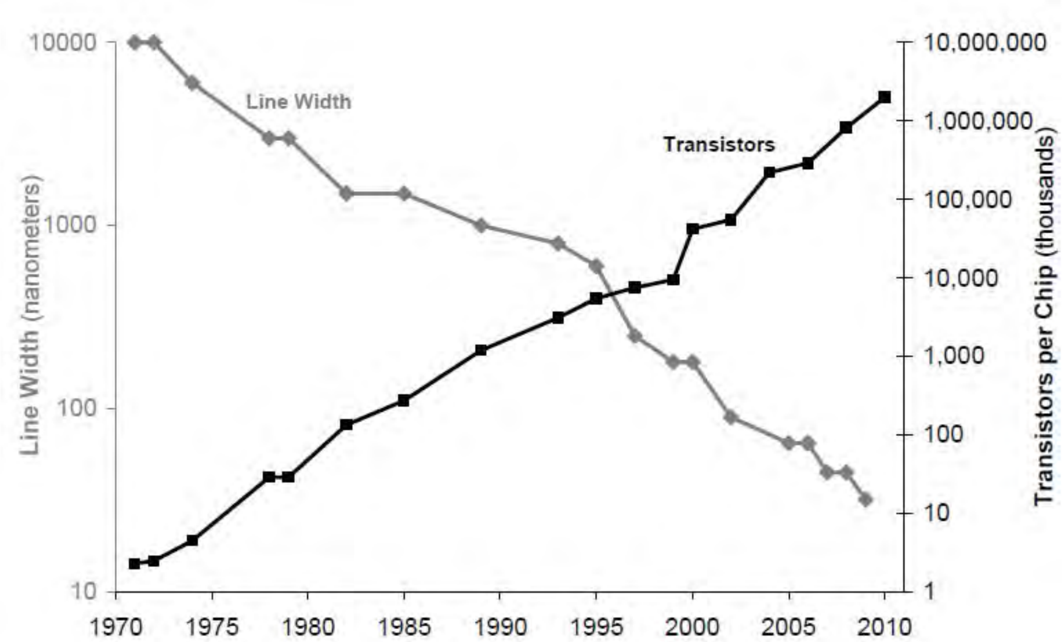
CONCLUSION

Our analysis exploits a rich new dataset to calculate constant quality price indexes for processed semiconductor wafers. We calculate a matched model price index, finding that wafer prices fall on average by 12.6 percent per year. Given that average prices, unadjusted for quality, remain fairly constant over the time period, the sharp yearly price decline demonstrates the importance of careful quality adjustment in this industry. Our results support the conclusion of numerous previous studies that official statistics substantially understate the rate of semiconductor price decline.

Since our dataset includes information on the source country for wafer purchases, we can also measure how geographic changes in sourcing patterns affect price measurement. Our approach is analogous to Reinsdorf's (1993) measurement of retail outlet substitution bias in the CPI. We calculate an average price index that captures the effects of shifting sourcing patterns toward wafer foundries in low-cost countries. Our results imply that the baseline matched model approach understates the yearly price decline by at most 0.8 percentage points.

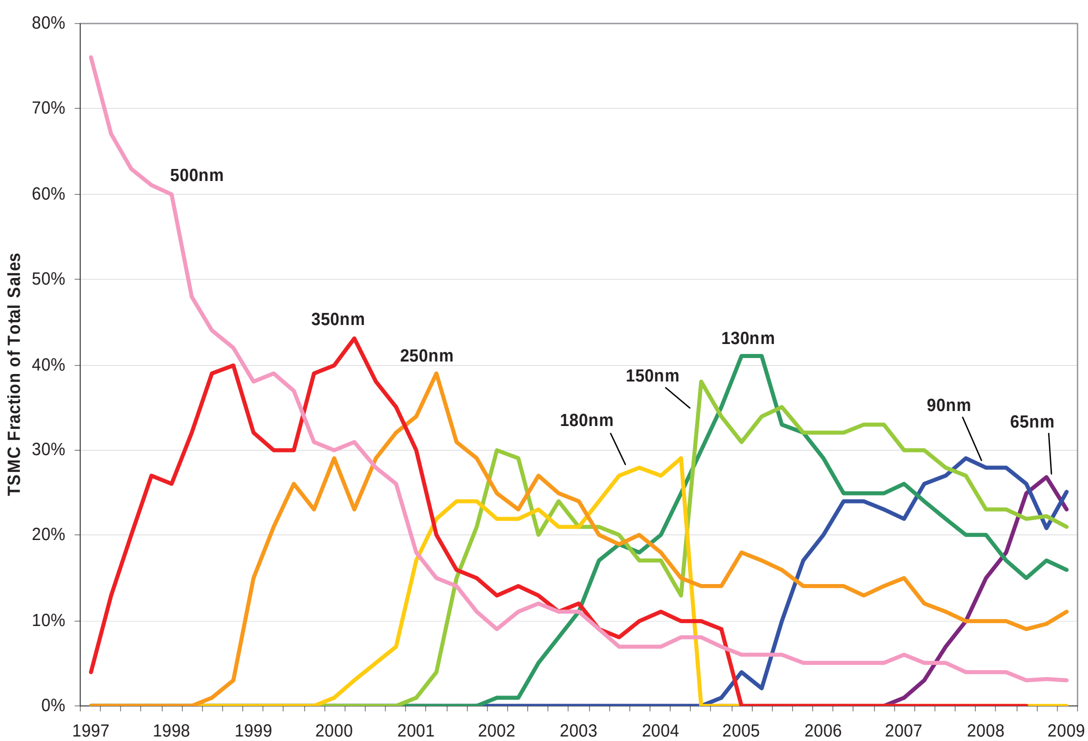
Although this problem is not overwhelming, particularly in comparison to the much larger issue of quality adjustment in the semiconductor industry, it is suggestive that continued shifts in international sourcing patterns will cause the problem to persist and potentially grow. Our findings here should motivate research into other industries that have seen large shifts in sourcing patterns across countries. Since there are large fixed costs of shifting suppliers in semiconductor production, the finding here may be smaller than the bias in more footloose industries that can substitute quickly in response to smaller price differences. Note however, that future analyses will need to motivate the assumption of persistent quality adjusted price differences across suppliers, as we do here.

Figure 1: Moore's Law – Intel Processors



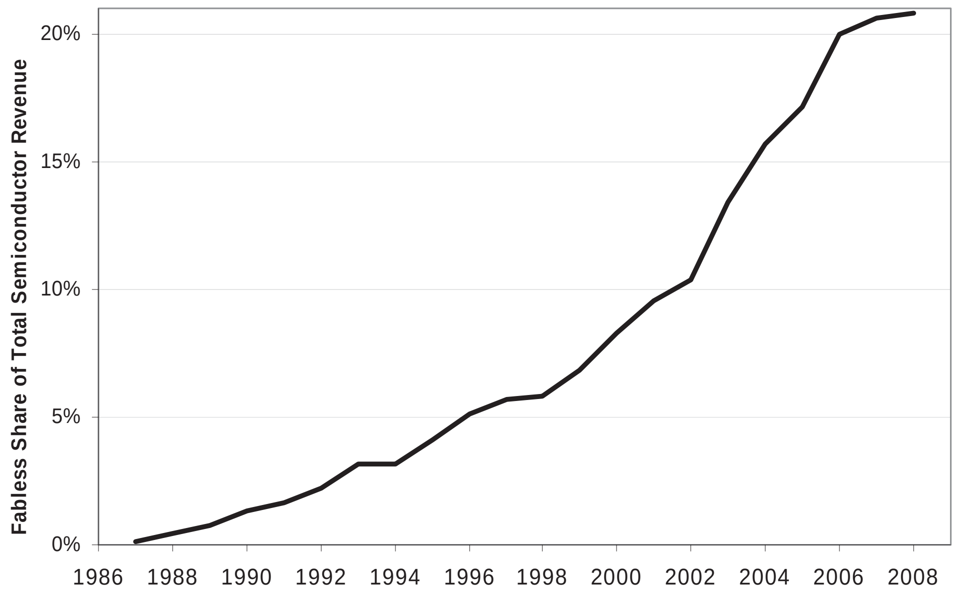
Sources: http://www.intel.com/technology/timeline.pdf
http://www.intel.com/pressroom/kits/quickreffam.htm

Figure 2: Technology Cycle – TSMC Sales by line width



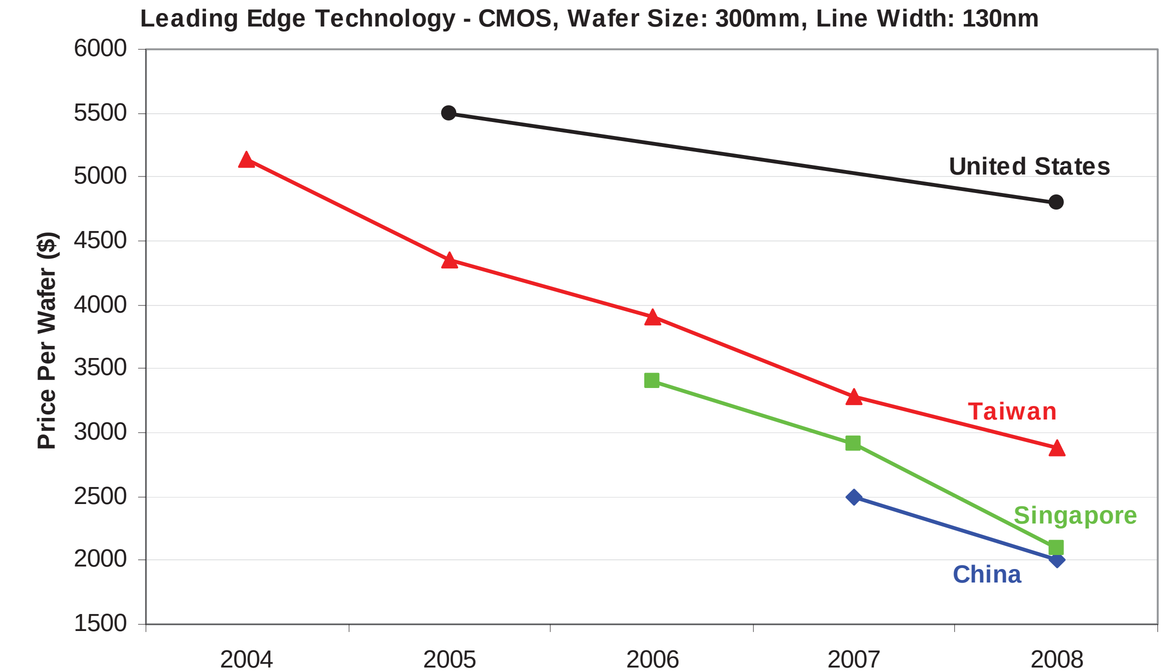
Source: TSMC quarterly reports

Figure 3: Growth of the Fabless Business Model



Sources: Global Semiconductor Association (GSA) and Semiconductor Industry Association (SIA)

Figure 4: Price Differences Across Locations



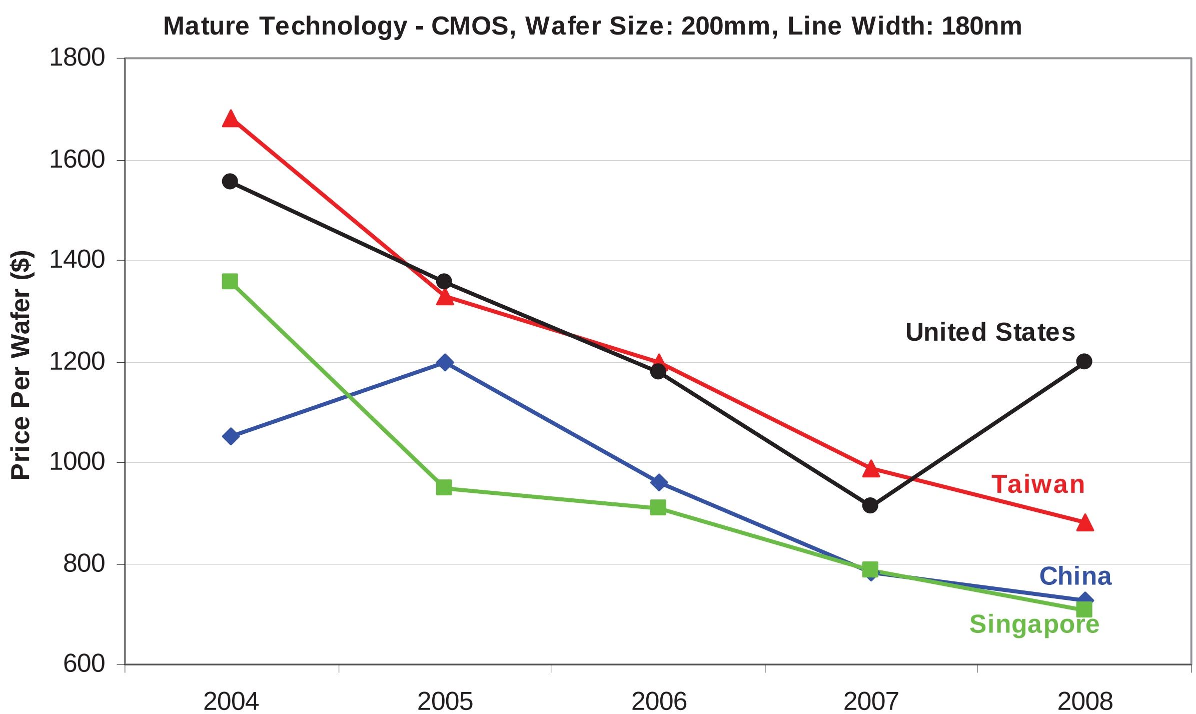


Table 1: Dropped Observations

Total observations	7455
Used in analysis	5464
Dropped	1991
Missing:	
foundry location	813
wafers purchased	19
price	19
Other reason:	
engineering run	778
location	499
100mm wafer	3
inconsistent	3

Note: there may be multiple reasons to drop a particular observation

Table 2: Descriptive Statistics

			Yearly Means				
	Mean	Std. Dev	2004	2005	2006	2007	2008
Price Per Wafer ($)	1575.40	1145.54	1,576.58	1,609.53	1,502.86	1,545.03	1,655.18
Number of Wafers Contracted	2307	7514	1924	2357	1941	2710	2627
Number of Layers Per Wafer	25.74	7.57	23.25	24.64	25.79	26.64	27.93
Metal Layers	4.77	1.81	4.23	4.55	4.75	4.97	5.27
Wafer Size							
150 mm or less	0.14	0.35	0.17	0.17	0.15	0.12	0.10
200 mm	0.76	0.42	0.80	0.77	0.79	0.76	0.70
300 mm	0.10	0.30	0.03	0.06	0.06	0.12	0.20
Line Width							
65 nm	0.00	0.06	0.00	0.00	0.00	0.00	0.01
90 nm	0.03	0.16	0.00	0.08	0.01	0.03	0.07
130 nm	0.23	0.42	0.14	0.18	0.22	0.27	0.32
180 nm	0.25	0.43	0.26	0.27	0.26	0.26	0.22
250 nm	0.13	0.34	0.13	0.16	0.12	0.12	0.09
older vintage	0.36	0.48	0.45	0.38	0.38	0.31	0.28
CMOS process	0.92	0.28	0.92	0.92	0.92	0.91	0.91

5464 Observations

Source: Authors' calculations based on GSA Wafer Fabrication & Back-End Pricing Survey

Table 3: Coverage of Constructed Capacity and Revenue

	Wafer Start Capacity (1,000 Wafers per Week)		Revenue (US $ Billion)	
	SICAS	Constructed	iSuppli	Constructed
2004	194	123	16.6	9.1
2005	252	139	16.3	9.0
2006	285	151	19.5	9.6
2007	288	172	19.7	9.8
2008	297	188	20.1	9.9

Source: SICAS, iSuppli, and author's calculations from sources described in text

Table 4: Foundry Revenue and Share for Major Offshore Locations

	Revenue ($million)	Taiwan	China	Singapore
2004	7232	66.0%	19.7%	14.3%
2005	8517	61.7%	20.4%	17.8%
2006	8549	62.0%	20.1%	17.9%
2007	8668	60.3%	21.6%	18.1%
2008	8432	59.8%	21.7%	18.5%

Note: Includes pure-play foundries only.

Source: Authors' calculations based on data from GSA, Gartner, and company reports

Table 5: Entry and Exit Statistics, CMOS Process

country technology cells with data	74
ave. no. quarterly prices per cell	10.18
new entrants	27
exits	23
cells with entry or exit	38
ave. quarters with missing prices	5.375

Table 6: Price Index Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Fisher Matched-Model Indexes						Average	Hedonic	BLS IPP
Quarter	Overall	Taiwan	China	Singapore	USA	Europe	Price Index	Index	HS 8542
2004Q1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2004Q2	101.5	101.7	99.9	102.7	97.5	108.5	100.7	99.5	98.3
2004Q3	99.6	103.2	90.1	101.7	97.2	94.6	98.4	97.7	97.1
2004Q4	93.5	95.1	84.3	102.1	95.5	89.1	89.5	91.3	95.9
2005Q1	91.3	86.9	100.5	101.5	93.0	89.5	87.7	87.4	95.5
2005Q2	83.5	76.9	95.2	94.1	95.2	85.1	79.1	87.3	95.1
2005Q3	81.7	79.5	85.5	88.7	80.0	86.8	79.5	83.8	93.9
2005Q4	82.0	79.2	90.6	85.8	79.3	92.1	77.8	82.7	93.5
2006Q1	76.4	73.6	83.5	82.0	69.4	87.2	72.8	78.4	94.0
2006Q2	74.4	71.6	77.8	84.2	70.8	82.0	70.4	74.1	93.8
2006Q3	72.4	69.4	78.0	80.8	66.4	82.0	68.7	73.6	94.6
2006Q4	69.6	65.9	78.6	76.4	64.1	82.1	66.3	71.0	95.3
2007Q1	70.3	67.1	77.7	75.7	65.6	87.6	66.9	69.2	93.3
2007Q2	67.9	63.3	77.4	77.1	59.1	90.0	64.8	67.6	88.8
2007Q3	62.8	58.7	67.2	74.8	56.0	88.4	59.7	65.3	90.0
2007Q4	59.6	55.5	65.3	70.1	52.2	84.1	56.5	64.5	90.3
2008Q1	60.4	55.7	66.3	71.7	58.2	83.7	57.3	65.0	88.5
2008Q2	57.1	51.9	63.9	68.2	57.1	83.3	54.3	61.9	87.5
2008Q3	58.2	52.5	68.2	65.0	69.2	85.3	55.3	59.6	85.8
2008Q4	54.2	49.2	63.1	59.7	63.4	82.9	51.4	59.7	85.6
Year									
2004	98.6	100.0	93.6	101.6	97.6	98.1	97.2	97.1	97.8
2005	84.6	80.6	93.0	92.5	86.9	88.4	81.0	85.3	94.5
2006	73.2	70.1	79.5	80.9	67.7	83.3	69.5	74.3	94.4
2007	65.2	61.2	71.9	74.5	58.2	87.5	62.0	66.6	90.6
2008	57.5	52.3	65.4	66.2	62.0	83.8	54.6	61.6	86.9
Avg. Yearly Change '04-'08	-12.6%	-14.9%	-8.6%	-10.2%	-10.7%	-3.9%	-13.4%	-10.8%	-2.9%

Table 7: Descriptive Wafer Price Regression Results

dependent variable: log of price per wafer

Variable	Coefficient	Std. Err.	t-Stat
Foundry Location			
China	-0.272	0.019	-14.59
United States	0.218	0.014	15.58
Europe	0.119	0.018	6.54
Singapore	-0.062	0.012	-5.30
Wafer Size			
150 mm	-0.344	0.015	-22.20
300 mm	0.645	0.014	47.68
Line Width			
≥ 1000 nm	-0.696	0.038	-18.24
800 nm	-0.353	0.027	-13.31
600 nm	-0.358	0.022	-16.12
450 nm	-0.355	0.019	-18.35
350 nm	-0.194	0.013	-14.59
250 nm	-0.092	0.012	-7.74
130 nm	0.306	0.012	26.31
90 nm	0.511	0.025	20.19
65 nm	0.737	0.050	14.63
layers per wafer	0.012	0.001	13.83
no. metal layers	0.057	0.004	14.30
log wafers contracted	-0.055	0.002	-32.92
constant	6.743	0.030	223.47
R-squared	0.8773		
Observations	5000		

Specification also includes quarterly indicator variables

non-CMOS production not included

Baseline case (omitted category) is Taiwan, 200mm, 180nm

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Globalization, Prices of IT Software & Services: Measurement Issues

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November 2009

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Conference on Measurement Issues Arising from the Growth of Globalization,

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Why Focus on IT Software & Services?

- A page from the IT hardware narrative
- Economically important
- Being globalized
- Have significant measurement issues
- Some puzzles

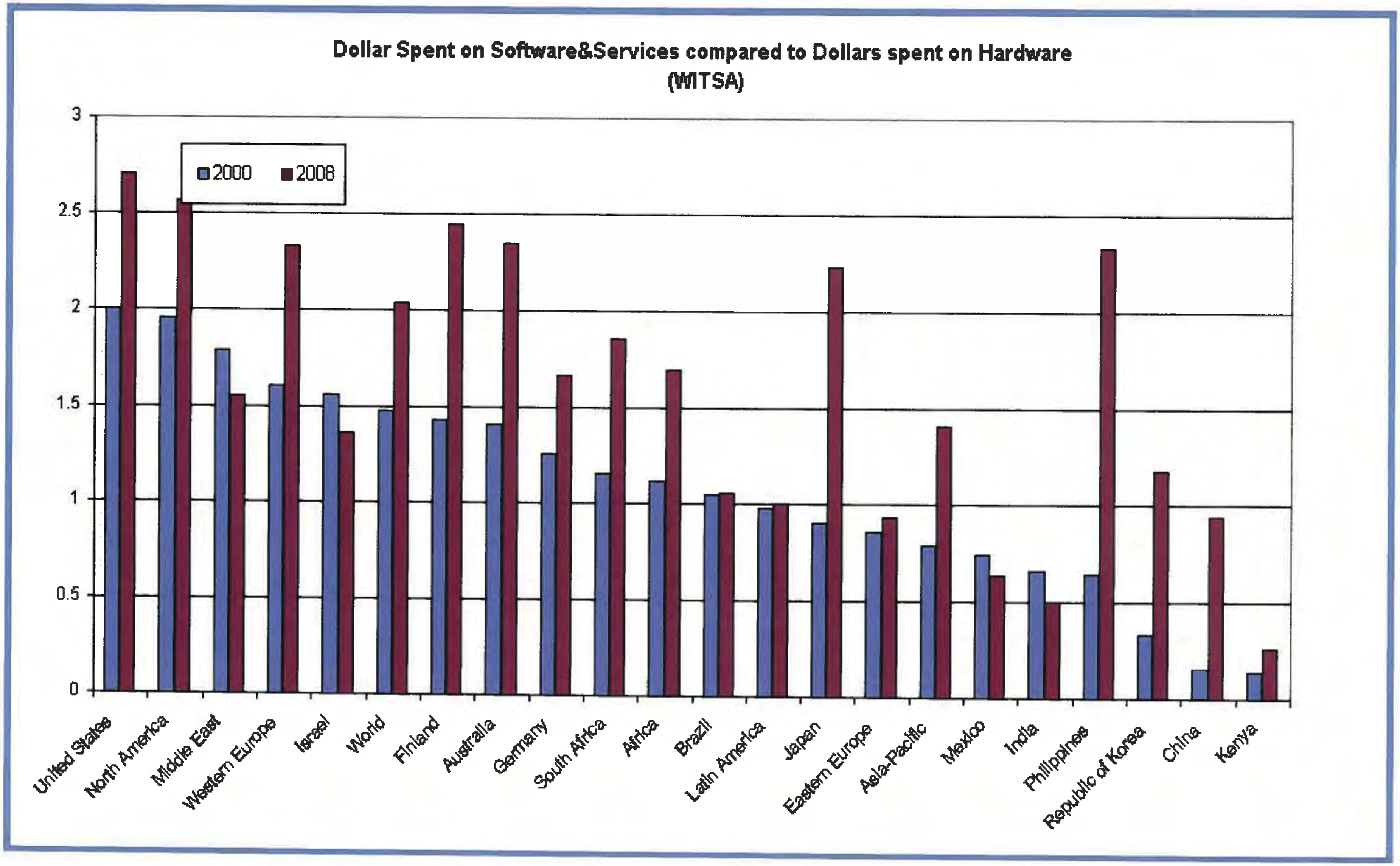
A Page From the IT Hardware Narrative

- US domestic production
  - high wage, high value added
- Technological change
  - Quality improvements… QA prices fall
- Globalization
  - Fragmentation of the global supply chain
  - QA prices fall more… or just transfer prices?
- Deeper integration throughout economy
  - Real trade and productivity implications

Vocabulary

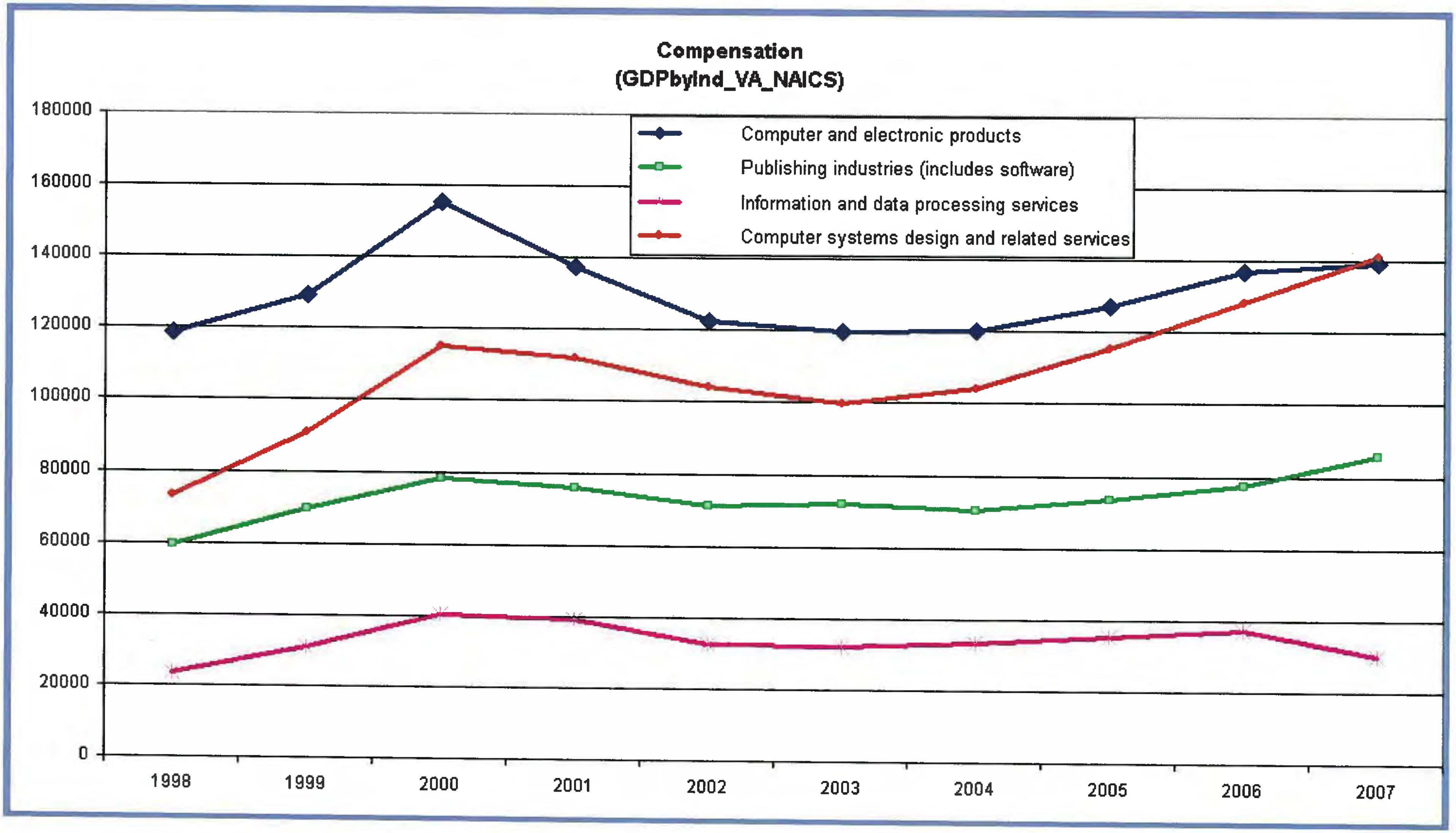
- Hardware
  - Computers, parts and peripherals
  - Semiconductors
- Software
  - General purpose, custom
  - Bundled (a particular problem)
  - Receipts and payments of IP (various ways treated)
- Services
  - CSD: computer systems design
  - IDP: Information data processing
  - CIS: Computer and information systems ~ IDP+CSD

Economically Important: Global



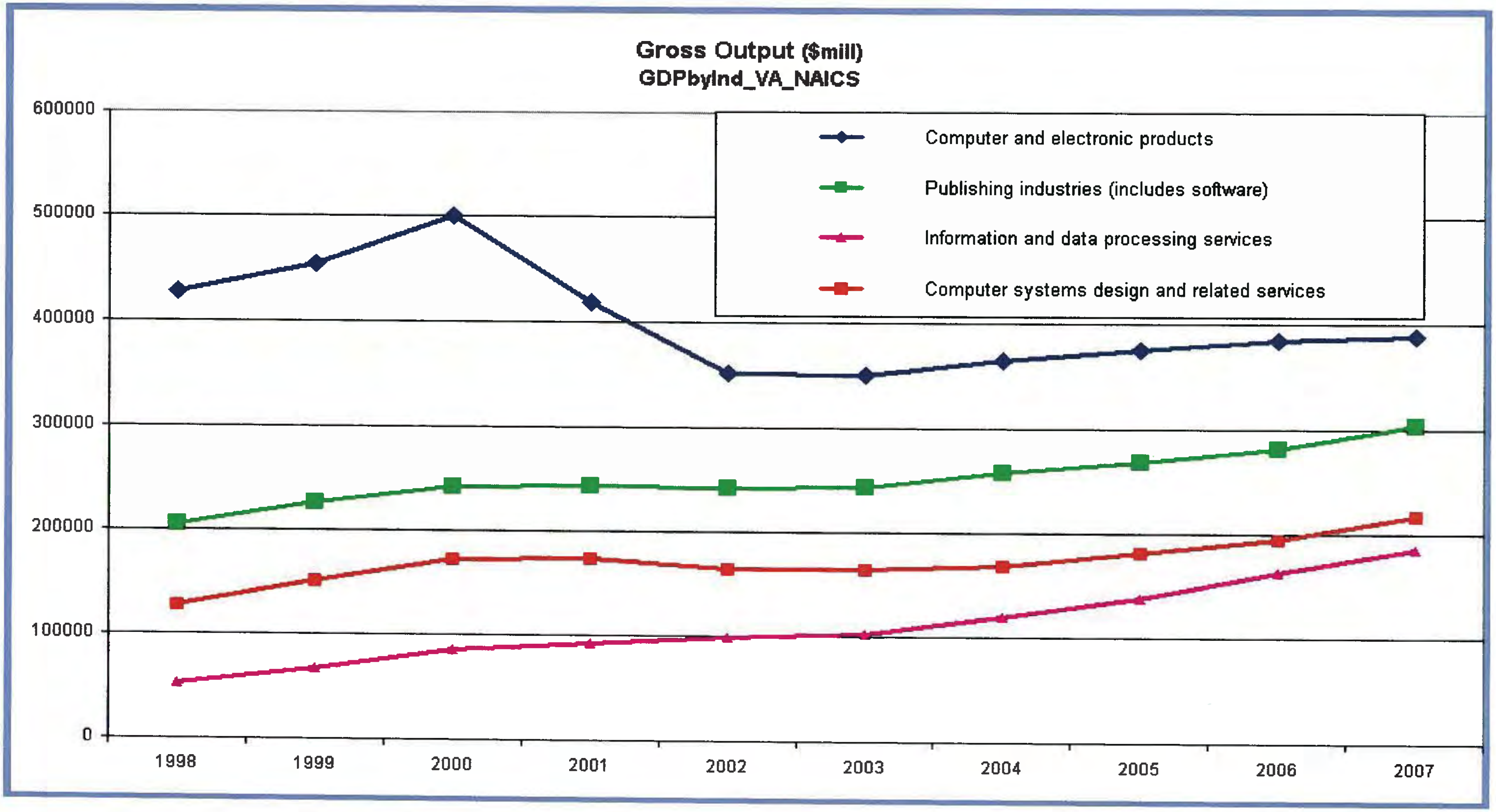
Increasing share of spending on IT products is on S&S, all countries, regardless of income level

Economically Important: US Compensation



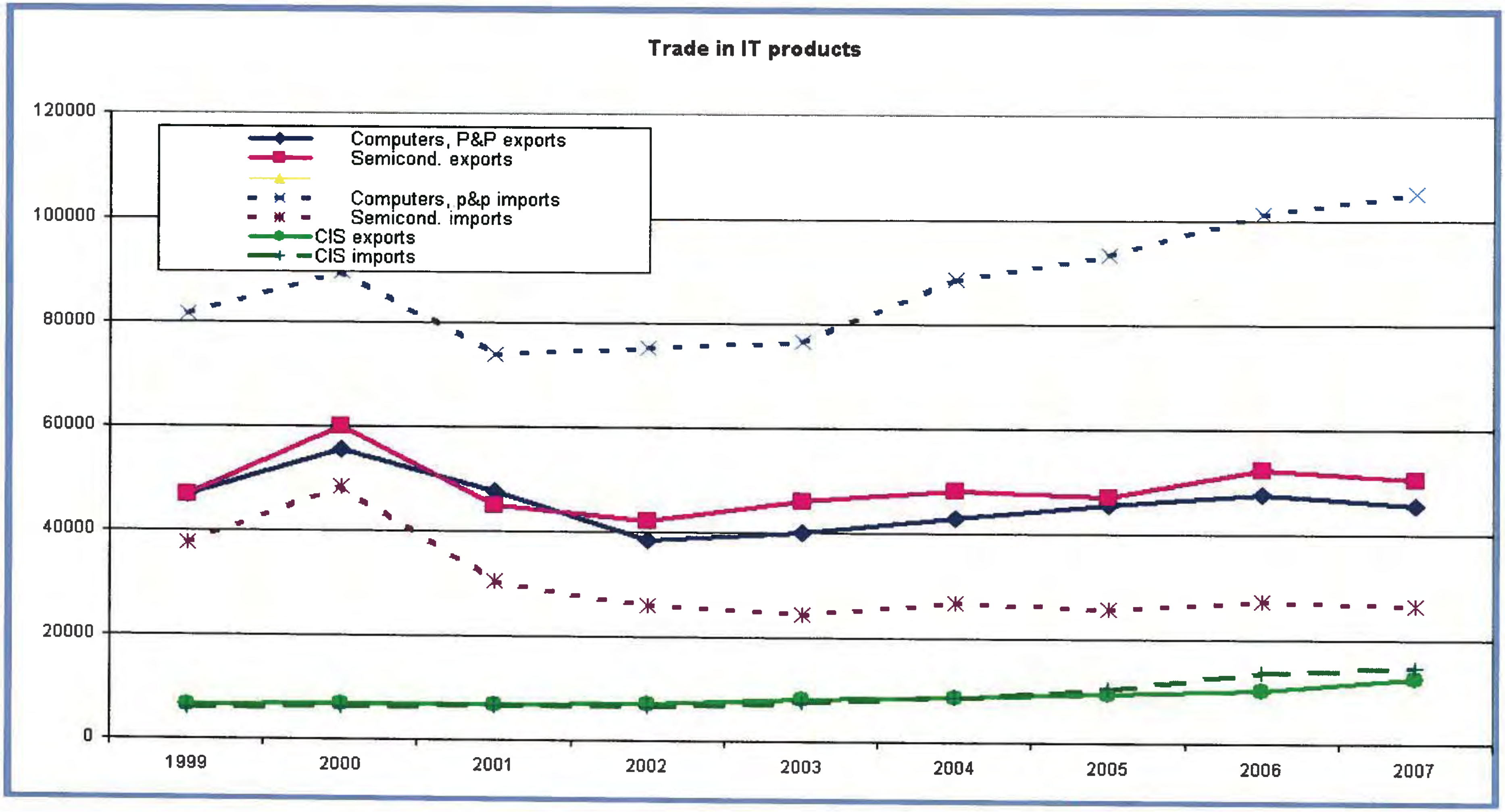
S&S compensation exceeds hardware, with CSD leading

Economically Important: US Gross Output



S&S gross output is growing; collectively is larger than hardware

Not So Economically Important: US Trade*



Gross flows of hardware components dwarf services flows(IDP and CSD)
Net trade semiconductors in surplus; computer P&P in deficit; CIS now in deficit
***software not broken out ....**

Economically Important: MNC sales

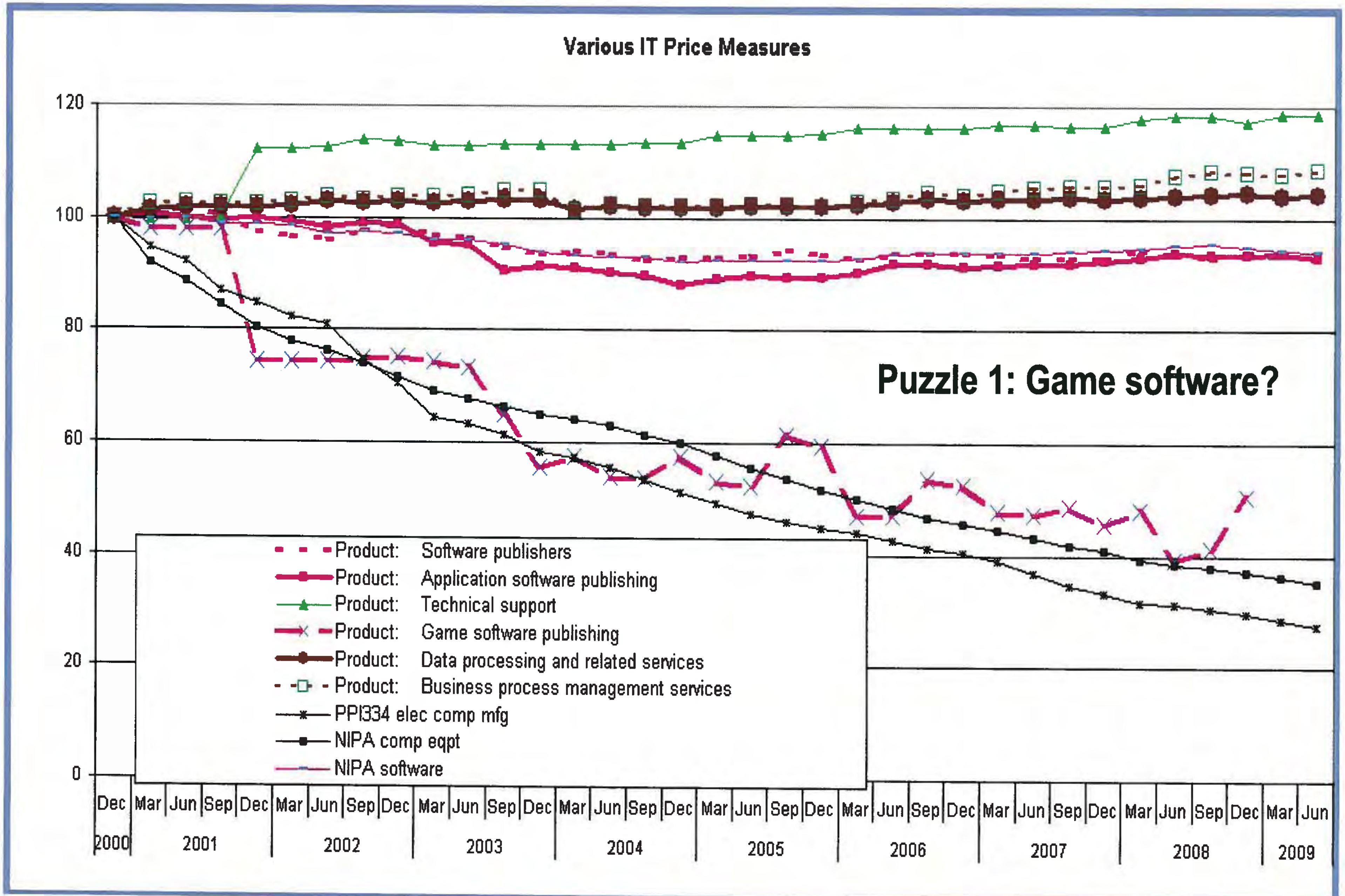
$ millon	1999	2000	2001	2002	2003	2004	2005	2006
Foreign MNCs to US persons								
Computers and electronic products	6392	8142	2746	7258	8446	3726	4884	6338
Software publishers	2200	2153	2215	2989	3726	4352	4383	3916
Internet service providers, web search portals, data processing services, internet publishing and broadcasting, and other	4022	5079			9132	8396		
Computer systems design and related services	4312	5021	6169	4998	10767	11347	12140	14847
US MNCs to Foreign persons								
Computers and electronic products	6855	4951	5239	5324	3745	4432		15671
Software publishers	7534	8086	9807	10624	12224	9879	12864	13679
Internet service providers, web search portals, data processing services, internet publishing and broadcasting, and other information services	14708		16866	18383			24636	29432
Computer systems design and related services						43914	52210	52102

Sales of S&S services through affiliates is economically meaningful
And larger than trade flows

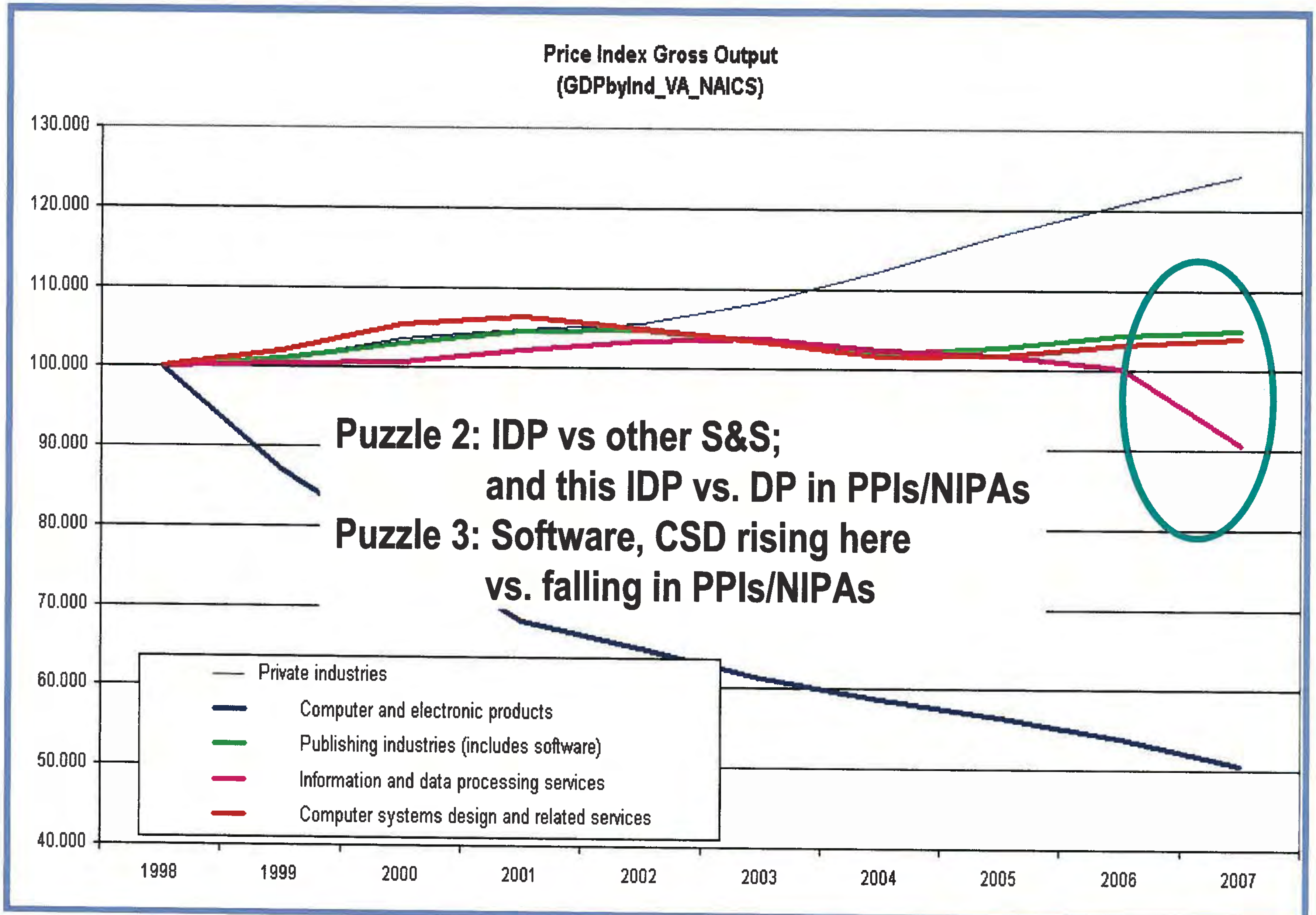
Derivation of Price Measures

- Hardware
  - Hedonic methods based on characteristics
- Software
  - Matched model
  - QA based on development cost of new features
- Services
  - functionality?

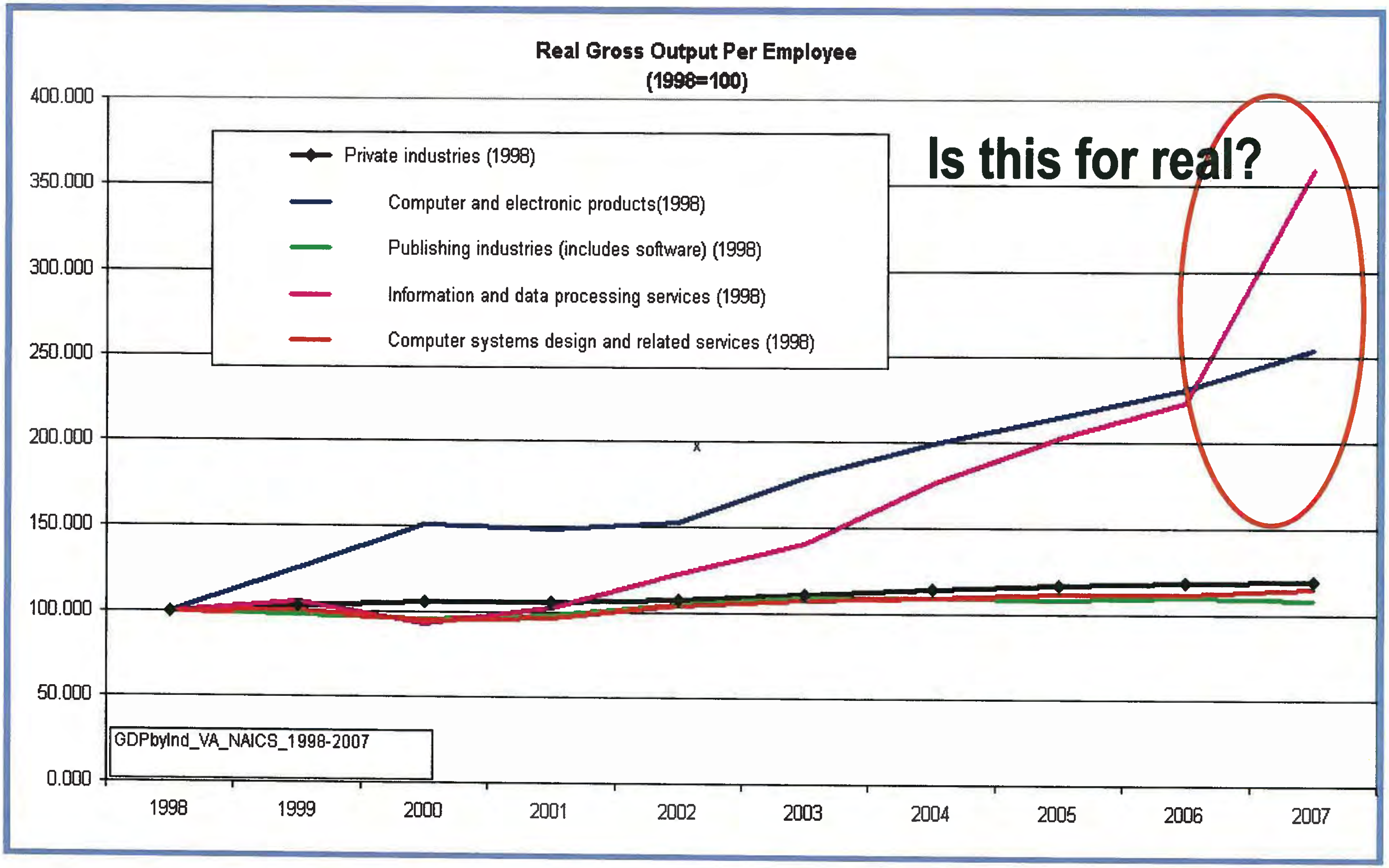
Comparative Price Dynamics: PPIs, NIPAs



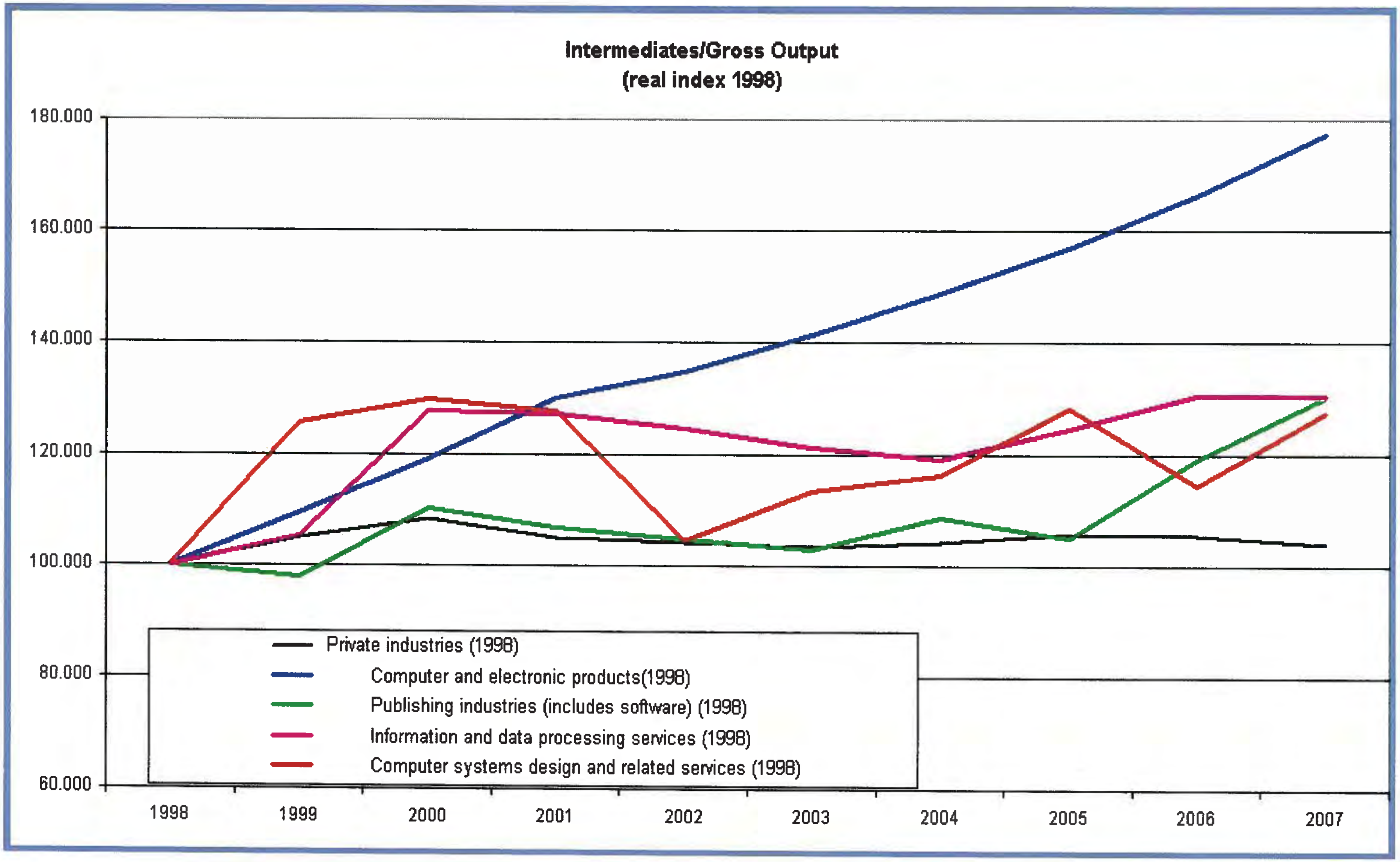
Comparative Price Dynamics: GDPbyInd



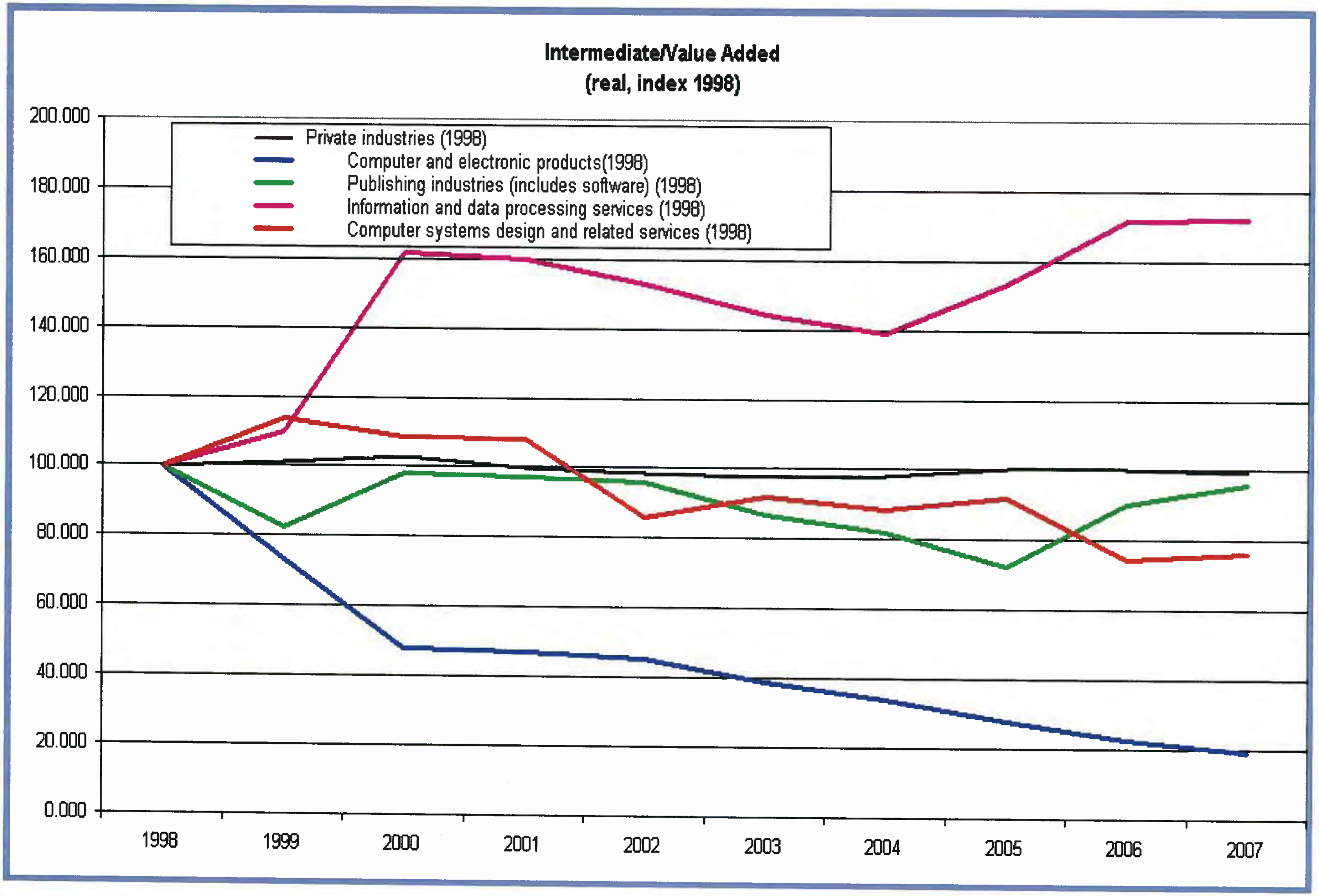
Productivity Implication of Price Metric



Puzzle Answers in Intermediates?



Puzzle Answers in Intermediates or Value Added?



Puzzle Answers in Share of IT in Intermediates?

2000	Computer and electronic product manufacturing	Publishing industries (includes software)	Information and data processing services	Computer systems design and related services
Computer and Peripheral Equipment Products	15713	1107	4821	2612
Semiconductor and Other Electronic Component Products	82271	3791	721	4614
Software Publishers	9934	5198	...	...
Information Services	460	2659	773	478
Data Processing Services	1849	805	1003	1095
Computer Systems Design and Related Services	5136	3173	1418	1635
Noncomparable imports	4923	1214	686	2177
share Noncomparable imports in intermediate inputs	**3.99**	**1.47**	**1.85**	**6.02**
share IT services in purchased services	**14.09**	**14.30**	**8.64**	**8.87**
share IT H&S&S in matls and purch servc	**36.96**	**13.46**	**8.32**	**16.81**

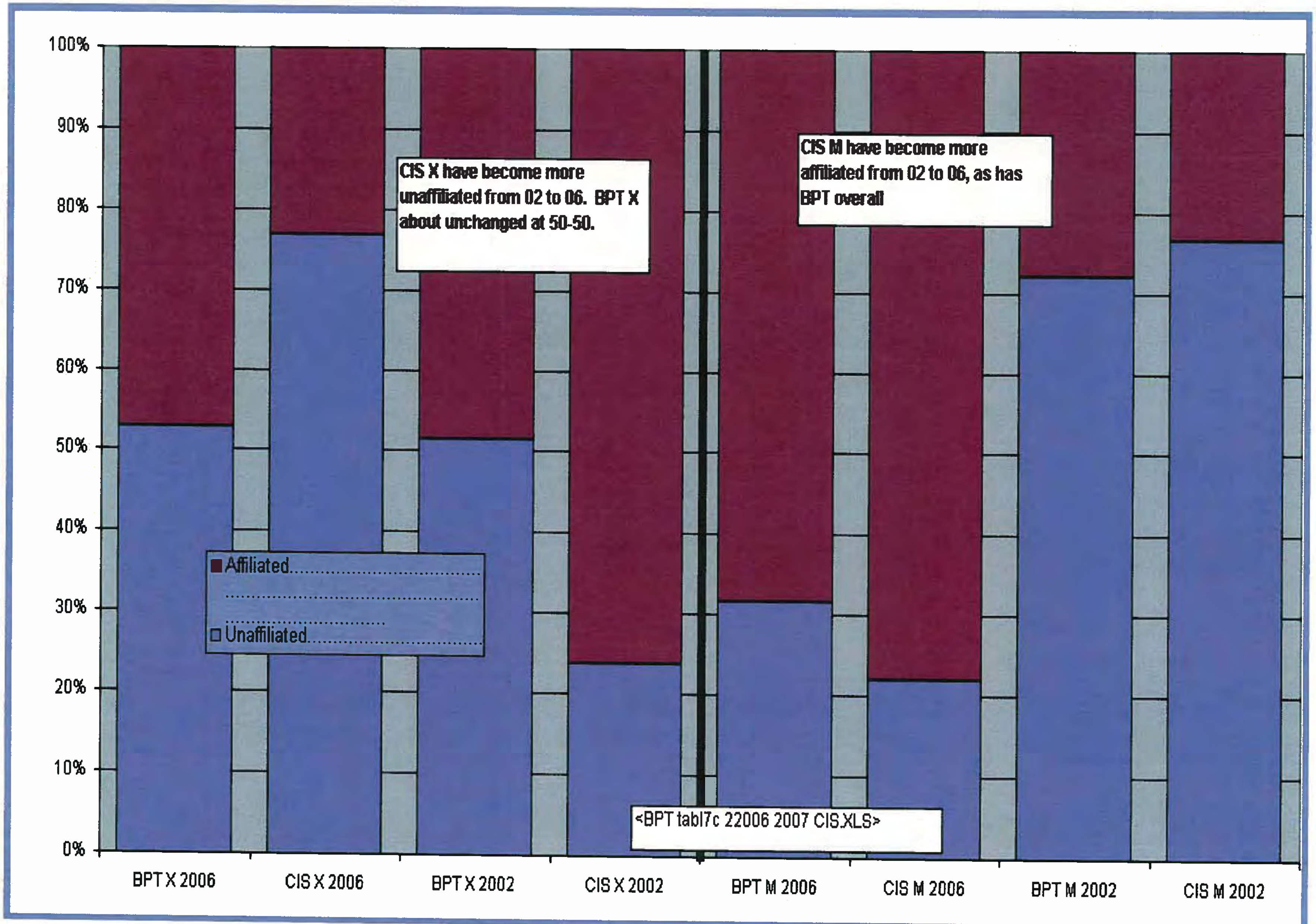
2006	Computer and electronic product manufacturing	Publishing industries (includes software)	Information and data processing services	Computer systems design and related services
Computer and Peripheral Equipment Products	12616	934	8133	2383
Semiconductor and Other Electronic Component Products	40736	2874	719	3984
Software Publishers	8377	7610	...	...
Information Services	521	3703	2150	721
Data Processing Services	1653	851	1776	1111
Computer Systems Design and Related Services	5435	4645	1673	1112
share Noncomparable imports in intermediate inputs	**9.40**	**2.40**	**1.66**	**8.41**
share IT services in purchased services	**23.20%**	**20.03%**	**9.45%**	**15.76%**
share IT H&S&S in matls and purch servc	**32.85%**	**17.46%**	**17.80%**	**25.29%**

<KLEMS_Intermediate_Use...>

Puzzle Answers in Imported Share of IT Incl. Non-comparable imports?

<ImportMatrices_Redefinitions_2002-2007.xls>	Computer and electronic products	Publishing industries (includes software)	Information and data processing services	Computer systems design and related services
2002				
share IT H and IT soft, IDP, CSD services in total imports	83.44%	62.74%	92.30%	85.84%
share of IT software + IDP + CSD in services imports	19.17%	60.49%	11.46%	5.62%
% non-comparable imports in total imports2002	18.75	38.80	14.12	58.83
2007				
share IT H + soft + IDP+ CSD services in total imports	76.89%	60.65%	90.05%	80.52%
share of IT soft CSD IDP in services imports	22.40%	54.22%	9.90%	5.16%
% non-comparable imports	25.95	45.03	10.65	96.79

Puzzle Answers in Affiliated Trade in IT Services?



Observations

- IT software and services economically important, globalizing, deeply integrated into economy.
- From hardware experience, we know that getting the prices 'right' is very important for real production, trade, and productivity
- Puzzles in IT soft&services prices, rapid globalization, limited ability to explain their movements, and continued data-matching problems means we have a lot of work to do

Imports of Intermediate Parts in the Auto Industry —A Case Study

Paper written for the "Measurement Issues Arising from the Growth of Globalization" conference, November 6–7, 2009, in Washington, D.C.

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Abstract

Intermediate parts contribute roughly 70 percent of the value added in production of motor vehicles. Carmakers like Ford and General Motors once made many of these parts in house, but now procure most of them from independent producers. Outsourcing of parts extends globally, with more than one-fourth of the parts in vehicles assembled in the United States imported from other countries. This paper describes the growing role of motor vehicle parts imports for U.S.-based light vehicle assembly. Imports of motor vehicle parts have increased to both substitute for U.S.-based parts production as well as to complement U.S.-based vehicle production of foreign producers. The paper assesses the effect of imports on production costs by distinguishing high- and low-cost source countries. This analysis is supplemented with anecdotal evidence on two key measurement issues: 1) the globalization of supply chains, as well as the relocation of production from a developed to a less-developed country; and 2) attendant changes in the structure of production costs.

The authors thank Cole Bolton, Taft Foster, and Justin Hess for excellent research assistance. Thanks to Susan Houseman and Richard Lilley for helpful comments.

MOTIVATION

The production of an automobile is complex, involving thousands of parts and hundreds of different companies.[106] As many of the intermediate parts cross international borders (some multiple times, especially between Michigan and Ontario along the U.S. Canadian border), automobile production is of interest from the vantage point of properly measuring the extent of offshoring as well as the price of attendant imported intermediate goods.

Intermediate parts contribute roughly 70 percent of the value added in production of motor vehicles. Carmakers like Ford and General Motors once made many of these parts in house, but now procure most of them from independent producers. Outsourcing of parts has also been globalized, with more than one-fourth of the parts in vehicles assembled in the United States imported from other countries. In the same vein, foreign-headquartered motor vehicle parts producers have established significant production operations in the United States.

This paper describes the growing role of motor vehicle parts imports for U.S.-based light vehicle assembly. Imports of motor vehicle parts have increased to both substitute for U.S.-based parts production as well as to complement U.S.-based vehicle production of foreign producers. The paper serves as a case study in the context of this conference by focusing on two key measurement issues: 1) the globalization of supply chains, as well as the relocation of production from a developed to a less-developed country; and 2) attendant changes in the structure of production costs. Both examples will be discussed in the context of Mexico as a production location for motor vehicle parts.

The paper is structured as follows. The following section summarizes the relevant literature. We then discuss the source for our data on the auto supplier industry. The next section presents the trends in imports of motor vehicle parts to the United States. We then focus on Mexico as a source for U.S. motor vehicle parts imports and present two examples illustrating in some detail the challenges for proper measurement of the imports of intermediate inputs in the auto industry: the shift of production for a specific product, aluminum wheels, from the United States to Mexico, and the globalization of the supply chain for an intermediate part, the seat.

LITERATURE

The auto industry is often highlighted as an example of a global manufacturing industry (see, for example, work at the International Motor Vehicle Program, as well as Sturgeon, Van Biesebroeck, and Gereffi [2007]). In North America, automobile and parts production has long been integrated across the U.S. and Canadian border (Weintraub and Sands 1998). Mexico became an important location for parts production starting in the late 1970s. Montout, Mucchielli, and Zignago (2007) suggest that the degree of intraindustry trade in the North American automobile industry increased at the beginning of the 1990s.

[106] In this paper the term automobile is used synonymously with "light vehicle," which is a term frequently used to summarize vehicles consumers tend to buy. Light vehicles are cars and light trucks, such as pick-ups, SUVs, and minivans.summarize vehicles consumers tend to buy. Light vehicles are cars and light trucks, such as pick-ups, SUVs, and minivans.

Most of the literature on the North American auto industry describes the evolution of especially Mexico as an important source of intermediate good production (see, for example, Gilmer and Canas [2008], Carillo and Contreras [2007], and earlier, Herzenberg [1991] and U.S. Congress, [1992]). In the last few years there have been a number of papers estimating the share of vertical and horizontal intraindustry trade in the auto industry (see Montout, Mucchielli, and Zignago [2007] and Ito and Umemoto [2004]). Regarding the focus of this conference, there is very little information on the relative production costs of auto parts, including comparisons between production in the United States and Mexico. The few published examples tend to be dated and apply to large and complex components, such as engines (see U.S. Congress [1992]).[107] Klier and Rubenstein (2008) provide a recent and comprehensive analysis of the trade flows in auto parts to and from the United States.

DATA

Detailed Harmonized Tariff System (HTS) code data are available from the U.S. International Trade Commission. That coding system was enabled by the 1988 Trade Act. It created the HTS system which authorized 8- and 10-digit codes for imports. This very detailed data source forms the basis for our analysis of changes in the nature and source of motor vehicle part imports to the United States. Many parts for motor vehicles are included in HTS code chapter 87, yet they are scattered throughout a number of other chapters as well.

To generate a comprehensive list of motor vehicle parts based on HTS codes, we painstakingly combed through all relevant HTS chapters. Our goal was to identify parts intended for use in the assembly of new light vehicles (so-called light vehicle OEM parts). Therefore we excluded parts for use in motorcycles, buses, or commercial trucks whenever possible. Despite the incredible detail available in the 10-digit HTS-code system, there is one major drawback to the data classification: trade data, just like census-based data on U.S. production, cannot identify where the parts will be used. Ideally we would like to focus in our analysis exclusively on parts that are intended for the assembly of new vehicles as opposed to “aftermarket” parts, which are parts that end up in the retail or wholesale channel (for example, for installation at a car repair shop). For large and complex parts, such as engines and transmissions, the HTS codes distinguish new from “remanufactured” parts. While that distinction does not substitute as an identification of OEM and aftermarket parts—e.g., a new engine can be purchased through a parts dealer—we excluded all remanufactured parts, as those are not intended for use in the assembly of a new vehicle. Our list of motor vehicle parts consists of just over 200 individual 8- and 10-digit HTS codes, representing 10 different 2-digit chapters.

We supplemented the trade data with a plant-level database that describes the geography of motor vehicle parts production by part in North America. The plant-level database covers 3,179 parts plants in the United States, 416 in Canada, and 673 in Mexico. It represents information

[107] The only exception we came across is a comparison of production costs of wiring harnesses for a U.S. and Mexico location (U.S. Congress 1992, p. 147). Assembly costs of wiring harnesses, a very labor-intensive product, in the United States around 1990 ranged from $12 to $23. Assembly cost in Mexico varied between $1 and $2; shipping and inventory added $7.50. All costs are expressed in U.S. dollars.

from late 2006 to early 2007 and is the basis for our book on the North American auto supplier industry.[108]

TRENDS IN MOTOR VEHICLE PARTS IMPORTS

Figure 1 shows that the value of imports of motor vehicle parts imports (as defined above) more than doubled between 1996 and 2008. Yet the volume of U.S. light vehicle production between 1996 and 2006 fluctuated in a rather narrow band, between 10 and 12 million units, before steadily declining to below 8 million units by the end of 2008. As a share of the material costs of light vehicle assembly (data available from the census of manufactures), imports have increased noticeably from 29 percent in 1997 to 36 percent in 2002.

Figure 2 breaks out data on U.S. imports of motor vehicle parts by countries of origin. It identifies the five largest countries in year 2008. The remainder is aggregated into the "rest of the world" category. There has been a fair amount of movement among the largest source countries during the last decade and a half. Canada and Mexico, the two NAFTA partners, have traditionally represented the origin for more than half of all U.S. imports of motor vehicle parts. In 1996 the two counties represented nearly 60 percent of all U.S. parts imports, with Canada firmly holding the lead. By 2008 Canada was essentially tied with Japan for rank three among import source countries, having lost more than 10 percentage points in almost a decade and a half. Mexico's share of U.S. motor vehicle parts imports held steady at just below 30 percent; by 2004 it had taken over as the largest source of imports from Canada. China represents the fastest growing origin of motor vehicle parts imports. It had eclipsed Germany for rank four by 2006 and represented 10 percent of U.S. imports in 2008.

Figure 3 breaks out all motor vehicle parts imports by high- and low-wage countries.[109] It demonstrates the steady growth of imports in motor vehicle parts from low-wage countries during the last decade and a half. Low-wage countries added about 25 percentage points of import share during that time. By 2007 the majority of all parts imports originated in low-wage countries. Stated differently, 69 percent of the growth in motor vehicle parts imports between 1996 and 2008 had originated in low-wage countries. Figure 4 identifies the three largest source countries for both high- and low-wage countries. Among high-wage countries, Canada's role has been shrinking, whereas China has been growing among low-wage countries.

FOCUS: MEXICO

We now look toward Mexico, the largest source of low-wage country imports of motor vehicle parts to the United States. After a brief recap of the history of the Mexican motor vehicle parts industry, we illustrate with two specific examples the growth in imports of motor vehicle parts: the shift of production from the United States to low-wage countries, and the complexity of the supply chain for intermediate parts.

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[108] See Klier and Rubenstein (2008, pp. 10–13) for a detailed description of the construction of the plant-level data.
[109] High-wage countries consist of Canada, Japan, and all of Western Europe.

Maquiladora Plants

The leading suppliers of motor vehicle parts from Mexico have been foreign-owned maquiladora plants.[110] Mexico's Border Industrialization Program, established in 1965, permitted foreign companies to import materials from the United States, assemble them in so-called maquiladora plants, and export them back to the United States without having to pay duty on the raw materials brought into Mexico, the equipment in the maquiladora plants, or the subassemblies shipped back to the United States.

U.S. auto parts makers started taking advantage of the maquiladora laws in the late 1970s. GM's Packard Electric Division, now part of Delphi, established Conductores y Componentes Electricos to make wire harnesses, a very labor-intensive part, in Ciudad Juarez in 1978. Electrical components dominated Mexican early maquiladora production, accounting for twice as many imports as all other systems combined into the 1990s.

GM's Inland Division, now also part of Delphi, arrived in Ciudad Juarez in 1978 to make seat covers and interior trim. Production of seat components expanded rapidly into the twenty-first century as the three large assemblers of complete seats, Lear, JCI, and Magna, relocated production of some individual components to Mexico and purchased more individual seat parts from Mexico-based lower-tier suppliers.

In terms of geography, maquiladora plants are strung out in Mexican cities along the U.S. border, especially (from east to west) in Matamoros (across the border from Brownsville, Texas), Reynosa (across from McAllen), Nuevo Laredo (across from Laredo), Ciudad Juarez (across from El Paso), and Tijuana (across from San Diego). The more easterly cities have attracted most of the auto parts maquiladoras because of their relative proximity to auto alley. Auto-related maquiladora production is also clustered in larger northern Mexican cities 100 miles or so south of the border, such as Nuevo Leon, Monterrey, Chihuahua, and Hermosillo.

According to the Mexico Maquila Information Center, 24 of the 100 largest maquiladoras in 2006 were motor vehicle parts suppliers. The three largest maquiladoras on the list were Delphi, Lear, and Yazaki, all motor vehicle parts producers. The 24 auto-related maquiladoras together employed 216,696 workers in Mexico in 2006, including 66,000 at Delphi, 34,000 at Lear, and 33,400 at Yazaki.

Figure 5 demonstrates the changing composition of motor vehicle parts imports from Mexico during the last decade and a half. The figure is based on HTS-code import data. We aggregated the individual parts into seven distinct subsystems, such as electrical and drivetrain (engine and transmission). The data illustrate the large share of electrical parts, even in 2008. To this day Mexico continues to be by far the largest source of automobile wiring harnesses imported into the United States (47 percent of all imported wiring harnesses came from Mexico in 2008, down slightly from 54 percent in 1996). Yet there is evidence that the composition of the types of auto parts produced in Mexico for U.S. consumption is changing. See, for example, Carillo and Contreras (2007), who point out that companies such as Delphi have upgraded their production operations in Mexico "from simple assembly to centralized coordination of functions including

[110] This section draws heavily on Klier and Rubenstein (2008, pp. 318–320).

sophisticated product design, development, and research (p. 2).” As part of that transformation Delphi transferred a technical center and its research, design, and product development functions from Anderson, Indiana, to Ciudad Juarez, Mexico, in 1995 (p. 4).

Shift of Production from the U.S. to Mexico: Aluminum Wheels

We chose the aluminum wheel as an example of a component for which most production has relocated during the past decade from the United States to low-wage countries. The wheel represents a rather well-defined stand-alone part. Its production is quite simple. About 70 percent of production costs are represented by alumina, the raw material, and the processing of it, such as casting, heat-treating, machining, and painting.[111] The aluminum wheel has its own 10-digit HTS code, although as noted already we are not able to distinguish between OEM and aftermarket imports. We were also able to obtain some detailed information about the cost structure of aluminum wheel production in the United States and Mexico from Richard M. Lilley of Lilley Associates, Inc., which publishes a biannual NAFTA Light Vehicle Road Wheel Survey.

Aluminum is the main material for the construction of wheels, representing roughly two-thirds of the OEM market for wheels in the world and in North America. Although more expensive than steel, aluminum has replaced steel during the past quarter-century as the metal of choice for casting wheels, because it is much lighter and can be more easily shaped into designs that carmakers prefer.

The mass-produced aluminum wheel is a commodity that is sourced by carmakers on the basis of price. Carmakers know to the fraction of a penny the cost of each component in the price of a wheel, especially standard wheels produced in high volumes. Profit margins on high-volume wheels are extremely small, according to Lilley Associates. Wheel suppliers make a profit primarily by producing low-volume niche and specialty wheels.

The two leading U.S.-based suppliers of wheels are Hayes-Lemmerz and Superior Industries. Hayes, a venerable supplier founded in 1908, filed for Chapter 11 in May 2009. Hayes has been shedding other parts units to focus on wheels. Once the dominant supplier of steel wheels, the company was slow getting into aluminum. Superior Industries, the other leading U.S.-headquartered producer, is the “upstart,” having been founded in 1973 in California. Superior specializes in the production of aluminum wheels. The company has about one-third of the U.S. market for aluminum wheels. Like Hayes, Superior has addressed the difficult economic climate by giving up production of parts other than wheels.

Superior produces aluminum wheels at two factories in the United States, both in Arkansas, and three in Mexico, all in Chihuahua. Between 2007 and 2009, the company closed three of its aluminum wheel plants in the United States, one each in California, Kansas, and Tennessee. As a result, two-thirds of Superior’s North American OEM wheel production is in Mexico and one-third in the United States, according to its 2008 annual report.

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[111] Once melted, the aluminum is fed to the wheel casting machines. After the aluminum has solidified, the blank casting is sent to trimming machines and to the heat treatment station. Each wheel is “baked” for several hours to give it the proper metallurgical structure and strength. Subsequently the wheel is sent to the machining stations for drilling. Afterward wheels are cleaned and painted.

All of Hayes' North American aluminum wheels are produced in Mexico. Hayes closed its only U.S. aluminum wheel factory in Gainesville, Georgia, in 2008. The company started wheel production in Mexico as the minority partner in a joint venture. It has since taken over full control over that operation.

Other North American producers of aluminum wheels include Alcoa Wheel Products, a division of Alcoa, which invented the forged aluminum wheel in 1948. It produces aluminum wheels in Cleveland, Ohio, and Lebanon, Virginia, but most of these wheels are destined for commercial vehicles and the aftermarket. The company closed an aluminum wheel plant in Beloit, Wisconsin, in 2008. Several Japanese-owned aluminum wheel suppliers have U.S. operations. Central Motor Wheels of America and Canadian Autoparts Toyota, both Toyota captives, produce aluminum wheels in Paris, Kentucky, and, Delta, British Columbia, respectively. These two companies are the principal supplier of aluminum wheels to Toyota's North American assembly operations.[112] AAP St. Mary's, a subsidiary of Hitachi, produces aluminum wheels in St. Mary's, Ohio, and primarily supplies Ford. Enkei America, located in Columbus, Indiana, mainly supplies Honda with aluminum wheels.

Figure 1 compares the costs of producing aluminum wheels in the United States and in Mexico. It is based on estimates provided by Lilley Associates for total production costs, as well as the share accounted for by various costs for a typical high-volume 17-inch wheel sold to the Detroit 3 carmakers.

The largest single cost of producing the wheels is the aluminum. According to *American Metal Market*, a 17-inch aluminum wheel contains roughly 20 pounds of aluminum. Lilley Associates suggests that aluminum accounts for around one-fourth of wheel production costs. According to *DataMonitor*, the principal supplier of alumina for the aluminum wheels is Alcoa, with 58.6 percent of the U.S. primary aluminum market in 2008.

[112] Canadian Autoparts Toyota only produces cast aluminum wheels; Central Motor Wheels makes both cast and steel wheels.

Table 1: Comparing aluminum wheel production costs between Mexico and the United States

	MEXICO		UNITED STATES	
	Percent	$	Percent	$
Materials	30		13	24
Processing[a]	41	18	52	28
Casting	16	7	20	11
Heat treatment	3	1	4	1
Machining	11	5	14	8
Painting	11	5	14	8
SG&A[b]	4	2	4	2
Profit	9	4	7	4
Other	16	7	13	7
Total	100	44	100	54

a All processing functions are assumed to be equally labor intensive.
b SG&A stands for selling as well as general and administrative expenses.

Source: Lilley and Associates

Alumina (also known as aluminum oxide) is sourced primarily within the United States for production of wheels in Mexico as well as in the United States. Alcoa's long-standing North American alumina facility is at Massena, New York. A plant at Rockdale, Texas, may also be a source of primary metal for the Chihuahua plants. Thus, a "Mexican" wheel is likely to include some U.S. content.

In our example, the $10 (or 22 percent) cost advantage to Mexico originates with the processing of the alumina, especially casting, machining, and painting as the processing operations are the most labor-intensive elements of the wheel production process. Yet Mexico no longer represents the largest source of aluminum wheel imports to the U.S.[113]

China accounts for an increasing share of global wheel production (as well as U.S. consumption), according to the trade data. According to Research in China (2008), total production of aluminum wheels in China has increased from 3.5 million in 2001 to 35 million in 2008. The 35 million figure includes an estimated 15–20 million for motorcycles, 1.5 million for the aftermarket, and 1.5 million in inventory, leaving 12–17 million for light and heavy motor vehicles. Per Richard Lilley, about half of the 12 million aluminum wheels imported by the United States from China in 2008 represent OEM wheels. In the same year, Mexico exported just under 4 million aluminum wheels to the U.S. Presumably most of these are OEM wheels.

We do not have authoritative information on production costs in China. While manufacturing wage rates in China are substantially lower than in Mexico, we don't have a basis for comparing productivity which would allow us to estimate processing costs in China. We assume them to be

[113] See Watkins (2006) on the challenges China represents to manufacturing in Mexico.

lower in China than in Mexico because of China's lower labor costs. China's aluminum wheels producers obtain materials from Chinese alumina sources.[114]

To reach the U.S. market, Chinese wheels incur additional shipping costs compared to production in Mexico. A standard 40-foot shipping container can hold around 1,000 17-inch wheels and costs around $1,100 to ship from China to the United States (Huber et al. 2009). Therefore the shipping cost from China amounts to just over $1 per wheel. While the additional shipping expense per wheel is likely much less than the labor cost savings on processing, production in China also triggers incremental inventory costs to make up for the greater distance to the customer.

Role of Imports in Assembly of Intermediate Part: Seat Assembly

This section demonstrates the complexity of supply chains in the motor vehicle industry and what this means for identifying the extent to which the import of intermediate goods is hidden. The seat provides a good example of the challenges in distinguishing between domestic and foreign sources for motor vehicle parts.

Seats are produced at two types of plants:

1) Plants that specialize in individual parts such as frames, cloth, and foam.
2) Seat assembly plants that assemble seat parts into finished seats ready for installation in vehicles.

Seat assembly plants are located extremely close to the carmakers' final assembly plants, normally within one hour. Seats are delivered to carmakers' final assembly plants on a just-in-time and in-sequence basis, minutes before they are actually installed in the vehicles. Suppliers assemble seats in response to specific orders from the carmakers; the seats are placed in delivery trucks in such a manner as to facilitate unloading in the sequence needed on the final assembly line.

A carmaker's final assembly plant typically obtains all of its seats from a single seat assembly plant, and a seat supplier in turn typically dedicates a single facility to producing seats for only one final assembly plant. Because carmakers have clustered their final assembly plants in auto alley, so have seat assemblers. Therefore, one might conclude that a seat is a good example of a domestically produced intermediate part.

However, a closer look at the supply chain reveals that many of the parts that go into making a seat are actually produced in other countries. A seat consists of several distinct pieces, including foam padding, leather or fabric, a metal frame, and controls for seat position and temperature. Most of the parts that go into seats involve straightforward labor-intensive tasks such as cutting and sewing. Plants producing seat parts do not have to be near seat assembly plants, and instead can locate in low-wage countries.

[114] GM struck a deal to obtain Chinese alumina a few years ago at a favorable price, but assigning a market price to Chinese alumina is not easy.

Trade data illustrate the challenge in identifying the extent of intermediate goods imports (Figure 6). The import of assembled seats is minimal, and is accounted for primarily by a Lear Corp. seat assembly plant in Windsor, Ontario, that delivers finished seats to a GM final assembly plant only 10 miles away, but on the other side of the Canada-U.S. border, in Hamtramck, Michigan. Other than Hamtramck, carmakers' final assembly plants in the United States receive finished seats from seat assembly plants also in the United States; therefore, the finished seat is considered a U.S.-made component.[115]

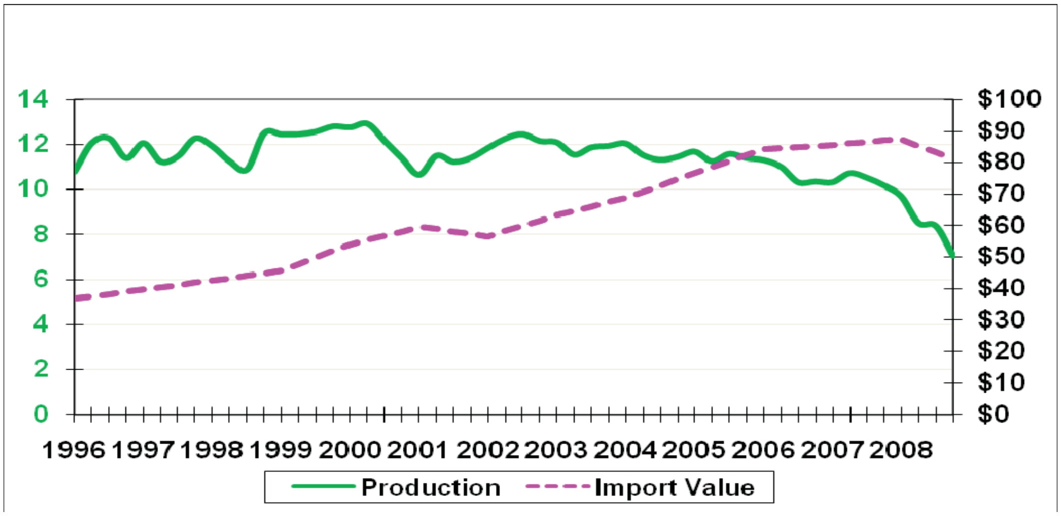
Meanwhile, between 1989 and 2007, import of seat parts increased from $621 million to nearly $5 billion. As U.S. motor vehicle production started to decline sharply toward the end of 2008, imports of seat parts fell to $4.1 billion in 2008. Imports of seat parts are destined for seat assembly plants. According to trade data, Mexico accounted for around $2.8 billion of the $4.1 billion imports of seat parts in 2008, and Canada nearly $667 million (Figure 7).[116] Thus, we can conclude that Mexico is a large producer of intermediate goods for U.S. seat assembly.
The example of seat assembly demonstrates that an intermediate good itself consists of intermediate goods, many of which can be imported. Such supply chain relations may not be currently reflected in the way import price indices are calculated.

SUMMARY

This paper tries to shed some light on the measurement issues related to growing globalization by illustrating the complexities of the supply chain of the automobile industry. The production of automobiles is a large and complex undertaking that involves nearly every manufacturing industry. Assembly of motor vehicles and production of parts represented 6.5 percent of all U.S. manufacturing jobs in 2008.
Imports of motor vehicle parts to the United States have been rising as supply chains increasingly extend across borders. Rising imports of vehicle parts both substitute for U.S.-based parts production and complement U.S.-based vehicle production of foreign producers. During the last 15 years the mix of source countries has changed considerably. In particular the share of imports of intermediate parts from low-wage countries has increased. This paper provides some background on these trends. The shift of production of aluminum wheels to Mexico as well as the sourcing of seat parts represent two specific examples discussed in more detail.

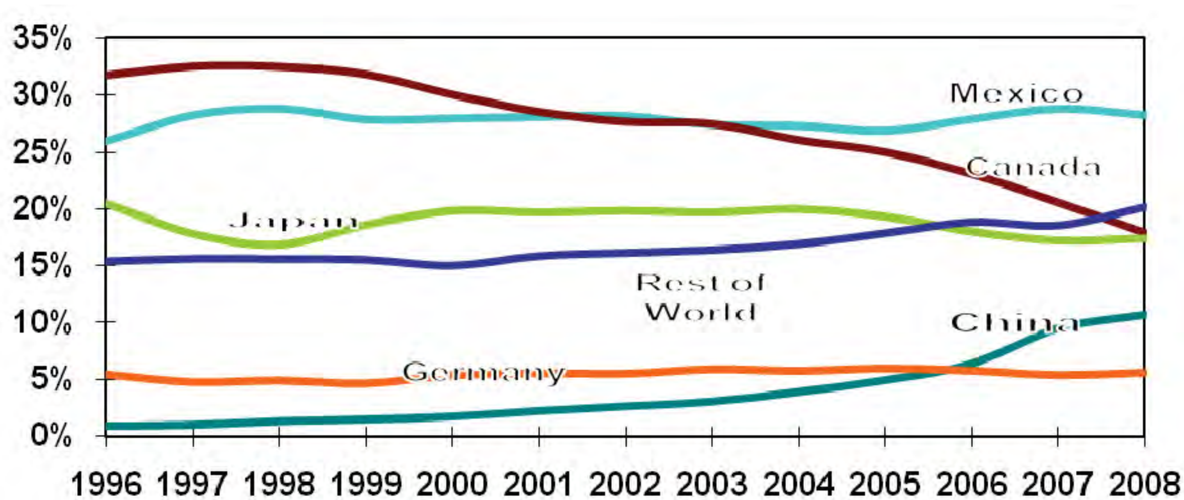
[115] Two companies dominate production of finished seats in the United States—Lear Corp. and Johnson Controls, Inc. (JCI). Each has roughly 40 percent of the North American market. Faurecia, Magna, and Trim Masters hold much of the remaining share.
[116] Mexico's share of seat part imports has averaged 70 percent since 2000.

Figure 1: U.S. Light vehicle production (million units) and motor vehicle parts imports ($ bn)



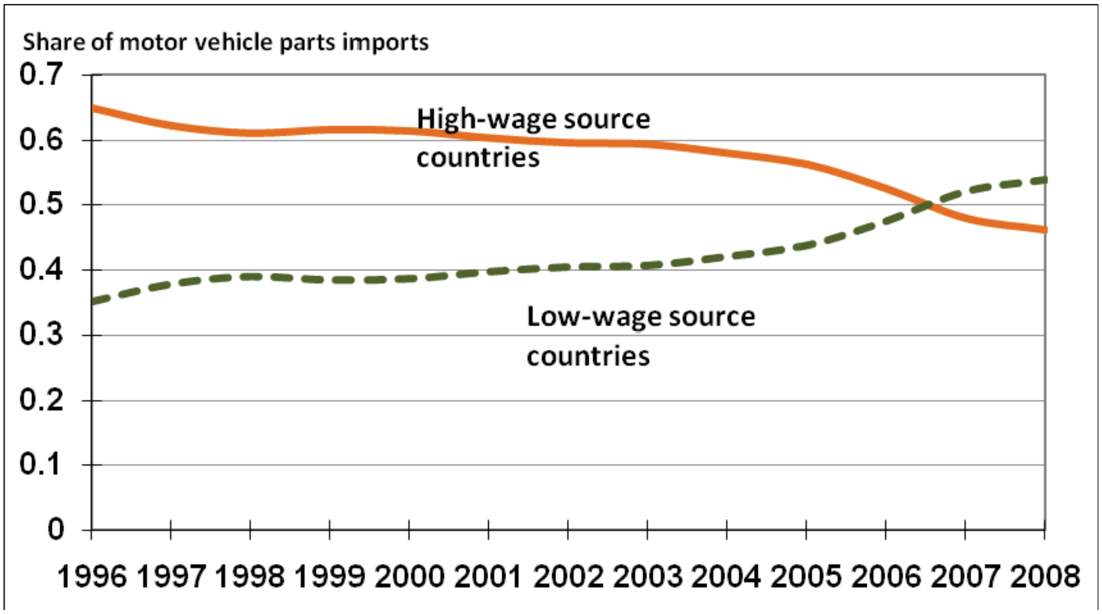
Source: USITC Dataweb, Federal Reserve Board via Haver Analytics
Note: trade data are of annual, light vehicle production data are of quarterly frequency.

Figure 2: U.S. motor vehicle parts imports by major source countries



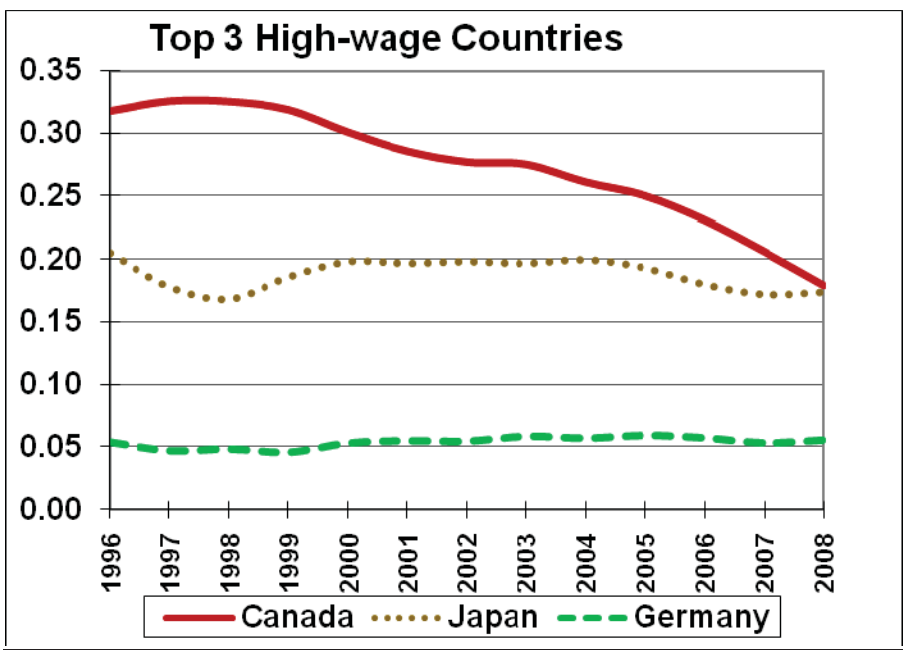
Source: USITC dataweb, author's calculations

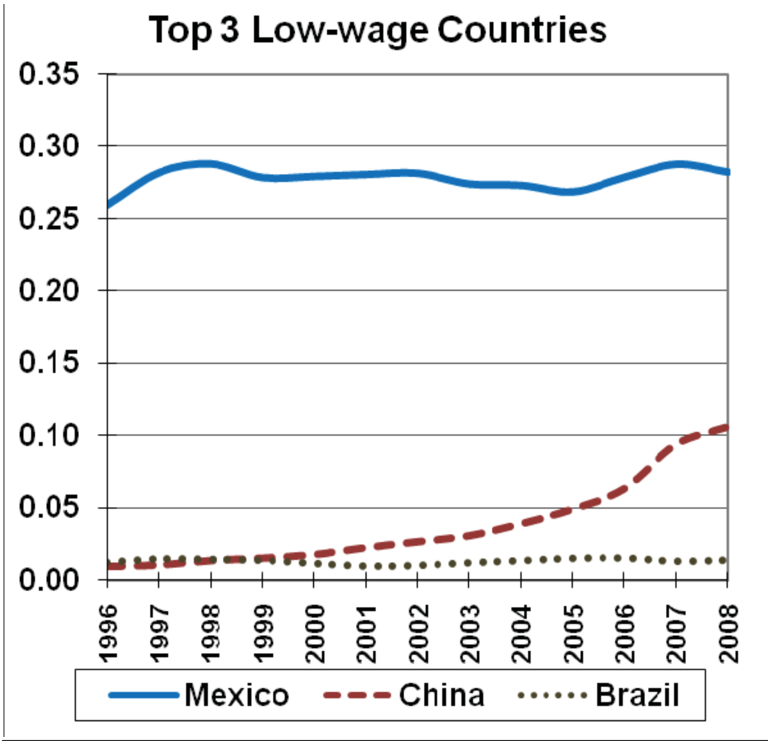
Figure 3: U.S. motor vehicle parts imports by high-wage and low-wage countries



Source: USITC dataweb, authors' calculations

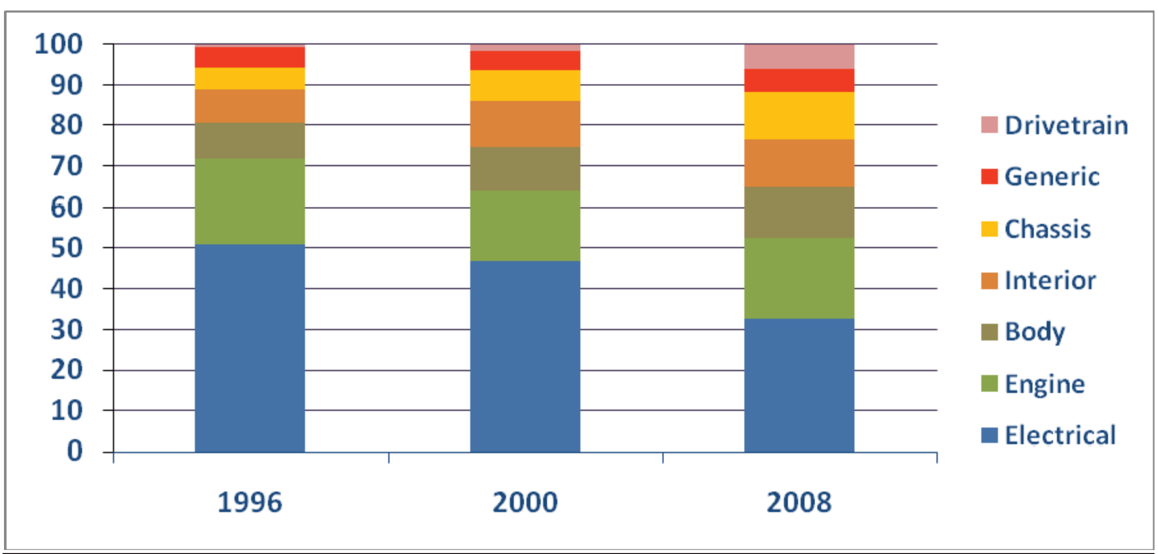
Figure 4: Largest high-wage and low-wage source countries for US auto parts imports





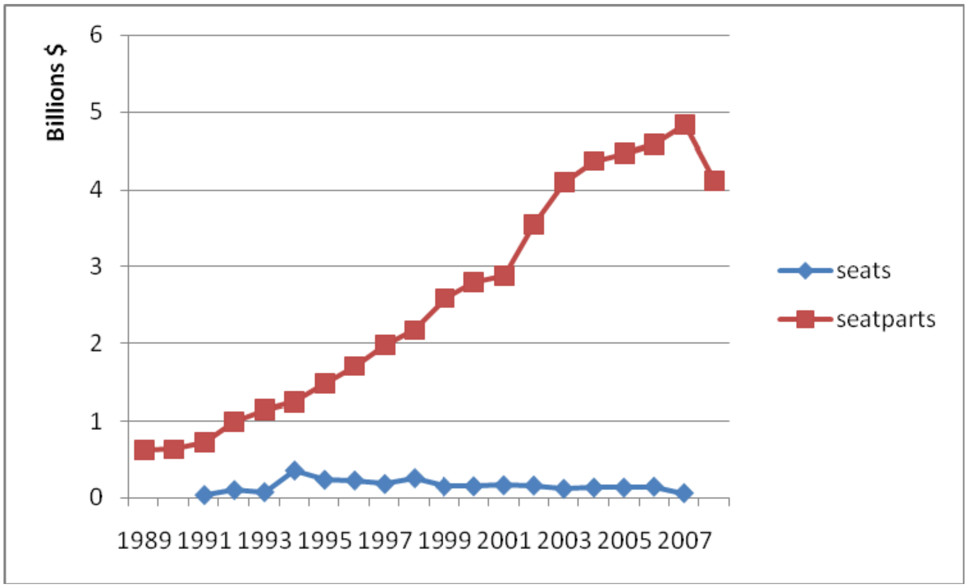
Source: USITC Dataweb and authors' calculations
Note: Shares are out of all imports

Figure 5: Motor vehicle part imports from Mexico by major subsystems



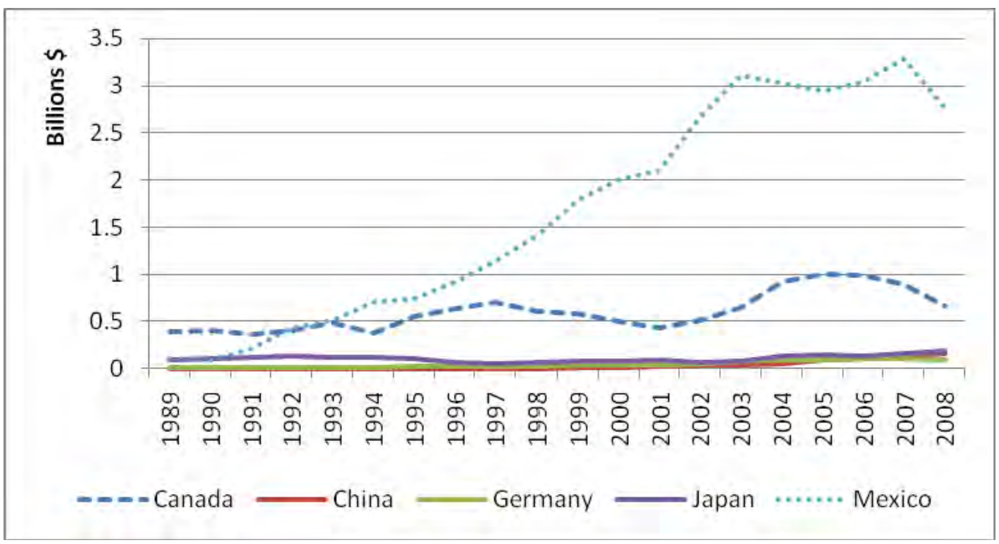
Source: USITC Dataweb and authors' calculations

Figure 6: U.S. Imports of automotive seats and seat parts



Source: USITC Dataweb, and authors' calculations

Figure 7: U.S. Imports of seatparts by largest source country



Source: USITC Dataweb and authors' calculations

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SESSION 5: MEASUREMENT OF IMPORT PRICES

CHAIR: Michael Horrigan (Bureau of Labor Statistics)

Bias Due to Input Source Substitutions: Can It Be Measured? Erwin Diewert (University of British Columbia) and Alice Nakamura (University of Alberta)

Are there Unmeasured Declines in Prices of Imported Final Consumption Goods?, Marshall Reinsdorf and Robert Yuskavage (Bureau of Economic Analysis)

DISCUSSANT: Barry Bosworth (Brookings Institution)

Bias Due to Input Source Substitutions: Can It Be Measured?

May 2, 2010

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Discussion Paper 10-07
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Abstract

Once a business opts to purchase rather than produce an input, it can also change the source from which the product is procured. Producer price index programs face problems in dealing with price changes associated with sourcing changes. We present measures for price index bias due to sourcing substitutions. We begin with highly simplified cases to convey the rationale for our approach, and then show how the measures could be generalized. We also explain related aspects of the industry accounts. This material makes it clear that the growth of outsourcing and the related increases in domestic and foreign sourcing substitutions pose important challenges for statistics agencies.

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[117] Department of Economics, University of British Columbia and the University of Alberta School of Business. This is a revised version of a paper presented at the Conference on "Measurement Issues Arising from the Growth of Globalization," sponsored by the W.E. Upjohn Institute and the National Academy of Public Administration and held in Washington, DC, November 6–7, 2009. The authors thank William Alterman, Robert Feenstra, Mike Horrigan, Susan Houseman, Emi Nakamura, and Jón Steinsson for helpful comments on various drafts, and the Social Sciences and Humanities Research Council of Canada (SSHRC) for partial funding. All errors and opinions are the sole responsibility of the authors.

Journal of Economic Literature Classification Numbers

C43, C67, C82, D24, D57, E31, F1

Keywords

Offshoring, outsourcing, consumer price indexes, producer price indexes, intermediate input price indexes, bias in price indexes, Fisher index, total factor productivity growth, production accounts, System of National Accounts, exports and imports in the input-output accounts.

Producers utilize and make many thousands of products in a year. Index numbers help reduce and summarize this abundance of microeconomic information. Hence, index numbers intrude themselves on virtually every aspect of empirical research about firms and the business sector.

The price index programs of the U.S. Bureau of Labor Statistics (BLS) were put in place back when firms produced on an in-house basis more of the intermediate goods and services required as inputs. When a firm switches from producing to procuring an input, this is called *outsourcing*. Of course, once a firm has found one external source for an intermediate input, it could switch to another source. Thus, *sourcing substitutions* should rise in the wake of increased outsourcing. Unfortunately though, the main producer side measures of inflation, which feed into productivity and other national economic performance measures, miss much of the price change associated with sourcing substitutions, and this can cause sourcing substitution bias in the producer price indexes. This has become an important problem because finding cheaper input sources is a prevalent modern day business strategy for lowering production costs.

Intermediate input price competition is also believed to play a key role in the survival and growth of new firms. Foster, Haltiwanger, and Syverson (2008) make this point in an important empirical study. For firms that produce physically homogenous products, they are able to evaluate and compare a measure of physical productivity with the more conventional productivity measure computed using revenue, cost, and price index information. Foster, Haltiwanger, and Syverson find a strong inverse correlation between physical productivity and prices that is consistent with newer entrants having lower marginal costs, and with this allowing those businesses to charge lower prices.[118] More generally, they and others document examples of physically identical producer inputs being available from different sources for different prices at the same point in time.[119]

The derivations of our bias formulas in the main body of the paper are easy to understand because they are for a highly simplified economy. In an appendix, we show that these formulas can be extended to a more realistic case. Fortunately, the same main parameters emerge as the determinants of the bias size, though the derivations are more involved.[120]

We also explain how price index bias problems undermine the validity of the industry accounts produced by the U.S. Bureau of Economic Analysis (BEA): accounts that support national productivity measurement and economic policy analysis. We explain how these bias problems are obscured by and impede efforts to understand the workings of the economy.

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[118] In another recent AER paper, Bergin, Feenstra, and Hanson (forthcoming) develop a model in which the timing of when firms begin to offshore a variable-cost activity to foreign firms is endogenously determined in response to economic conditions, including unit cost price differences for input factors.

[119] For example, Byrne, Kovak, and Michaels (2009) report that shifts in the location of production to lower-cost countries can deliver cost declines of up to 0.8 percent per year. Also, Klier and Rubenstein (2009) report that "The mass-produced aluminum wheel is a commodity that is sourced by carmakers on the basis of price." Of course, firms sometimes purposely buy inputs from sources charging premium prices because of perceived benefits offered by the higher priced suppliers. In a later section in the paper, "Recommended Data Gap Fixes," a potential procedural solution is proposed for dealing with quality differences that might be associated with price changes that occur together with sourcing substitutions.

[120] Houseman et al. (2009) demonstrate the value of this formulation for empirical studies.

SETTING THE STAGE

We begin by considering an economy with just enough in it so that we can show how input source substitution bias arises and can be measured. We consider an economy with four firms, one truly homogeneous product, and no taxes or transport costs. To explore the importance of certain price index compilation protocols, we take a case where firms 1 and 2 are suppliers and firms 3 and 4 are purchasers of the homogeneous product, and where firms 1 and 3 are large and firms 2 and 4 are initially small, but grow substantially from period 0 to 1. In other words, we allow for the situation that Foster, Haltiwanger, and Syverson (2008) document where firms enter that have found ways of producing at lower cost and then gain market share by selling their products for less than the incumbent firms.

The activities of the four firms can be summarized as follows:

- Firm 1 is a higher-cost producer that sells exclusively to firm 3 in periods 0 and 1.
- Firm 2 is a lower-cost producer that is small and only sells to small firm 4 in $t = 0$. However, in $t = 1$, firm 2 moves out of the small firm category by selling to firm 4, which has grown, and by also winning a contract to supply part of the intermediate product needs of large firm 3.
- Firm 3 only purchases the output of the higher-cost supplier, firm 1, in period 0, but shifts some of its purchases to firm 2 in period 1: a sourcing substitution.
- Firm 4, which is small in $t = 0$, only uses the output of the lower cost firm 2 in $t = 0{,}1$.

We let p^t_{jk} and q^t_{jk} denote the price and quantity for sales of the one product from firm j to firm k in period $t = 0{,}1$.[121] The firm value flows in Table 1 have a positive sign for outputs and a negative sign for inputs. Firm 1 is always the higher-cost supplier. Thus we always have

(1) $p^0_{13} > p^0_{24} > 0$; $p^1_{13} > p^1_{24} > 0$; and $p^1_{13} > p^1_{23} > 0$.

Table 1. Value Flows between the Four Firms

Output flows		Input flows	
Firm 1	**Firm 2**	**Firm 3**	**Firm 4**
Period 0 Value Flows			
$p^0_{13}q^0_{13}$	$p^0_{24}q^0_{24}$	$-p^0_{13}q^0_{13}$	$-p^0_{24}q^0_{24}$
Period 1 Value Flows			
$p^1_{13}q^1_{13}$	$p^1_{23}q^1_{23} + p^1_{24}q^1_{24}$	$-p^1_{13}q^1_{13} - p^1_{23}q^1_{23}$	$-p^1_{24}q^1_{24}$

[121] Normally we would expect p^1_{23} to be close to p^1_{24}, but we allow for possible price discrimination by firm 2.

It is important to understand some specifics of the price collection and index compilation practices of the BLS. The Producer Price Index (PPI) measures inflation in the prices of the outputs of domestic producers: products sold to other domestic businesses as intermediate inputs as well as final demand outputs. The Import Price Index (MPI) measures inflation for the products imported by U.S. businesses and residents. The Export Price Index (XPI) measures inflation for U.S. export products.[122] When a producer changes from buying an intermediate input from a domestic source to buying that same input from a foreign producer, the product price will drop out of the domain of definition for the PPI and will become part of the domain of definition for the MPI, and any price change associated with that sourcing substitution will not be included in either the PPI or the MPI.

For the PPI and XPI, price collection is on the sellers' side, whereas for the MPI, price collection is on the buyers' side.

As the first step in the procedures for collecting prices from producers, the BLS first selects establishments. Products are then chosen and prices are collected at the chosen establishments. The BLS collects price data from establishments roughly in proportion to their transaction volumes. Prices are collected from some small establishments for both the PPI and the International Prices Program (responsible for the MPI and the XPI). However, the proportion of establishments selected for price collection falls steeply with establishment size below a threshold value for each program.

BLS protocols specify that price collection from businesses should focus on the price forming units. Firms often centrally determine the selling prices for all of their establishments. Some price collection is now carried out in a "head office" format, but most still involves interactions with the establishments where the productive activities are carried out. Of course, it is only for single establishment firms that the establishment and the firm are the same. Nevertheless, for convenience, hereafter we will usually refer to the production units as firms.

Abstracting from some of the finer points, the current BLS price index compilation practices for the PPI and MPI have the consequence that the prices used for index compilation are only for ongoing supply contracts (see Nakamura and Steinsson [2008, 2009]). The objective of these BLS practices is to ensure that only identical products, of identical quality, are priced period to period. This is how the BLS has been implementing the matched model methodology for comparing price change over time. However, one important reason why firms make sourcing substitutions is to benefit from lower prices. When firms change the input suppliers they are using, this inevitably results in the initiation of new supply contracts that, we would think, usually involve lower prices. Hence, a statistical agency practice of using only the prices from ongoing supply contracts in index compilation will miss a substantial and systematic source of price change.

Summarizing the key points from the above discussion, BLS procedures miss price changes that accompany producer sourcing switches for three main reasons:

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[122] See Chapter 14 on the PPI Chapter 15 on the MPI and the XPI in the *BLS Handbook of Methods*, available at http://www.bls.gov/opub/hom/homtoc.htm . See also Diewert (2007a,b).

When a producer switches from a domestic to a foreign supplier (or vice versa), any price change for the input falls into a price collection gap between the PPI and MPI programs.

In an effort to control for quality differences in products and possible bundled services and amenities, the BLS typically only uses prices from ongoing contracts for index number compilation purposes. This practice was instituted to avoid treating quality-related price differences as true price change.

The lower-cost suppliers that producers switch to are often new, small suppliers trying to gain market share by undercutting the prices of established firms. Existing BLS price collection practices mean there is relatively little price collection from small firms, which will tend to result in missing the lower-price transactions for purchases from newer firms.

We want to focus attention on the above problems that are believed to be the biggest causes of sourcing substitution bias in the PPI and MPI. Thus, for now, we do not bother with specifying the relevant BLS program or with whether the price collection is from sellers or purchasers for the relevant BLS price index program: issues we return to briefly later in the section titled "Price Collection from Sellers versus Buyers."

Table 2 shows unit values, given the value flows in Table 1. The unit value for a homogeneous product is the total cost of all purchases, or the total revenue from all sales, of the product divided by the number of items transacted.[123] Table 3 shows inflation measures for specificed cases. These inflation measures are ratios of the period 1 to the period 0 unit values for the different cases in Table 2.

For panel 1 in Tables 2 and 3, only the prices from the sales or purchases of large firms are included. In contrast, for panel 2, transactions for firms of all sizes are included. Now there are no blank cells. However, firm 2 sales to firm 3 and firm 3 purchases from firm 2 are still ignored. In the rest of this paper, we focus on this panel 2 case. (Actual BLS practice falls between the panel 1 and panel 2 cases in the sense that the BLS does collect prices from some small firms.)

For panels 3 and 4, all transactions for all firms are included. In panel 3, firm-specific expressions are shown whereas panel 4 gives the corresponding economy wide aggregate expressions. We refer subsequently to the expressions in these panels 3 and 4 as *true targets*. The "true" or "target" firm indexes in panel 3 of Table 3 can be compared with the incorrectly measured price indexes given in panels 1 and 2 of Table 3. The entries in Tables 2 and 3 are used in the following section for showing how the sourcing substitution bias could be measured

[123] Since the product being traded between firms is assumed to be homogeneous in all of the following scenarios, the methodological advice given in the *Producer Price Index Manual* applies, and unit value prices are the appropriate prices to insert into index number formulas in deriving the true target price index measures. See IMF et al. (2004, pp. 509–510), Reinsdorf (1993), and Diewert (1995). The idea that a unit value for homogeneous items is the appropriate price to use in a bilateral index number formula can be traced back to Walsh (1901, p. 96) (1921, p. 88), and Davies (1924, 1932). Other index formulas are used in the appendix.

when all four firms in the hypothetical economy are domestic. Then in the next two sections, we extend the analysis to cover cases where some of the firms are foreign.[124]

[124] The "optimal" procedures may simply be too expensive for the agency to implement. But it is good to have our analysis so that rough estimates of bias could be made.

Table 2. Unit Values for Domestic Firms under Alternative Measurement Conditions

	Output flows		Input flows	
	Firm 1	**Firm 2**	**Firm 3**	**Firm 4**
Period	**Large in** $t=1$	**Small in** $t=1$	**Large in** $t=1$	**Small in** $t=1$
1. Firm unit values; based on prices for continiuing contracts at large firms only.				
0	$\frac{p_{13}^0 q_{13}^0}{q_{13}^0}$	no price collection	$-\frac{p_{13}^0 q_{13}^0}{q_{13}^0}$	no price collection
1	$\frac{p_{13}^1 q_{13}^1}{q_{13}^1}$	no price collection	$-\frac{p_{13}^1 q_{13}^1}{q_{13}^1}$	no price collection
2. Firm unit values; based on prices for continiuing contracts at all firms.				
0	$\frac{p_{13}^0 q_{13}^0}{q_{13}^0}$	$\frac{p_{24}^0 q_{24}^0}{q_{24}^0}$	$-\frac{p_{13}^1 q_{13}^1}{q_{13}^1}$	$-\frac{p_{24}^0 q_{24}^0}{q_{24}^0}$
1	$\frac{p_{13}^1 q_{13}^1}{q_{13}^1}$	$\frac{p_{24}^1 q_{24}^1}{q_{24}^1}$	$-\frac{p_{13}^1 q_{13}^1}{q_{13}^1}$	$-\frac{p_{24}^0 q_{24}^0}{q_{24}^0}$
3. Firm unit values; based on all prices at all firms.				
0	$\frac{p_{13}^0 q_{13}^0}{q_{13}^0}$	$\frac{p_{24}^0 q_{24}^0}{q_{24}^0}$	$-\frac{p_{13}^0 q_{13}^0}{q_{13}^0}$	$-\frac{p_{24}^0 q_{24}^0}{q_{24}^0}$
1	$\frac{p_{13}^1 q_{13}^1}{q_{13}^1}$	$\frac{p_{23}^1 q_{23}^1 + p_{24}^1 q_{24}^1}{q_{23}^1 + q_{24}^1}$	$\frac{-p_{13}^1 q_{13}^1 - p_{23}^1 q_{23}^1}{q_{13}^1 + q_{23}^1}$	$-\frac{p_{24}^1 q_{24}^1}{q_{24}^1}$
4. Economy wide unit values; based on all prices at all firms.				
0	$\frac{p_{13}^0 q_{13}^0 + p_{24}^0 q_{24}^0}{q_{13}^0 + q_{24}^0}$		$-\left[\frac{p_{13}^0 q_{13}^0 + p_{24}^0 q_{24}^0}{q_{13}^0 + q_{24}^0}\right]$	
1	$\frac{p_{13}^1 q_{13}^1 + p_{23}^1 q_{23}^1 + p_{24}^1 q_{24}^1}{q_{13}^1 + q_{23}^1 + q_{24}^1}$		$-\left[\frac{p_{13}^1 q_{13}^1 + p_{23}^1 q_{23}^1 + p_{24}^1 q_{24}^1}{q_{13}^1 + q_{23}^1 + q_{24}^1}\right]$	

Note: The unit value expressions shown above *are only observable for domestic firms*.

Table 3. Price Indexes for Domestic Firms under Alternative Measurement Conditions

Output flows		Input flows	
Firm 1	**Firm 2**	**Firm 3**	**Firm 4**
Large in $t = 0$	**Small in** $t = 0$	**Large in** $t = 0$	**Small in** $t = 0$
1. Firm unit values; based on prices for continiuing contracts at large firms only.			
$\frac{p_{13}^1}{p_{13}^0}$	no price collection	$\frac{p_{13}^1}{p_{13}^0}$	no price collection
2. Firm unit values; based on prices for continiuing contracts at all firms.			
$\frac{p_{13}^1}{p_{13}^0}$	$\frac{p_{24}^1}{p_{24}^0}$	$\frac{p_{13}^1}{p_{13}^0}$	$\frac{p_{24}^1}{p_{24}^0}$
3. Firm unit values; based on all prices at all firms.			
$\frac{p_{13}^1}{p_{13}^0}$	$\frac{p_{23}^1 q_{23}^1 + p_{24}^1 q_{24}^1}{p_{24}^0 q_{24}^0}$	$\frac{p_{13}^1 q_{13}^1 + p_{23}^1 q_{23}^1}{p_{13}^0 q_{13}^0}$	$\frac{p_{24}^1}{p_{24}^0}$
4. Economy wide unit values; based on all prices at all firms.			
$\frac{p_{13}^1 q_{13}^1 + p_{23}^1 q_{23}^1 + p_{24}^1 q_{24}^1}{p_{13}^0 q_{13}^0 + p_{24}^0 q_{24}^0}$		$\frac{p_{13}^1 q_{13}^1 + p_{23}^1 q_{23}^1 + p_{24}^1 q_{24}^1}{p_{13}^0 q_{13}^0 + p_{24}^0 q_{24}^0}$	

Note: The inflation measures shown *are only observable for domestic firms*.

DOMESTIC SOURCING SUBSTITUTION BIAS

We first take up sourcing substitutions among domestic sources: the most prevalent case. For the Table 1 value flows, we consider the case for which results are given in panel 2 of Tables 2 and 3.[125] We consider the situation in which the *only* reason some changes in price for the homogeneous product are missed is because only prices for continuing contracts are used in index compilation. For reasons expalined later, we focus on the measures for the purchasing firms 3 and 4 rather than the corresponding measures for the selling firms 1 and 2.

The firm 4 price index that would be computed, denoted here by $P_I^{(4)}$ and shown in panel 2 of Table 3, is compared with the true target index for firm 4, $P_T^{(4)}$, shown in panel 3 of Table 3.

[125] In Appendix A, we extend the analysis in this section to the case where we are dealing with the simultaneous outsourcing of N products instead of just a single product. The methods we use to measure sourcing substitution bias are similar to, but not the same as, the method used by Diewert (1998) to measure outlet substitution bias in the CPI.

Both are simply the ratio of the firm 4 purchase price for the homogeneous product in period 1, p_{24}^{1}, to its price in period 0, p_{24}^{0}. Thus, for firm 4, we have[126]

(2) $P_T^{(4)} \equiv p_{24}^{1} / p_{24}^{0} = P_I^{(4)}$.

The sourcing substitution bias is defined as the measured index minus the true target index. This difference is zero for firm 4, so there is no sourcing substitution bias problem for this firm.

The analysis for firm 3 is more complex. There are two transactions in period 1 for this firm at potentially different prices. Since the product being traded is assumed to be homogeneous, as already noted, the unit value is the appropriate price to use for price (and also quantity) index compilation. The true firm 3 *unit value*, u_3^1, for period 1 is

(3) $u_3^1 \equiv [p_{13}^1 q_{13}^1 + p_{23}^1 q_{23}^1] / [q_{13}^1 + q_{23}^1]$,

as also shown in panel 3 in Table 2. We find it convenient to define share parameters for the proportions of firm 1 and firm 2 output sold to firm 3 in period 1; i.e.,

(4) $S_{13}^1 \equiv q_{13}^1 / [q_{13}^1 + q_{23}^1]$ and

(5) $S_{23}^1 \equiv q_{23}^1 / [q_{13}^1 + q_{23}^1]$,

with $S_{13}^1 + S_{23}^1 = 1$. The unit value expression in Equation (3) can now be rewritten as

(6) $u_3^1 = p_{13}^1 S_{13}^1 + p_{23}^1 S_{23}^1$.

Using Eqs. (3)–(6), the target firm 3 price index, shown in panel 3 of Table 3, is

(7) $P_T^{(3)} \equiv u_3^1 / p_{13}^0 = (p_{13}^1 / p_{13}^0) S_{13}^1 + (p_{23}^1 / p_{13}^0) S_{23}^1$.

However, the formula given in Equation (7) is not what would be evaluated for firm 3 if the period 1 sales of firm 2 to firm 3 are ignored because this is the first period for a new contract. As given in panel 2, the measured price change component for firm 3 would be

(8) $P_I^{(3)} \equiv p_{13}^1 / p_{13}^0$.

[126] We assume that the corresponding true quantity index is obtained by deflating the value ratio by the true price index. Thus $Q_T^{(1)} \equiv [p_{13}^1 q_{13}^1 / p_{13}^0 q_{13}^0] / P_T^{(1)} = q_{13}^1 / q_{13}^0$ and $Q_T^{(4)} \equiv [p_{24}^1 q_{24}^1 / p_{24}^0 q_{24}^0] / P_T^{(4)} = q_{24}^1 / q_{24}^0$.

The numerator in this incorrect index is the period 1 price from the high-cost supplier, p_{13}^{1}, rather than the unit value price, u_{3}^{1}, which is an average price for firm 3 input purchases in period 1 from both the high- and low-cost suppliers.

Before specifying a formula for the bias for the firm 3 price index, it is helpful, for interpretive purposes, to introduce a bit more notation. We will let i be the rate of price inflation for deliveries from the high-cost supplier, firm 1, to firm 3.

(9) $(1+i) \equiv p_{13}^{1} / p_{13}^{0} = P_{I}^{(3)}$, using Equation (8).

Also, we let $0 \le d < 1$ be a *discount factor* reflecting the proportional price discount for firm 3 purchases from firm 1 versus firm 2. Thus, we have

(10) $(1+i)(1-d) = p_{23}^{1} / p_{13}^{0}$,

where $(1-d) = p_{23}^{1} / p_{13}^{1} \le 1$. From Equation (9), Equation (10), and Equation (7), we now have

(11) $P_{T}^{(3)} = (p_{13}^{1} / p_{13}^{0})S_{13}^{1} + (p_{23}^{1} / p_{13}^{0})S_{23}^{1}$

$= (1+i)S_{13}^{1} + (1+i)(1-d)S_{23}^{1}$

$= P_{I}^{(3)} - (1+i)dS_{23}^{1}$ also using Equation (8) and the property $S_{13}^{1} + S_{23}^{1} = 1$.

Therefore, for the case of a purchasing substituion from one domestic producer to another, the sourcing substitution bias for firm 3 is defined as the index that is computed, given in Equation (8), less the true target index given in Equation (7):

(12) $B^{(3)} \equiv P_{I}^{(3)} - P_{T}^{(3)} = (1+i)dS_{23}^{1} > 0$.

From Equation (12) we see that the sourcing bias is positive since $d > 0$, and the product of three factors:

1) The rate of price inflation for the high-cost supplier; i.e., $(1+i) \equiv p_{13}^{1} / p_{13}^{0}$;

2) The proportional cost advantage of the low-cost supplier over the high-cost supplier; i.e., $d = 1 - [(p_{23}^{1} / p_{13}^{0}) / (p_{13}^{1} / p_{13}^{0})] > 1$; and

3) The share of deliveries to sector 3 in period 1 that are from the new low-cost supplier; i.e., $S_{23}^1 \equiv q_{23}^1 / [q_{13}^1 + q_{23}^1]$.

If rough guesses can be made for the cost advantage of the low-cost supplier and the input shares displaced, then a rough approximation of the bias in the intermediate input price index could be made using Equation (12).[127]

We conclude this section with some observations regarding two extensions of the above results for domestic sourcing substitutions: 1) an extension to the whole economy level, and 2) an extension to the case where the higher cost supplier, firm 1, shuts down in period 1 because of the competition from firm 2, so p_{13}^1 and q_{13}^1 are not available.

Regarding the whole economy extension, since the firms 1 and 2 are selling a homogeneous commodity, the true period 1 unit value for the combined economy-wide inputs of firms 3 and 4 is $u^1 \equiv -[p_{13}^1 q_{13}^1 + p_{23}^1 q_{23}^1 + p_{24}^1 q_{24}^1] / [q_{13}^1 + q_{23}^1 + q_{24}^1]$, and the corresponding period 0 whole economy unit value is $u^0 \equiv -[p_{13}^0 q_{13}^0 + p_{24}^0 q_{24}^0] / [q_{13}^0 + q_{24}^0]$, as in panel 4, Table 2. Thus the *target price index* is $P_T^{(3+4)} \equiv u^1 / u^0$, which equals the expression in panel 4 of Table 3.

If the statistical agency fails to include the price information for the new period 1 contract that firm 2 has to supply firm 3, then the computed economy-wide index would be $[p_{13}^1 q_{13}^1 + p_{24}^1 q_{24}^1] / [p_{13}^0 q_{13}^0 + p_{24}^0 q_{24}^0]$, which will yield a higher value than the target index. Thus the computed index for the combined firms will have an upward bias.

Moving on to the second extension, suppose firm 1 shuts down in period 1 because of the competition from firm 2, so that p_{13}^1 and q_{13}^1 are not available. Now it is not possible to define an observable true output price index for firm 1 in period 1. However, the true input price index for firm 3 can still be defined by Equation (7) with $S_{13}^1 = 0$ and $S_{23}^1 = 1$, so $P_T^{(3)}$ could be specified to be the (unmatched) price ratio p_{23}^1 / p_{13}^0, and the rest of the algebra above goes through.

However, although the true input price index for firm 3, p_{23}^1 / p_{13}^0, *could* be evaluated, note that the period 0 and period 1 price observations come from different suppliers. Given currently accepted practices, a statistical agency would be more likely to measure the price change by p_{24}^1 / p_{24}^0. With low inflation for the prices charged by any one firm, this price ratio would be close to one and hence generally larger than the mixed price ratio, p_{23}^1 / p_{13}^0. Thus, in general,

[127] In Appendix A, we show that the bias formula becomes more complex when we generalize the above one commodity case to the case of many commodities, but Equation (12) is valuable as a rough approximation to the bias.

the incorrect index will again have an upward bias, though this bias is not given by Equation (12).[128]

OFFSHORE SOURCING SUBSTITUTION BIAS

The extension of the analysis in the previous section to cover the case of a domestic firm switching among foreign suppliers is straightforward. We simply reinterpret firms 1 and 2 as foreign suppliers. Now none of the column 1 and 2 expressions can be evaluated in Table 2, so we focus on the prices that can be observed for firms 3 and 4. Inflation measurement for imports *must* be carried out using prices collected from purchasers. (Comparability with the results here is one reason we chose to focus on price indexes for firms 3 and 4 in the previous section too.)

All of the algebra in the previous section can be applied. There are no sourcing substitution bias problems for firm 4. However, the statistical agency will be likely to compute the incorrect price index for firm 3 given by Equation (8) instead of the true target index given by Equation (7), for the same reasons explained above. Thus, the bias Equation (12) is again operative.

Now imports are in the picture, for each firm in the domestic economy, *input purchases should be distinguished by their point of origin* so it can be determined whether a purchase should be classified as a domestic or an imported input. We further discuss this issue in the next to last section which is on the BEA Industry Accounts.

DOMESTIC TO FOREIGN SOURCING SUBSTITUTIONS

Finally, we take up the case where firm 1 is a domestic supplier and firm 2 is a lower-cost foreign supplier of the same homogeneous product. Now it is just the column 2 expressions in Tables 2 and 3 that cannot be evaluated. However, since firms 3 and 4 are domestic, the column 3 and 4 expressions can still be evaluated. The sourcing substitution for firm 3 is now the switch from exclusively using a domestic supplier (firm 1) in period 0 to importing some of the firm's requirements for the homogeneous input from the foreign firm 2 in period 1.

All of the algebra in section 3 for firm 3 remains valid. Thus the bias analysis in the third section carries over to the present context in a straightforward manner.

PRICE COLLECTION FROM SELLERS VERSUS BUYERS

With the producer price indexes currently produced by the BLS, the price collection is on the purchasers' side for the MPI since it is only the purchasers that are domestic, but it is on the sellers' side for the PPI. We ignored this institutional information in the previous sections and proceeded as though all price collection were on the buyers' side. We did this partly for expositional convenience, but also because doing this allowed us to demonstrate that the

[128] The new bias formula will be $B \equiv P_I^{(3)} - P_T^{(3)} = (p_{24}^1 / p_{24}^0) - (p_{23}^1 / p_{13}^0)$.

sourcing substitution bias problem cannot be corrected solely by creating a comprehensive input price index with price collection on the purchasers' side.[129]

As of now, the United States does not have a comprehensive input price index. Rather, the components of the PPI program that are for intermediate products sold to other businesses and the price index components of the MPI for purchases by businesses are combined to form a pseudo input price index. The BLS hopes to begin producing a true Input Price Index (IPI) in the future, as explained in Alterman (2009), but has not yet been given the funding to do so. We view this as an important step forward. However, to deal with the sourcing substitution bias problem, the BLS also needs to utilize the initial observation when a new procurement contract is started, relating this price to the price paid under the previous contract, and to collect prices from all firms rather than mostly from large ones. The purchaser knows, presumably, whether the product is truly the same despite a price change.[130] On the other hand, a seller typically has no information about the prior purchasing choices of their customers or their reasons for making sourcing changes. So, new sources of supply should be flagged and the statistical agency must decide, case by case, on whether the product from a new source of supply is closely comparable to the product from the old source of supply. This is the information that would make the BLS feel comfortable about including prices for first time purchases under new procurement contracts in producer price index calculations. Making these changes will not be easy, but our bias Equation (12) makes it clear the changes are important!

THE BEA INDUSTRY ACCOUNTS

One important use of producer price indexes is for use by the BEA for producing industry accounts that are corrected for pure price change over time. The BEA industry accounts, which include the benchmark input-output (I-O) accounts and annual GDP-by-industry accounts, are heavily used for economic policy analyses.[131] Benchmark I-O accounts are produced every five years using data from the quinquennial economic census of businesses. These include make, use, and requirements tables. A make table shows the value of each product produced by each industry in a given year.[132] A use table shows the uses of products by intermediate and final users.[133]

Starting with the initial benchmark make and use tables, the BEA produces *balanced make and use tables* using a procedure that sequentially changes row and column figures until the recorded

[129] Almost 50 years ago, the 1961 report of the NBER Price Statistics Review Committee (the *Stigler Report*) also recommended that the BLS should rely on purchasers' prices rather than the sellers' prices.
[130] If the purchaser is acting on behalf of another party, then the question might need to be referred to that other party.
[131] See, for example, Streitwieser (2009) on the ongoing sorts of public policy uses of the BEA industry accounts.
[132] Each industry gets a row in a make table, and each product gets a column. The values in a row sum to the current value of output for the stated industry. Each column total equals the total output for the given product.
[133] Each product gets a row, and each row sum is the gross output for the given product. There are columns for the industry intermediate uses and columns for final uses. The value added for an industry is the sum of the values of total industry sales (gross output) minus the value of purchases from other industries (aggregate intermediate industry input). Industry value added summed over industries equals the business sector GDP for the nation.

total use of each product equals its recorded total supply, and the recorded final demands equal the values given in the U.S. national income and product accounts (NIPAs).[134]

Requirements tables are derived from the balanced make and use tables. The coefficients in the requirements tables represent interindustry linkages that, in turn, link output and final demand. For example, the entries in the employment requirements table show the estimated direct and indirect impacts of a change in final demand on employment in the different industries. Requirements tables are used for policy impact analyses.

For the purpose of producing constant price real I-O accounts from nominal I-O accounts, price indexes are needed for deflating the outputs and also the inputs. Unfortunately, as explained above, we believe the input price indexes for producers are distorted by sourcing substitution biases. In addition, there are gaps in intermediate product price collection. Imputed rather than direct pricing is used for numerous products. Moreover, the same economy-wide producer price deflator is generally used to deflate the value flows between and from each of the industries. Diewert (2007c) notes that this procedure is correct only if each industry produces the same mix of micro commodities within each of the broad commodity classes and micro commodity prices move together across industries: conditions unlikely to be satisfied for a nation!

Moving to the annual industry accounts (AIAs), these consist of the annual GDP-by-industry accounts and the annual I-O accounts. The annual GDP-by-industry estimates are based on annual survey and administrative data from several sources. In contrast, the annual I-O accounts are produced by updating the benchmark I-O accounts utilizing the assumption that the real (constant-price) use of intermediate inputs relative to each industry's real gross output does not change year-to-year; see Strassner, Yuskavage, and Lee (2009). The estimates of an industry's real intermediate inputs are first updated based on projected changes in the industry's real gross output from the GDP-by-industry accounts and using the observed ratios of intermediate input use to gross output. The AIAs are then "integrated" internally and with the NIPAs. The integration achieved is referred to as *partial integration*.

The balancing process can be viewed, Parker (2004) suggests, as using the relative strengths of the available data to produce the best possible data for users. However, an initial imbalance, say, in the initial use table in the form of too little, or too much, supply of a product after the estimated intermediate input and final uses have been accounted for represents either an inconsistency in the data or in the framework for the accounts. The balancing process renders less visible the initial imbalances; see Meade (2006).

Filling the intermediate products value and price data gaps would help the BEA to move toward full rather than just partial integration of the industry accounts. Lawson, Moyer, and Okubo (2006) note that the methods developed by the BEA to achieve partial integration were never seen as an adequate substitute for the needed improvements to the source data. They explain that, with full integration, the measures of value added by industry would be independent of the NIPAs and could provide a useful "feedback" loop that would improve the estimates of the product composition of GDP.

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[134] The techniques used for this balancing are explained in Appendix B of Lawson, Moyer, and Okubo (2006). See also Horowitz and Planting (2006) and Yuskavage, Strassner, and Medeiros (2008).

Also, policymakers would like to know what factors account for current U.S. offshoring. They would like to understand and be able to foresee and perhaps influence the major effects of offshoring on U.S. workers and the economy.[135] The I-O tables serve as the framework for combining the available data for estimated GDP, and are essential to empirical studies of how outsourcing and offshoring and inshoring are affecting the U.S. economy. However, to properly allow for foreign engagement, the commodity classification that is used in the I-O tables must be expanded. A gross output that is being produced by a particular industry in a particular commodity category must be further distinguished as being supplied to the domestic market or as an export while an intermediate input that is being used by a particular industry in a particular commodity category must be further distinguished as being purchased from a domestic or a foreign supplier. Making these changes would not be a dramatic methodological leap since the 1993 System of National Accounts (SNA93) guidelines already suggested this treatment of intermediate inputs as a supplementary table.[136] However, this change would be expensive.

If it is deemed important to have information on the exports produced and the imports demanded by each industrial sector, it will be necessary to construct unit value output prices for both exports and deliveries to domestic demanders and to construct unit value input prices for both imports and deliveries to the sector from domestic suppliers. If we take this approach as the ideal, the dimensionality of the supply and use tables would be expanded beyond what could conceivably be implemented in terms of needed data collection, *given present survey data collection methods* and business concerns about confidentiality. However, the suggested approach could be partially implemented at least, as suggested by Diewert (2001).[137]

If our purpose is to measure industry productivity, or to measure industry level product or labor demand impacts, then the answer is reasonably straightforward. When calculating the constant dollar I-O matrices, each value cell for outputs and each value cell for inputs needs to be deflated by a price index that matches up with the value flows in that cell. At present, however, there simply are no adequate surveys on the interindustry flows of services. Even in manufacturing, where information on commodity flows is relatively complete thanks to explicit surveys of manufacturing industries, relatively little information on the flows of purchased services is collected. More attention also needs to be given to the development of basic prices by industry and by commodity—i.e., we need accurate information on the exact location of indirect taxes (and commodity subsidies) by commodity and industry on both outputs and inputs.

[135] See Dey, Houseman, and Polivka (2006); Freenstra and Bradford (2009); Jarmin, Krizan and Tang (2009); Kletzer (2009); and Norwood et al. (2006).
[136] See Table 15.5 in Eurostat et al. (1993). For a more detailed discussion of how exports and imports could be introduced into the production accounts, see Diewert (2007a,b) and IMF et al. (2009).
[137] See Diewert (2005, 2007c) for a treatment of these problems in a closed economy context, and Diewert (2007a,b) for an open economy treatment.

RECOMMENDED DATA GAP FIXES

As explained following Table 1, the present BLS price collection procedures miss price changes of three sorts that accompany producer sourcing switches: 1) price changes associated with domestic to foreign sourcing substitutions (or vice versa), 2) price changes associated with the start of new procurement contracts, and 3) price changes involving sales of or purchases from small firms for one of the two time periods involved for the price change. The resulting price data gaps lead to sourcing substitution bias problems.

Changes in statistical agency practices could fix these data-based problems, though these are changes that a statistical agency like the BLS would need additional funding to implement. A comprehensive Input Price Index (IPI) is needed of the sort the BLS would like to have the funds to produce. Price collection should be from purchasers rather than sellers whenever possible, since it is only the purchasers who are in a position to state whether there were quality changes as well as price changes associated with sourcing changes. Also, it is important for data to be collected from all firms, or at least from higher proportions of small firms.

We believe that an important step toward achieving the needed expansion of data collection from firms is for the present survey data collection methods to progressively be replaced with full electronic price and value data capture for all transactions of all businesses large enough to have electronic information systems.[138] Many firms have taken advantage of the low cost of computing and now have detailed data on all their financial transactions (e.g., they have the value of each sale and the quantity sold by commodity).[139] This information could enable industry and firm research like the scanner data studies that have proven to be so useful in the context of the Consumer Price Index.[140] This information would permit the construction of true microeconomic price and quantity indexes at the firm level and the evaluation of more accurate firm and industry productivity indexes. The 2008 *American Economic Review* study of Foster, Haltiwanger, and Syverson makes it clear that having this sort of information could result in a revolutionary rewrite of our understanding of how productivity growth takes place in the U.S. economy. Some additional tentative conclusions also follow from our analysis:

- Basic index number theory and statistical agency practice has not paid enough attention to the problems that arise when new firms enter and some grow, and some established firms shrink and then exit.
- It seems likely that statistical agency operating procedures have led to upward sourcing substitution biases in the intermediate product components of the PPI and MPI. Upward biases in input price indexes lead to downward biases in the corresponding quantity indexes and have the effect of overstating total factor productivity improvements.

[138] Abraham and Spletzer argue convincingly that economies of scale would be realized if data were collected, when possible, for entire firms from their head offices. The context in which Abraham and Spletzer (2009) present these options is different, but the options they outline seem relevant for our context too.
[139] For more on new ways of collecting price data, see also Gudmundsdottir, Gudnason, and Jonsdottir (2008) and Grimm, Moulton, and Wasshausen (2002).
[140] See, for example, Reinsdorf (1994a,b); Nakamura (2008), Ivancic, Diewert, and K.J. Fox (forthcoming); and Nakamura, Nakamura, and Nakamura (forthcoming).

- Since the value of international trade as a proportion of GDP has mostly increased over time, it seems likely that sourcing substitution bias has also increased over time.
- There are other data gaps in the U.S. economic statistics that compound the problems resulting from sourcing substitution bias. In particular, currently in the United States, value information for intermediate products is only collected every five years, and there is no direct price collection for large numbers of intermediate products of economic importance.

N. Gregory Mankiw (2006, p. 44) quotes John Maynard Keynes as stating:

> "If economists could manage to get themselves thought of as humble, competent people on a level with dentists, that would be splendid."

Mankiw explains that Keynes was expressing a hope that macroeconomics would evolve into a useful sort of engineering and that "avoiding a recession would be as straightforward as filling a cavity." He goes on to lament a paucity of those in our profession who are willing to commit their time and energies to helping to achieve the objectives that Keynes enunciated. However, dentists work on the teeth of their patients with the aid of lights, special mirrors, patients who willingly open their mouths, and dental X rays. In our view, for economists to make greater progress on understanding the economy and for economists and government policymakers to be able to do better on managing the economy, we need better "equipment" for *seeing* the economy. The data improvements recommended in this article would help in this regard.

Appendix A: Outsourcing Bias when there are N Commodities Being Outsourced

The analysis in the main text associated with Table 1 deals only with the case of a single homogeneous product. In this appendix, we define indexes as aggregates over N products instead of a single product. The overall message remains the same but the details are more complex.

In this more general setup, there are four groups of firms. We will assume that group 3 *simultaneously switches their sourcing arrangements for N homogeneous commodities*. In particular, group 3 switches some of its input procurement contracts for N commodities group 3 firms need as inputs from group 1 (the higher-cost supplier) to group 2 (the lower-cost supplier) for N commodities. Thus, the flows shown in Table 1 are still applicable except that now each price and quantity shown in the table is interpreted as a vector and the old ordinary price and quantity products must now be interpreted as inner products of the corresponding price and quantity vectors. Thus, the old value flow of supplies from group i to group j in period t, $p_{ij}^t q_{ij}^t$, is replaced by $p_{ij}^t \cdot q_{ij}^t \equiv \sum_{n=1}^N p_{ijn}^t q_{ijn}^t$ for $t = 0,1$ where now $p_{ij}^t = [p_{ij1}^t, p_{ij2}^t, \ldots, p_{ijN}^t]$ is a price vector and $q_{ij}^t = [q_{ij1}^t, q_{ij2}^t, \ldots, q_{ijN}^t]$ is a quantity vector.

Let p^t and q^t be generic price and quantity vectors pertaining to a group for periods $t = 0,1$. Then the *Laspeyres and Paasche price indexes*, P_L and P_P, are defined as follows:

(A1) $P_L(p^0, p^1, q^0, q^1) \equiv p^1 \cdot q^0 / p^0 \cdot q^0$ and $P_P(p^0, p^1, q^0, q^1) \equiv p^1 \cdot q^1 / p^0 \cdot q^1$.

The *Fisher* (1922) *ideal price index*, P_F, is defined as the geometric mean of the Laspeyres and Paasche price indexes:

(A2) $P_F(p^0, p^1, q^0, q^1) \equiv [P_L(p^0, p^1, q^0, q^1) P_P(p^0, p^1, q^0, q^1)]^{1/2}$.

The Fisher price index can be justified as a "best" index from multiple perspectives[141] and will be used for forming the "true" target index in what follows.

Looking at Table 1, it is straightforward to define the *true output price index for group 1*, $P_T^{(1)}$, as the Fisher index $P_F(p_{13}^0, p_{13}^1, q_{13}^0, q_{13}^1)$ and the *true input price index for group 4*, $P_T^{(4)}$, as the usual Fisher index $P_F(p_{24}^0, p_{24}^1, q_{24}^0, q_{24}^1)$. There are no sourcing substitution complications here. However, in period 1, group 2 firms began selling the same product to group 3 as well as group 4 firms, possibly at different prices. Thus, proper measurement of inflation for group 2 and group 3 transactions is more complicated.

For groups 2 and 3, the *unit value prices* for the N commodities ($n = 1, \ldots, N$) in period 1 are

[141] See Diewert (1976, 1992) and the *Producer Price Index Manual*.

(A3) $u_{2n}^1 \equiv [p_{23n}^1 q_{23n}^1 + p_{24n}^1 q_{24n}^1]/[q_{23n}^1 + q_{24n}^1] = p_{23n}^1 S_{23n}^1 + p_{24n}^1 S_{24n}^1$;

(A4) $u_{3n}^1 \equiv [p_{13n}^1 q_{13n}^1 + p_{23n}^1 q_{23n}^1]/[q_{13n}^1 + q_{23n}^1] = p_{13n}^1 S_{13n}^1 + p_{23n}^1 S_{23n}^1$;

where the *group 2 and 3 (physical) quantity shares for product n in period 1* are given by

(A5) $S_{23n}^1 \equiv q_{23n}^1/[q_{23n}^1 + q_{24n}^1]$; $S_{24n}^1 \equiv q_{24n}^1/[q_{23n}^1 + q_{24n}^1]$; $S_{23n}^1 + S_{24n}^1 = 1$; and

(A6) $S_{13n}^1 \equiv q_{13n}^1/[q_{13n}^1 + q_{23n}^1]$; $S_{23n}^1 \equiv q_{23n}^1/[q_{13n}^1 + q_{23n}^1]$; $S_{13n}^1 + S_{23n}^1 = 1$.

Let the vector of group 2 unit value prices for period 1 be $u_2^1 \equiv [u_{21}^1,u_{22}^1,...,u_{2N}^1]$ where the u_{2n}^1 are defined by (A3) and let the vector of group 3 unit value prices for period 1 be $u_3^1 \equiv [u_{31}^1,u_{32}^1,...,u_{3N}^1]$ where the u_{3n}^1 are defined by (A4). The period 1 quantity vectors that correspond to these unit value vectors in period 1 are $q_{23}^1+q_{24}^1$ for group 2 and $q_{13}^1+q_{23}^1$ for group 3. Thus our *true output index* for group 2 and our true input index for group 3 are defined to be the following Fisher ideal price indexes, respectively,

(A7)
$$P_T^{(2)} \equiv P_F(p_{24}^0,u_2^1,q_{24}^0,q_{23}^1 + q_{24}^1) = [P_L(p_{24}^0,u_2^1,q_{24}^0,q_{23}^1 + q_{24}^1)P_P(p_{24}^0,u_2^1,q_{24}^0,q_{23}^1 + q_{24}^1)]^{1/2};$$

(A8)
$$P_T^{(3)} \equiv P_F(p_{13}^0,u_3^1,q_{13}^0,q_{13}^1 + q_{23}^1) = [P_L(p_{13}^0,u_3^1,q_{13}^0,q_{13}^1 + q_{23}^1)P_P(p_{13}^0,u_3^1,q_{13}^0,q_{13}^1 + q_{23}^1)]^{1/2}.$$

In principle, a statistical agency could compute the true output price index $P_T^{(2)}$ defined by (A7) and the true input price index, $P_T^{(3)}$ defined by (A8). In practice, there are likely to be problems. Of particular relevance here, group 3 has switched to a new supplier in period 1 for the N commodities under consideration, so there will be no matching price for these supplies in period 0. Given current BLS practices, it is likely that the statistical agency will use the following "matched model" *incorrect intermediate input price index* for group 3:

(A9) $$P_I^{(3)} \equiv [P_L(p_{13}^0,p_3^1,q_{13}^0,q_{13}^1)P_P(p_{13}^0,p_3^1,q_{13}^0,q_{13}^1)]^{1/2}.$$

The incorrect index $P_I^{(3)}$ is the geometric mean of the Laspeyres and Paasche price indexes, $P_L(p_{13}^0,p_3^1,q_{13}^0,q_{13}^1)$. and $P_P(p_{13}^0,p_3^1,q_{13}^0,q_{13}^1)$, that use only the price and quantity data for the incumbent supply source (group 1 firms) for both periods. Since group 1 is a high-cost supplier, we can expect $P_I^{(3)}$ to be higher than the true index, $P_T^{(3)}$. Here we will develop formulae that will enable us to determine the magnitude of this upward bias.

It is cumbersome to develop a bias formula for the difference of $P_I^{(3)}$ less $P_T^{(3)}$ but it is fairly easy to develop bias formulas for the differences between the Laspeyres and Paasche components of these indexes. Thus, we start our analysis by expressing the high-cost supplier price relatives, p_{13n}^1 / p_{13n}^0, as the following high-cost supplier *product specific inflation rates*:

(A10) $p_{13n}^1 / p_{13n}^0 \equiv (1 + i_n)$; $\quad n = 1, \ldots, N$;

Next, the lower-cost supplier prices in period 1 relative to the corresponding high-cost supplier prices in period 0 are expressed as:

(A11) $p_{23n}^1 / p_{13n}^0 \equiv (1 - d_n)(1 + i_n)$, $\quad n = 1, \ldots, N$

where d_n is a *proportional discount factor* for the low- versus the higher-cost supplier for product n that satisfies

(A12) $0 < d_n < 1$; $\quad n = 1, \ldots, N$.

We start our analysis by looking at the *Laspeyres component* $P_{TL}^{(3)}$ of the true input price index defined by (A8)

(A13)
$$P_{TL}^{(3)} \equiv P_L(p_{13}^0, u_3^1, q_{13}^0, q_{13}^1 + q_{23}^1)$$
$$\equiv u_3^1 \cdot q_{13}^0 / p_{13}^0 \cdot q_{13}^0$$
$$= \sum_{n=1}^N [p_{13n}^1 S_{13n}^1 + p_{23n}^1 S_{23n}^1] q_{13n}^0 / p_{13}^0 q_{13}^0 \quad \text{using definitions (A4)}$$
$$= \sum_{n=1}^N [(p_{13n}^1 / p_{13n}^0) S_{13n}^1 + (p_{23n}^1 / p_{13n}^0) S_{23n}^1] p_{13n}^0 q_{13n}^0 / p_{13}^0 q_{13}^0$$
$$= \sum_{n=1}^N [(1 + i_n) S_{13n}^1 + (1 - d_n)(1 + i_n) S_{23n}^1] p_{13n}^0 q_{13n}^0 / p_{13}^0 q_{13}^0$$

using (A10) and (A11)

$$= \sum_{n=1}^N [(1 + i_n) S_{13n}^1 + (1 - d_n)(1 + i_n) S_{23n}^1] s_{13n}^0 \quad \text{using (A14) below}$$
$$= \sum_{n=1}^N [(1 + i_n) s_{13n}^0 - \sum_{n=1}^N d_n (1 + i_n) S_{23n}^1 s_{13n}^0 \quad \text{using (A6)}$$

where the *period 0 expenditure shares on the N commodities in group 3* are defined as follows:

(A14) $s_{13n}^{0} \equiv p_{13n}^{0}q_{13n}^{0} / p_{13}^{0}q_{13}^{0}$; $\quad n = 1,\ldots,N$.

It is straightforward to show that $\sum_{n=1}^{N}(1+i_n)s_{13n}^{0}$ is the *incorrect Laspeyres component*, $P_L(p_{13}^{0},p_{13}^{1},q_{13}^{0},q_{13}^{1})$, in the incorrect Fisher price index for group 3 defined by (A9) above; so,

(A15) $P_{IL}^{(3)} \equiv P_L(p_{13}^{0},p_{13}^{1},q_{13}^{0},q_{13}^{1}) = \sum_{n=1}^{N}(1+i_n)s_{13n}^{0}$.

Thus if we define the *bias* B_L *in the incorrect Laspeyres index* as the difference between $P_{IL}^{(3)}$ and $P_{TL}^{(3)}$, using (A13) and (A15), we have the following expression for this bias:

(A16) $B_L \equiv P_{IL}^{(3)} - P_{TL}^{(3)} = \sum_{n=1}^{N} d_n(1+i_n)S_{23n}^{1}s_{13n}^{0} > 0$,

where the inequality follows from the nonnegativity of the physical shares S_{23n}^{1} (with at least one of these shares being positive), the positivity of the base period expenditure shares s_{13n}^{0} and the positivity of the discount factors d_n. The bias formula (A16) has the same general structure as the bias formula (12) in the main text except that now it is the base period expenditure shares s_{13n}^{0} of the group making the N-product sourcing switch that enter the formula.

We now need to repeat the above analysis for the *Paasche component of the true index* $P_T^{(3)}$ defined by (A8) and the *Paasche component of the incorrect index* $P_I^{(3)}$ defined by (A9). Define these Paasche components as follows:

(A17) $P_{TP}^{(3)} \equiv P_P(p_{13}^{0},u_3^{1},q_{13}^{0},q_{13}^{1}+q_{23}^{1}) \equiv u_3^{1}(q_{13}^{1}+q_{23}^{1}) / p_{13}^{0}(q_{13}^{1}+q_{23}^{1})$;

(A18) $P_{IP}^{(3)} \equiv P_P(p_{13}^{0},u_3^{1},q_{13}^{0},q_{13}^{1}) \equiv p_{13}^{1}q_{13}^{1} / p_{13}^{0}q_{13}^{1}$.

In place of the base period expenditure shares s_{13n}^{0}, for our Paasche analysis, we require two sets of expenditure weights that use the prices of period 0 but quantities that pertain to period 1. These *hybrid expenditure shares* are given by:

(A19) $s_n^{01} \equiv p_{13n}^{0}q_{13n}^{1} / p_{13}^{0}q_{13}^{1}$; $\quad n = 1,\ldots,N$;

(A20) $s_n^{01*} \equiv p_{13n}^{0}(q_{13n}^{1}+q_{23n}^{1}) / p_{13}^{0}(q_{13}^{1}+q_{23}^{1})$; $\quad n = 1,\ldots,N$.

The expenditure shares s_n^{01} use the base period prices for group 3, p_n^{01}, and the deliveries of the high cost group to group 3 in period 1, q_{13}^{1}, whereas the expenditure shares s_n^{01*} use the base period prices for group 3, p_{13}^{0}, as the price vector and the sum of all deliveries to group 3 in period 1, $q_{13}^{1}+q_{23}^{1}$, as the quantity vector.

We must now look at the *Paasche component* $P_{TP}^{(3)}$ of the true input price index defined by (A8). Using definition (A17), we have

(A21) $P_{TP}^{(3)} \equiv u_3^1(q_{13}^1+q_{23}^1)/p_{13}^0\cdot(q_{13}^1+q_{23}^1)$

$$= \sum_{n=1}^{N}[p_{13n}^1 S_{13n}^1 + p_{23n}^1 S_{23n}^1][q_{13n}^1+q_{23n}^1]/p_{13}^0[q_{13}^1+q_{23}^1] \qquad \text{using (A4)}$$

$$= \sum_{n=1}^{N}[(p_{13n}^1/p_{13n}^0)S_{13n}^1 + (p_{23n}^1/p_{13n}^0)S_{23n}^1]s_n^{01*} \qquad \text{using (A20)}$$

$$= \sum_{n=1}^{N}[(1+i_n)S_{13n}^1 + (1-d_n)(1+i_n)S_{23n}^1]s_n^{01*} \qquad \text{using (A10) and (A11)}$$

$$= \sum_{n=1}^{N}[(1+i_n)s_n^{01*} - \sum_{n=1}^{N}d_n(1+i_n)S_{23n}^1 s_n^{01*} \qquad \text{using (A6).}$$

Moreover, for the *Paasche component* $P_{IP}^{(3)}$ of the incorrect input price index defined by (A9), using definition (A18), we have

(A22) $P_{IP}^{(3)} \equiv p_{13}^1\cdot q_{13}^1/p_{13}^0\cdot q_{13}^1$

$$= \sum_{n=1}^{N}(p_{13n}^1/p_{13n}^0)p_{13n}^0 q_{13n}^1/p_{13}^0 q_{13}^1$$

$$= \sum_{n=1}^{N}(1+i_n)s_n^{01} \qquad \text{using (A10) and (A19).}$$

Define the *bias* B_P *in the incorrect Paasche index* as the difference between $P_{IP}^{(3)}$ and $P_{TP}^{(3)}$. Using (A21) and (A22), we have the following expression for this bias:

(A23) $B_P \equiv P_{IP}^{(3)} - P_{TP}^{(3)}$

$$= \sum_{n=1}^{N}(1+i_n)s_n^{01} - \sum_{n=1}^{N}(1+i_n)s_n^{01*} + \sum_{n=1}^{N}d_n(1+i_n)S_{23n}^1 s_{13n}^{01*}$$

$$= \sum_{n=1}^{N}(1+i_n)[s_n^{01}-s_n^{01*}] + \sum_{n=1}^{N}d_n(1+i_n)S_{23n}^1 s_{13n}^{01*}.$$

Under normal conditions, the first term in the last line of (A23) will be close to zero[142] so the second term, $\sum_{n=1}^{N} d_n(1+i_n)S_{23n}^{1}s_{13n}^{01*}$, will dominate. Since this second term is positive under our assumptions, the Paasche component of the bias, B_P, will usually be positive. This second term has the same general form as the Laspeyres bias component B_L defined above by (A16).

We can approximate the true Fisher index $P_T^{(3)}$ defined by (A8) by the arithmetic mean of its Laspeyres and Paasche components. Also, we can approximate the incorrect Fisher index $P_I^{(3)}$ defined by (A9) by the arithmetic mean of its Laspeyres and Paasche components. Expressions (A16) and (A23) can be used to form an overall bias estimate for the incorrect Fisher index.

[142] If all of the commodity specific inflation rates for the high cost producer are equal (i.e., the i_n are all equal), then it can be seen that the first term on the right hand side of (A23) will vanish since the two sets of shares sum to one. This term will also be zero if the correlation between the vector of commodity specific inflation rates i_n and the vector of differences in the shares is zero.

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Are there Unmeasured Declines in Prices of Imported Final Consumption Goods?

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One of the ways in which the U.S. economy has been transformed since the 1970s is the growth of its engagement in international trade. Imports of nonpetroleum goods have risen particularly rapidly. They amounted to about 10 percent of final domestic uses of goods in personal consumption expenditures and gross investment in 1975, about 20 percent in 1991–1992, and about 30 percent in 2008 (Figure 1).

Many factors have been found to contribute to growth of imports, including lower transport costs, lower communications costs, advances in managing the logistics of fragmented supply chains, multilateral trade liberalizations, scale economies, growth in varieties, rising productivity and capital stocks of emerging Asian economies, and undervalued foreign currencies. These factors can be expected to act to lower prices of imports to domestic buyers. Substitution to lower-priced sources of supply therefore seems to be an important driver of the growth of nonpetroleum goods imports.

Yet the U.S. import price indexes generally give no indication that prices have been a significant factor in the displacement by imports of domestic sources of supply. Goods prices at the consumer level should be an average of prices from domestic and imported sources of supply adjusted for trade and transportation margins, so if import prices are falling relative to domestic prices, we might expect to see the price index for imports of nonpetroleum goods rising more slowly (or falling faster) than a price index for nonenergy goods in personal consumption expenditures (PCE) in the national income and product accounts (NIPAs). Although this pattern did occur between 1996 and 2001, in most years since 1990 the imports index has risen *faster* than an index of PCE nonenergy goods prices (Figure 2). On a cumulative basis over the time span from 1990 to 2008, prices for imports of nonpetroleum consumer goods rose about 4 percent more than the PCE prices.

Figure 2 suggests that the import indexes might be missing some price declines, but comparisons of aggregate indexes like those shown in Figure 2 can be affected by differences in commodity composition or weights. If commodities with above-average rates of price growth are more heavily represented in the mix of items included in the nonpetroleum goods import index, declines in relative prices of imports might have occurred at the level of detailed items but have been masked in the more aggregated indexes by the mix effects.

TWO HYPOTHESES CONCERNING THE BEHAVIOR OF THE IMPORT PRICE INDEX

Newly Imported Products

Imports could gain market share through lower prices in two ways that would be difficult for the import price indexes to measure. First, when substitution from a domestic supplier to a foreign supplier involves a product that was not previously imported, that product constitutes a new good for purposes of the import price index. This means that it will be linked into the import price index in a way that avoids an effect on the index's level. If the newly imported product starts out priced on a par with competing domestic products (perhaps subsequently picking up market share by falling in relative price), and it is brought into the import index promptly, the index will not suffer any bias. (Of course, bringing the new import into the index promptly may not be easy, particularly if it does not fit into the preexisting product classification system used for the imports index.) Yet a more likely scenario for a newly imported product that succeeds in capturing a significant market share is that it already has a substantially lower quality-adjusted price than the domestic incumbents at the time of entry. If an imported product enters at a low price, a temporary state of disequilibrium may ensue as information about the price and quality of the newly available import diffuses and preexisting contracts with incumbent suppliers expire.

When entry occurs at a substantially lower price level than that prevailing in the marketplace, prompt linking of the new import into the buyers' price index is not sufficient to capture all the gains to buyers. A theoretical measure all of the gains would bring the newly imported product into the index by creating a hypothetical observation for the time period before the one in which actual purchases of the product begin with a quantity of zero and a price equal to the Hicksian virtual price (which is defined as the price that is just high enough to drive demand to zero). The consumer surplus from the drop from the Hicksian virtual price to the price at which purchases are first occur can then be measured by integrating the area under a compensated demand curve.

A practical approximation to this theoretical concept would use a Törnqvist, Fisher, or Fisher-like index formula and an estimated value of the virtual price at which quantity demanded would be zero. For example, if the entrant offers a quality level that is identical to that of the incumbent supplier, the Hicksian virtual price equals the price of the incumbent supplier. This principle was used by Griliches and Cockburn (1995) to argue that when a branded pharmaceutical goes off patent, the low-priced generic should not be linked into the CPI. Instead, the prices of the generic and its branded counterpart should be directly compared, with a quality adjustment for the generic that attributes half of the savings enjoyed by those consumers who substitute to the generic to a quality decline and counts the other half as a pure price reduction. Similarly, Reinsdorf (1993) argues that when consumers change their purchasing patterns to lower-priced discount outlets, linking the lower-priced outlets into the CPI would result in outlet substitution bias. As in the case of generic pharmaceuticals, the Hicksian virtual price for those consumers who substitute the discount outlet for the full-service outlet can be estimated by the price of the full-service outlet.

A buyers' price index that combined imported and domestic sources of supply could also properly account for the gains from the entry of a new product into the imports basket if the newly imported product matched the characteristics of a domestically supplied product. In the case of matching characteristics, the import could be brought into the buyers' price index as a directly comparable substitute, meaning that its price would be directly compared with the price of the domestically supplied item that it replaced. In addition, if the characteristics are not exactly identical, a direct quality adjustment could be made to the price of the imported item to allow it to be compared to its domestically supplied counterpart. In many cases, imported sources of supply will involve extra delivery lags, communications problems, and warehousing costs, so that even if the physical characteristics are identical to those of the domestic product that it replaces, some downward quality adjustment is warranted. In a buyers' price index, it might therefore be reasonable to treat a physically identical import the same way that a generic drug is treated in the CPI index for pharmaceuticals of Griliches and Cockburn (1995).

New Product Varieties

The second hard-to-measure way that imports could gain market share is through the entry of new *varieties* (or source countries) of products that are already present in the imports index's basket. A difficult challenge in the construction of import (and export) price indexes is that price changes tend to coincide with changes in product specifications. (This may be because foreign trade occurs under contracts that fix the price for the lifespan of the variety, and the signing of a new contract presents an opportunity to revise both the price and the item characteristics.) The effect on the price of a change in an item's characteristics is difficult to measure directly, so new varieties are usually linked in a way that avoids any effect on the index's level. This practice tends to result in an index that is artificially flat if the market is one in which price changes tend to be delayed until the item's characteristics are updated.

In contrast to the "new goods" hypothesis, which always implies an upward bias, the new varieties hypothesis implies that an upward bias in the import prices indexes arises only for items whose true price trend (including correctly measured quality change effects) is downward. Many electronic and technology-intensive goods do, in fact, have falling price trends, so a bias toward zero in the measured rate of price change could plausibly have a positive effect on the rate of growth of the aggregate import index for nonpetroleum goods.

Nakamura and Steinsson (2008) find that in the samples used to construct the imports indexes, prices frequently remain constant for the life of a quote (that is, for the length of time that the specific version of an item remains in the sample). Respondents tend to report a price change only at the time of a change in the version of the item that they import. When price and characteristics change simultaneously, separating the reported change in price into a quality change component and a pure price change component is difficult. Consequently, the new version of the product is typically linked into the index, which is equivalent to attributing *all* of the reported price change to quality change. The fraction of the observed price changes that are effectively treated as price changes of zero is high for some products in the import and export indexes. This is not the case of the CPI, because most products in the CPI do not behave in this way, and because the CPI uses hedonics or other methods to value characteristics changes for those products where price changes tend to coincide with characteristics changes.

USE OF CPIs FOR COMPARISONS

Construction of Suppliers' Price Indexes and Purchasers' Price Index

Although no buyers' index that allows price comparisons of imported and domestic-sourced products exists at the wholesale level or for intermediate inputs, buyers' indexes for final consumer goods do exist. In particular, CPIs for individual goods or classes of goods are buyers' indexes that can include both imported and domestically produced items.

Although the CPI does bring in some foreign-sourced items by linking, it appears to be less vulnerable to linking bias than the import price index. In the CPI, a foreign-sourced item would be directly compared to a domestic-sourced item if the consumer is thought to perceive their quality levels as the same. Furthermore, the CPI makes more use of direct quality adjustment techniques, such as hedonic regressions and suppliers' cost estimates, than do the import and export indexes.

On the assumption that some declines in prices paid by buyers from substitutions from domestic to imported versions of products and from substitutions between imported versions of products are reflected in the CPI but not in the imports price indexes, CPIs should tend to show lower inflation rates than import price indexes covering similar detailed items. In Figure 3, for example, the average rate of growth of tire prices is 4.1 percent in the import price indexes, but only 3.2 percent in the CPI. Moreover, if the growth rate of the CPI for tires is an average of true import price growth rate and the correctly measured growth rate of the PPI, the lower rate of growth of the CPI than of the PPI implies that true growth rate of the import prices must be below that of the CPI.

To take a more systematic approach to comparing import prices and CPIs for detailed items, we used BEA's industry accounts data to identify commodities included in PCE that are at least partly supplied by imports. The industry accounts also show the proportion of total domestic supply of each commodity that come from imports. Using this weighting information we constructed Fisher indexes that combine prices received by domestic producers (which BEA measures based on PPIs from BLS) and prices received by suppliers of imports (which BEA measures based on import price indexes from BLS). Even "producer prices" can include imports in BEA's industry accounts, at BLS "producer price indexes" do not include imports, so we term these indexes *suppliers' price indexes*.

Prices at the retail level include transportation margins, wholesale and retail distribution margins, and commodity taxes. Therefore, in addition to our indexes of suppliers' prices, we constructed *purchasers' price indexes* that combine the suppliers prices with price indexes for transportation and distribution margins and adjust for changes in commodity taxes. Our purchasers' price indexes represent predicted CPIs based on prices and weights from BEA's industry accounts. However, we are not entirely confident of the quality of some of the price indexes for distribution margins, so we will compare both our suppliers' price index and our purchasers' price index with a CPI at the most detailed level of aggregation that is available.

If we take the CPI and the supplier price index as given, the equation that expresses the log-change in the CPI as a weighted average of log-changes in the supplier price index and the price index for transportation and distribution margins and taxes contains only one unknown value, that of the price index for distribution margins and taxes. We can therefore solve this equation for the implied price index for the margin industry services and taxes. Assuming that the CPI is correct and that the quality of the match between the CPI and the suppliers' price index is good, an implausible value for this implied index would imply that the suppliers' index is biased. If we also assume that PPI is correct, then the bias in the suppliers' price index would have to come from its imports component.

Under the assumption that the prices of inputs into transportation and distribution are not changing and that tax rates are not changing, the rate of decline in the implied price index for the margin industries will equal their rate of productivity growth. If the implied productivity growth rate in transportation and distribution is implausibly high, that is evidence of either upward bias in the suppliers price index, downward bias in the CPI, or mismatch between the microlevel composition of the detailed CPI that we used and the microlevel composition of our suppliers index.

Aggregation as a Solution to the Problem of Poor Match Quality

At the level of detailed comparisons, the quality of the matches between CPIs and suppliers' price indexes is often dubious. However, if poor match quality is a source of random noise in the comparisons that is as likely to be positive as negative, a consistent pattern of implausibly high implied estimates of productivity growth in transportation and distributions would still suggest a systematic downward bias in the import indexes. In addition, the industry accounts data show the importance of each commodity in final uses in personal consumption expenditures (PCE), allowing us to use appropriate weights to aggregate commodities. Problems of misclassification become much less important at aggregate levels such as all durable goods, all nondurable goods, and all goods that have imported sources of supply. Therefore, comparisons made at aggregate levels are likely to be robust problems with matches between CPI items and our detailed suppliers' price indexes.

The main impediment to constructing good matches between CPIs and our suppliers' price index is that the most detailed CPIs available are generally broader in coverage than the commodity categories in the industry accounts. For example, fur coats are a commodity in our industry accounts data, but BLS does not publish a CPI for fur coats. We therefore had to match fur coats to a CPI for women's coats in general. To give another example, we matched boat building in the industry accounts to a CPI for recreational vehicles including bicycles. The unavailability of sufficiently detailed CPIs means that at the level of individual items, many of the comparisons of CPIs to our suppliers and purchasers indexes do not hold the commodity mix constant. This problem becomes less severe when detailed items in the industry accounts are aggregated.

Two other caveats are also worth noting. First, the indexes that we use have positive variances, which we have not attempted to estimate. Second, the import price indexes exclude tariffs, but tariffs undoubtedly influence the retail prices for imported items that are measured by the CPI. Tariff rates have trended down in recent decades, so declines in tariffs have probably acted to reduce the growth rate of the CPIs compared to those of the import price indexes. Nevertheless, for most items with significant volumes of imports, average effective tariff rates started out at low levels, so most of the reductions during the period covered by our sample were modest.

EMPIRICAL RESULTS

Suppliers' Price Index Comparisons

Differences in average annual growth rates of suppliers' indexes from matched CPIs between 1997 and 2007 are shown in the first column of Table 1. For most nondurables types of goods, the indexes of suppliers' prices do not differ significantly from their CPI counterparts. Indeed, in the cases of food and alcoholic beverages, the difference in growth rates is zero after rounding.

For the other categories of goods, however, the suppliers' indexes rise more than their CPI counterparts. In the case of apparel and textiles, the growth rate of the suppliers' price index exceeds that of the CPI by 1.5 percent per year. At the retail level, seasonal apparel items tend to enter at a high price at the beginning of the selling season, then go on sale later in the selling season before they exit the marketplace. This pattern of falling prices during the life of a quote would cause downward bias in the CPI if at the beginning of a selling season quotes tend to enter the index via linking rather than via a comparison with the final price of the previous selling season. However this problem appeared to have been largely resolved in 1991 when hedonic methods were introduced into the CPI for apparel.

Another factor that likely contributes to the gap between the apparel indexes' growth rates is the use of different index formulas to construct elementary aggregates. A geometric mean index formula is used to construct most of the elementary aggregates in the CPI, including apparel, but a Laspyeres-like formula is used in the IPP and the PPI. Geometric mean indexes have a number of desirable axiomatic properties that Laspyeres-like indexes lack, and under certain assumptions they do a better job of accounting for substitution behavior. The dataset used in Feenstra et al. (2009) shows that the effect of changing to a Törnqvist formula (which resembles a geometric mean formula) on the import price indexes would reduce the growth rate of the apparel indexes by about 0.3 percent per year. On the other hand, comparisons of the CPI-Uto the CPI-RS from 1991 to 1998—years when the CPI-U did not use geometric means—imply that the effect of adopting the geometric mean formula on the CPI for apparel is about 1.3 percent per year. Such a large effect is troubling, as it suggests that quotes linked out of the index at sale prices may have a disproportionate effect on the geometric mean formula. Thus, downward bias in the CPI for apparel could account for some of the gap between its growth rate and that of the suppliers' index. The gap between the suppliers' index and the matched CPI for apparel is not large enough to constitute evidence of the existence of an upward bias in the imports price index considering the possible presence of downward bias in the CPI and the noisiness in the index comparisons arising from differences in index composition.

On the other hand, for durable goods other than motor vehicles, the growth rate gaps are larger than for apparel. The most troubling growth rate discrepancies are for computers and related equipment, where the suppliers' price index grows 6.4 percent per year faster than the CPI, and other electronic equipment, where it grows 4.2 percent per year faster. However, even for durables in general, the growth rate gap is pretty high, at almost 2 percent per year.

Purchaser Price Index Comparisons

Adding in distribution and transportation margins to obtain purchasers' price indexes makes the growth rate gaps smaller for nondurable and apparel, reducing the overall average gap from 1 percent per year to 0.6 percent per year, or from 1.1 to 0.7 percent per year if tobacco is excluded. (Note however, that to be in our sample, an item in the industry accounts needed to have positive imports, few or no missing values, and a CPI counterpart, so "all items" in our sample covers only about 20 percent of personal consumption expenditures on nonenergy goods.) Indeed, a number of nondurable goods have negative growth rate differences between their purchasers' price index and the corresponding CPI.

On the other hand, the growth rate differentials for most apparel items still remain above 1 percent per year. What is more, the product categories with large gaps between their CPIs and their suppliers' indexes have even larger growth rate gaps using a purchasers' index. In particular, the growth rate gap for electrical equipment excluding computers rises to 4.7 percent per year, while the growth rate gap for computers and related equipment rises to 11.6 percent per year.

The electronic and computer items have falling CPIs, so the upward bias in their import indexes is consistent with Nakamura and Steinsson's (2009) theory that a pattern of price changes coinciding with linking causes excessive flatness in the import indexes.[143] Furthermore, in the case of tobacco products, the negative gaps of the suppliers', purchasers', and import price indexes compared with the CPI are also consistent with the hypothesis of artificial flatness in the imports index, as these products have high rates of price growth in the CPI.

Similarity of PPIs and Import Price Indexes for Certain Items

Simple comparisons of import price indexes with corresponding aggregates of domestic prices as measured by producer price indexes can also shed light on relative growth rates of the import indexes. In constructing the aggregates used for these comparisons, we weight the indexes for detailed commodities in proportion to the importance of these commodities in final goods uses as measured in the industry accounts.

These comparisons also suggest the presence of an upward bias in the import index for durable goods, but not in other categories of goods. In the case of nondurable goods, domestic prices at the producer level rise faster than prices at the consumer level, while import prices rise more slowly than consumer prices. Thus, the closeness of the suppliers' indexes to the CPIs is a result of offsetting effects of slow growth in import prices and fast growth in producer prices. For apparel and textile items, import and domestic producer prices both differ from CPI growth rates by about +1.5 per cent per year. However, for durable goods, the growth rate of import indexes is 2.3 percentage points *above* that of the corresponding CPI and 0.7 (= 2.3 – 1.6) percentage points above that of domestic producer prices. For computers and peripherals, domestic producer prices fall nearly as fast as the CPI, but the growth rate of import index is about 11.8 percent per year above that of the rapidly falling CPI.

Implied Productivity Growth in Transportation and Wholesale and Retail Distribution

Under neoclassical assumptions, the difference between the growth rate of the price index for the output of an industry and the price index for the inputs that it uses is an estimate of its productivity growth. Price indexes for labor and other inputs are unlikely to have growth rates

[143] From January 1998 to September 2003, CPI computer price indexes used hedonic regressions for quality adjustment, and since then these indexes have used direct methods to estimate attribute values. These techniques allow measurement of price changes that are time to coincide with changes in attributes.

below zero, so reversing the sign of the growth rate of the implied price index for transportation and distribution services gives a lower bound estimate of productivity growth in these services.

Solving for the price index for transportation and distribution services that would explain the difference between our suppliers price index and the matched CPI, we find a plausible positive rate of growth for nondurables other than apparel of 1.3 percent per year and a not inconceivable growth rate for apparel and textile products of -2.5 percent per year (Table 2). On the other hand, for durable goods the implied price change for transportation and distribution is about -8 percent per year, which is too low to be believed. For computers and peripherals, the implied growth rate is almost -30 percent per year. Although strong productivity growth in distribution services is plausible, rates as high as 8 percent per year or more are not plausible. They therefore suggest that the difference between the growth rates of the import and domestic producer price indexes and the growth rate of the CPI is too large to be correct.

RELATION BETWEEN IMPORTS AND WHOLESALE AND RETAIL DISTRIBUTION MARGINS

Price reductions that are realized by substituting foreign sources of supply for final consumption items for domestic ones are unlikely to be completely passed on to consumers. Instead, some of these price reductions are likely to result in expansions of margins received by the wholesale and retail distribution sectors. One reason for this is that more distribution services are required to set up and manage international supply chains. In addition, distributors are likely to have higher inventory costs and greater risks of being stuck with unwanted inventory when suppliers are distant and turnaround times for restocking are long. In addition, while the process of switching to foreign sources of supply is under way, markets are likely to be in a temporary disequilibrium that allows early switchers to earn economic rents.

To test whether higher proportions of imports in the overall domestic supply of a commodity are associated with higher distribution margins, we regress trade margin levels and growth rates on import share levels and growth rates. The regression in Table 3 implies that a 10 percent increase in the share of domestic supply sourced from imports is associated with a 1.3 percentage point expansion in the distribution margin.

Commodities that are heavily imported—such as apparel—might also have characteristics that require lots of distribution services. If so, import share could be a proxy for the types of characteristics that make a commodity require more distribution services, resulting in upward bias in the regression coefficient in Table 3. We therefore also test for a relationship between the growth of imports as a share of total commodity supply and the growth of distribution margins. The growth rate regression also shows a positive and statistically significant relationship between imports and distribution margins (Table 4). The regression coefficient implies that a commodity with a 10 percentage point increase in its import share would have 0.93 percentage points more growth in its margin rate than a commodity with no change in its import share. Thus, the theoretical prediction of a link between imports and margins received by the distribution industries finds some empirical support.

CONCLUSION

The increased international engagement of the U.S. economy has enhanced the roles of the import and export price indexes in the measurement of real output growth. For imported final goods that enter personal consumption expenditures in the NIPAs, an upward bias in the import index would result in upward bias in the measure of GDP; these items are deflated by an import index in the M component of the formula GDP = C + I + G + X – M but then deflated by a consumer price index when they reach the C component.

In the case of nondurable goods, comparisons of import indexes and of suppliers' and purchasers' price indexes with CPIs at the most detailed level possible given the available data indicate no systematic differences in behavior of these indexes. But for apparel and textile items, the import prices seem to grow faster than CPIs by about 1.5 percent per year, and for durable goods they seem to grow faster by more than 2 percent year. A very large discrepancy of over 11 percent per year for computers contributes significantly to this discrepancy for durable goods. Furthermore, the implied rates of change in prices for transportation and distribution services for durable goods are implausibly negative. The index comparisons therefore suggest the presence of a significant upward bias in the import price indexes for some types of durable goods, especially computers, as well as the possible presence of a modest upward bias in the import indexes for apparel. Nevertheless, these comparisons are not definitive evidence of the existence of a problem because the CPIs used in the comparisons often differ in their detailed item composition from the indexes with which they are compared.

The results in this paper are consistent with Nakamura and Steinsson's finding of a bias toward zero in the rate of growth of the import price indexes caused by linking out of a large fraction of the price changes that occur. The substantial positive discrepancies between the growth of the import index and the growth of the CPIs occur for the apparel and durable goods items that have falling CPIs, and the largest negative discrepancy occurs for an item with a very high growth rate in the CPI, tobacco products. Further research on solutions to the linking problem identified by Nakamura and Steinsson could yield important benefits for our measures of import and export prices, and improve our measures of the growth of output and productivity, especially at the industry level.

Finally, we note that if any bias that is present in the import indexes is matched by a similar bias in the export indexes if exports and imports had the same nominal value, the net effect of the two biases on our estimates of real GDP growth would be zero. However, complete cancellation is unlikely to occur in practice because exports of goods are less than imports of nonpetroleum goods (the difference is between 2 and 4 percent of GDP in most of the years in our sample) and because some sources of upward bias in the import indexes are either not present or less important on the export side. In particular, imported versions of many products are likely to have entered the U.S. market at a significantly lower price level than the incumbent domestic version of the product. This results in a gain to consumers that should theoretically be accounted for by use of a high Hicksian virtual price in period before entry was observed to bring the imported version into the import index. Yet on the export side, when new opportunities to export a particular product arise, the Hicksian virtual price would be lower than the first observed selling price, implying the presence of a *downward* bias in the export index. Alternatively, we could model new exports as having been caused by positive technology shocks to exporters and ask how much lower the first observed price is than the virtual price at which exports would first become profitable with technology held constant at the new level. This would yield a correction of the same sign as the one that is applicable to the import index. Yet growth of exports has been less than growth of imports, and the value of the export products that could reasonably be modeled in this way is undoubtedly less than the value of the new types of imports.

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Nakamura, Emi, and Jón Steinsson. 2009. "Lost in Transit: Product Replacement Bias and Pricing to Market." NBER Working Paper 15592. Cambridge, MA: National Bureau of Economic Research.

Figure 1: Nonpetroleum Goods Imports as Percent of GDP, PCE Goods and PCE Goods+Investment

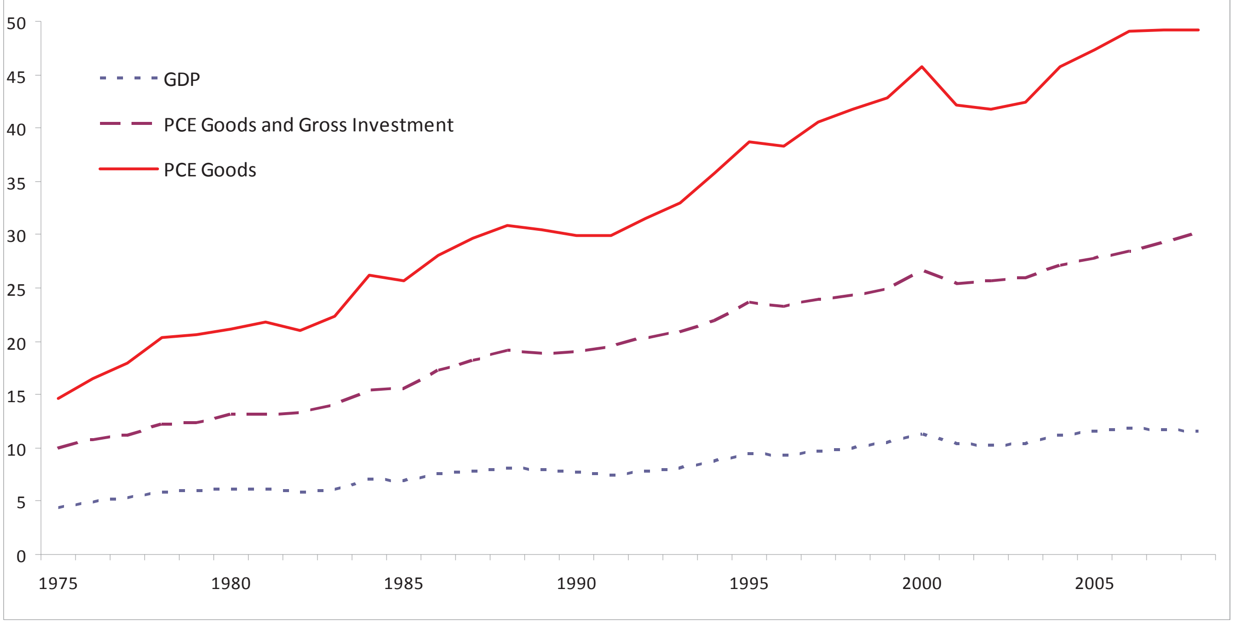
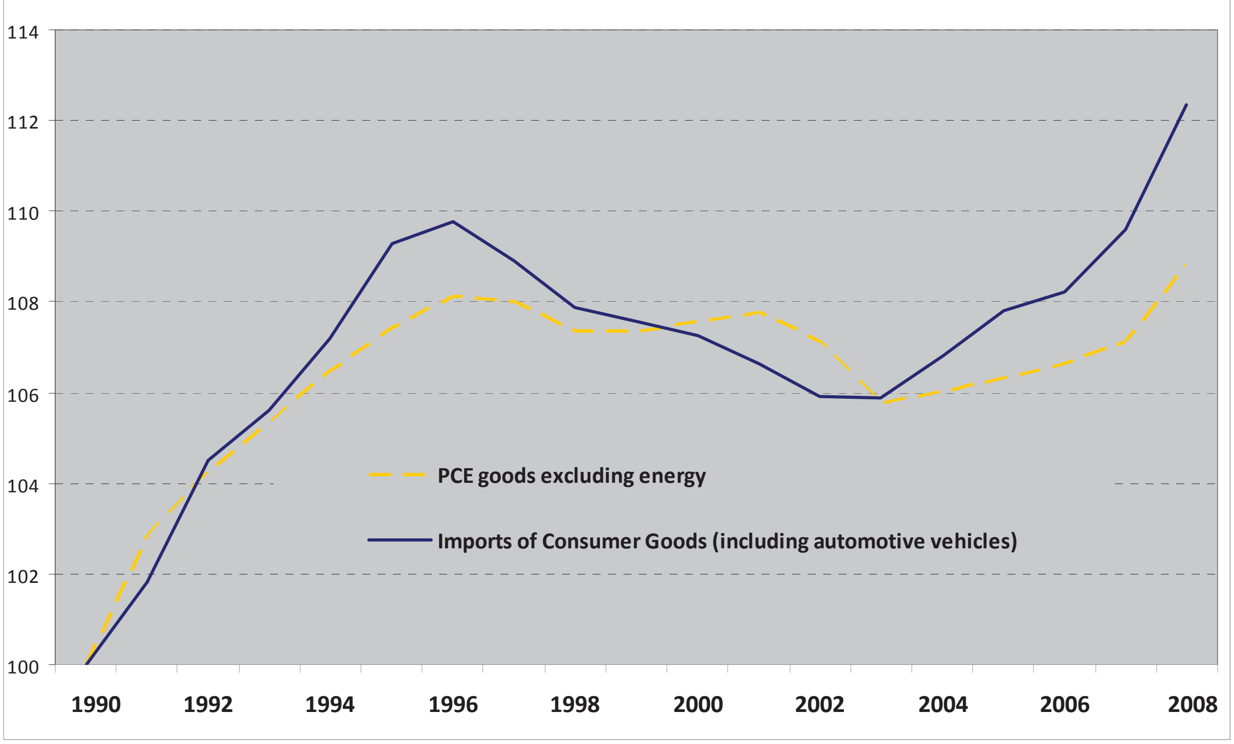


Figure 2: Price Indexes for Consumer Good Imports and for Personal Consumption Expenditure Goods ex Energy



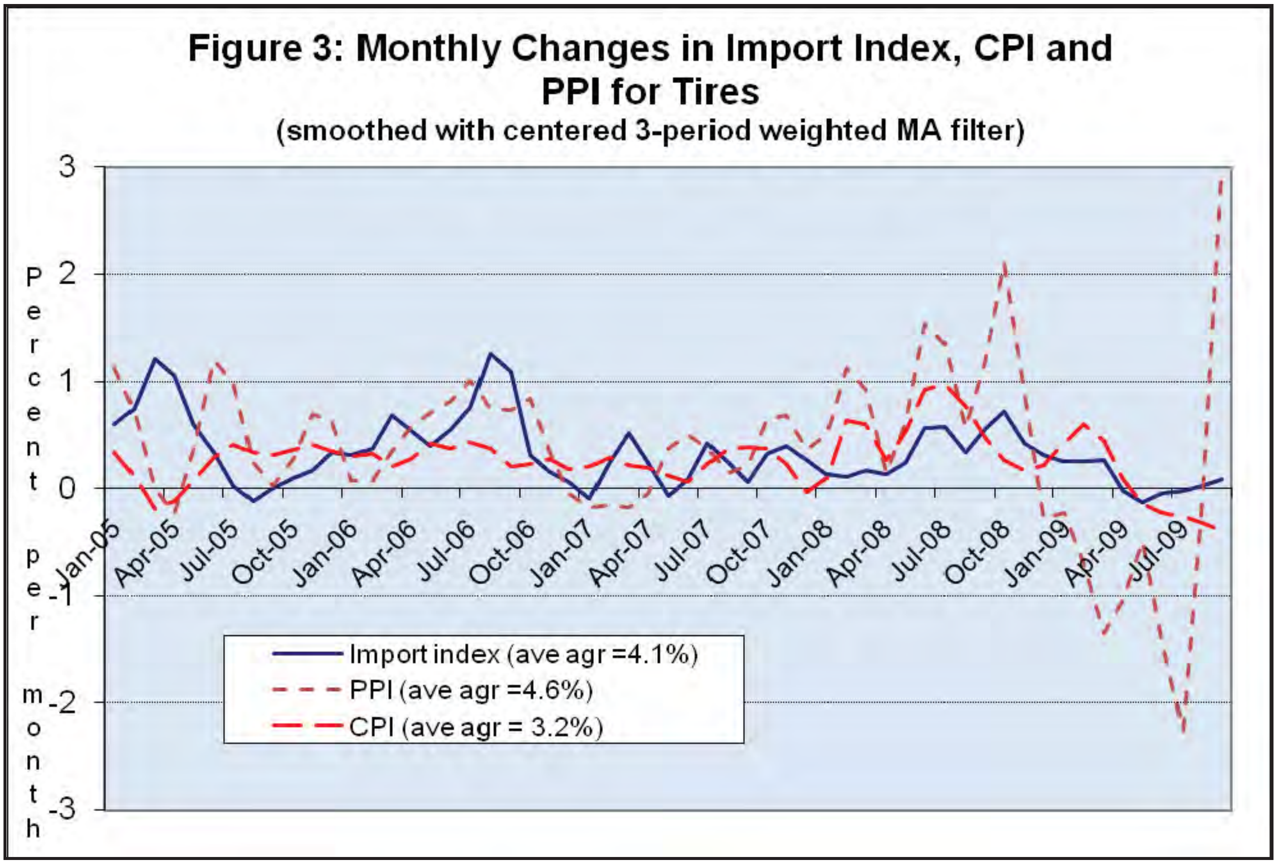


Figure 3: Monthly Changes in Import Index, CPI and PPI for Tires
(smoothed with centered 3-period weighted MA filter)
Percent per month
3
2
1
0
-1
-2
-3
Jan-05
Apr-05
Jul-05
Oct-05
Jan-06
Apr-06
Jul-06
Oct-06
Jan-07
Apr-07
Jul-07
Oct-07
Jan-08
Apr-08
Jul-08
Oct-08
Jan-09
Apr-09
Jul-09
Import index (ave agr =4.1%)
PPI (ave agr =4.6%)
CPI (ave agr = 3.2%)

Table 1: Growth Rate Differences from Matched CPIs of Suppliers and Purchasers Price Industry,1997-2007

	Difference from Matched CPI				MEMO: Index of Matched CPIs
	Suppliers' prices	Purchasers' prices	Import Prices	Domestic Prices	
Nondurables ex apparel	**0.3**	**-0.6**	**-0.6**	**0.6**	**2.2**
Food	0.0	-0.7	0.1	0.0	2.1
Alcohol	0.0	-0.6	-0.5	0.0	1.9
Misc. household supplies	0.6	-0.1	-0.2	1.3	1.5
Paper products, books and magazines	1.1	0.2	-0.4	1.1	1.4
Tobacco products	-0.6	-3.3	-6.6	-0.5	8.1
Durables	**1.9**	**2.0**	**2.3**	**1.6**	**-2.2**
Motor vehicles and parts	0.2	0.2	0.7	-0.1	-0.1
New cars and trucks	0.4	0.5	1.2	-0.2	-0.6
Electrical equipment ex. computers	4.2	4.8	3.5	4.3	-5.6
Computers, peripherals and software	6.4	11.7	11.8	3.8	-20.8
Furniture and wood products	2.3	1.4	1.5	2.5	-0.6
Clocks and watches	1.8	1.7	1.8	1.9	-1.4
Tools, hardware and supplies	1.8	0.9	1.7	1.7	-0.2
Other durables	3.0	1.9	3.1	2.4	-0.8
Apparel and textiles	**1.5**	**1.4**	**1.5**	**1.5**	**-1.2**
Women's and girls' apparel	1.9	1.7	1.9	1.8	-1.5
Men's and boy's apparel	1.3	1.4	1.4	0.7	-1.5
Other apparel	2.4	1.7	2.4	2.4	-1.2
Footwear	0.6	0.5	0.6	1.2	-0.4
Textile and sewing products	1.5	1.1	1.4	1.6	-0.8
All products	**1.0**	**0.6**	**0.7**	**1.1**	**0.2**
All products ex tobacco	**1.1**	**0.7**	**1.0**	**1.1**	**-0.1**

Table 2: Growth Rates of Price Index for Transportation and Distribution Services implied by Difference between Suppliers Price Index and Matched CPI, 1997-2007

	Implied price index for Transport & Distribution	Actual price index for Transport & Distribution
Nondurables ex. apparel	**1.3**	**0.5**
Food	2.2	0.2
Alcohol	1.9	0.9
Misc. household supplies	1.1	0.3
Paper products, books and magazines	0.3	0.4
Tobacco products	8.7	2.4
Durables	**-7.9**	**0.1**
Motor vehicles and parts	-1.3	0.3
New cars and trucks	-1.8	0.4
Electrical and electronic equipment ex. Computers	-11.0	0.2
Computers, peripherals and software	-29.7	0.1
Furniture and wood products	-2.7	0.0
Clocks and watches	-1.7	0.1
Tools, hardware and supplies	-1.8	0.0
Other durables	-3.3	0.1
Apparel and textiles	**-2.5**	**-0.0**
Women's and girls' apparel	-3.0	-0.0
Men's and boy's apparel	-2.6	-0.0
Other apparel	-3.0	0.0
Footwear	-0.9	0.0
Textile and sewing products	-2.2	0.0
All products	**-0.8**	**0.3**
All products ex tobacco	**-1.2**	**0.2**

Table 3: Regression of Average Level of Distribution Margin on Share of Domestic Supply from Imports

	Coefficient	t statistic
Intercept	0.3663	29.8
Share supplied by imports	0.1290	4.3
Growth of share of imports	0.0985	1.4

Table 4: Regression of Growth of Distribution Margin from 1997 to 2006 on Share of Domestic Supply from Imports

	Coefficient	t statistic
Intercept	0.0067	1.2
Share supplied by imports	0.0272	1.9
Growth of share of imports	0.0934	2.8

SESSION 6: MEASUREMENT OF IMPORT AND INPUT PRICES

CHAIR: Julia Lane (National Science Foundation)

Offshoring and the State of American Manufacturing, Susan Houseman (Upjohn Institute), Christopher Kurz (Federal Reserve Board), Paul Lengermann (Federal Reserve Board), and Benjamin Mandel (Federal Reserve Board)

Producing an Input Price Index, William Alterman (Bureau of Labor Statistics)

DISCUSSANT: Emi Nakamura (Columbia University)

Offshoring and the State of American Manufacturing

Susan Houseman+
Christopher Kurz*
Paul Lengermann*
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June 2010

ABSTRACT

The rapid growth of offshoring has sparked a contentious debate over its impact on the U.S. manufacturing sector, which has recorded steep employment declines yet strong output growth—a fact reconciled by the notable gains in manufacturing productivity. We maintain, however, that the dramatic acceleration of imports from developing countries has imparted a significant bias to the official statistics. In particular, the price declines associated with the shift to low-cost foreign suppliers generally are not captured in input cost and import price indexes. To assess the implications of offshoring bias for manufacturing productivity and value added, we implement the bias correction developed by Diewert and Nakamura (2009) to the input price index in a growth accounting framework, using a variety of assumptions about the magnitude of the discounts from offshoring. We find that from 1997 to 2007 average annual multifactor productivity growth in manufacturing was overstated by 0.1 to 0.2 percentage point and real value added growth by 0.2 to 0.5 percentage point. Furthermore, although the bias from offshoring represents a relatively small share of real value added growth in the computer and electronic products industry, it may have accounted for a fifth to a half of the growth in real value added in the rest of manufacturing.

JEL Classification Codes: O41, O47, F14, L60
Key Words: offshoring, manufacturing, price measurement, productivity, output growth

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Offshoring and the State of American Manufacturing

Developing economies have become the new, low-cost suppliers of a wide range of products purchased by consumers and used as intermediate inputs by producers, with China—now the largest exporter to the United States—accounting for about a third of the growth in commodity imports over the last decade. The rapid growth of offshoring—defined as the substitution of imported for domestically produced goods and services—contributed to a ballooning trade deficit and sparked a contentious debate over its impact on the U.S. manufacturing sector, which shed 20 percent of its employment, or roughly 3.5 million jobs, from 1997 to 2007. Concerns over employment losses and the trade deficit have prompted a recent spate of government and private sector proposals to revitalize manufacturing.[144]

Our paper highlights the dramatic growth of offshoring and the structural changes occurring in manufacturing in the decade prior to the current recession. During this time, more than 40 percent of imported manufactured goods were used as intermediate inputs, primarily by domestic manufacturers. Using a growth accounting framework, we examine the contributions to the growth in real (constant price) domestic shipments in manufacturing from the inputs to production and from multifactor productivity (MFP). A novel feature of our analysis is that we distinguish between imported and domestic materials inputs, which enables us to more closely examine offshoring by manufacturers. We find substantial evidence of offshoring. The contribution from imported materials to the growth in real manufacturing shipments was larger than that of any other factor input and was more than twice the contribution from capital. At the same time, contributions from domestic materials and, reflecting declining employment, labor were negative.

In spite of the steep employment declines in manufacturing, official statistics indicate that real value-added growth in U.S. manufacturing was robust, increasing almost as quickly as that for all nonfarm business. What happened in manufacturing? As put by former Labor Secretary Robert Reich (2009), "In two words, productivity growth." Indeed, the disparate trends in manufacturing—steep employment declines and strong output growth—are reconciled in the data by high productivity growth. While Reich and others have cited the strong output and productivity figures as evidence of the strength of the American manufacturing, we discuss reasons to qualify this conclusion.

First, the robust output and productivity growth in manufacturing is largely attributable to one industry: computer and electronic products manufacturing. The average annual growth rate of value added in manufacturing excluding computers—which accounted for about 90 percent of manufacturing value added throughout the period—was less than a third of the published growth rate for all manufacturing. As a result, the aggregate numbers do not accurately characterize trends in most of manufacturing.

Second, the price declines associated with the shift to low-cost foreign suppliers generally are not captured in price indexes. The problem is analogous to the widely discussed problem of

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[144] See, for example, Executive Office of the President (2009), Helper (2008), New America Foundation (2010), Pisano and Shih (2009), Pollin and Baker (2010), and Surdna Foundation (2010).

outlet substitution bias in the literature on the Consumer Price Index (CPI). Just as the CPI fails to capture lower prices for consumers due to the entry and expansion of big-box retailers like Wal-Mart, import price indexes and the intermediate input price indexes based on them do not capture the price drops associated with a shift to new low-cost suppliers in China and other developing countries. A bias to the input price index from offshoring implies that the real growth of imported inputs has been understated. And if input growth is understated, it follows that the growth in MFP and real value added have been overstated.

Building upon Diewert's (1998) characterization of the bias from outlet substitution to the CPI, Diewert and Nakamura (2010) demonstrate that the bias to the input price index is proportional to the growth in share captured by the low-cost supplier and the percentage discount offered by the low-cost supplier. Although the actual input price changes from offshoring are not systematically observed, evidence from import price microdata from the Bureau of Labor Statistics (BLS), industry case studies, and the business press indicate that there are sizable discounts from offshoring to low-wage countries.

If this evidence is representative of the actual discounts manufacturers realized from offshoring, then the biases to MFP and value-added growth may well be significant. We estimate that average annual MFP growth in manufacturing was overstated by 0.1–0.2 percentage points and real value-added growth by 0.2–0.5 percentage points from 1997 to 2007. And, although the bias from offshoring represents a relatively small share of real value-added growth in the computer industry, it may have accounted for one-fifth to one-half of the growth in real value added in the rest of manufacturing. Moreover, our work only examines biases to manufacturing statistics from the offshoring of material inputs. Additional biases may have arisen from the substitution of imported for domestically produced capital equipment and from the offshoring of services.

These biases have implications not only for the industry statistics, but also for the analyses based on them. Because the growth of these imports will be understated in real terms, offshoring will, at least to some degree, manifest itself as mismeasured productivity gains. As a result, studies that endeavor to assess the impact of low-cost imports on the American economy and its workers may well understate the true effects.

INTERNATIONAL TRADE AND THE STATE OF AMERICAN MANUFACTURING

One of the most important developments in the U.S. economy in recent years has been the rapid growth of trade. After being little changed in the early 1990s, the total value of imports and exports of goods and services jumped from roughly 20 percent of U.S. GDP to 28 percent prior to the recent downturn. About 80 percent of the increase was attributable to a run up in the value of imports. The growth of nonoil imports was the most important contributor to the increase in imports during this period, and nonoil goods imports—largely manufactured goods—accounted for almost half of total import growth, while oil accounted for about a third and services for the remainder.[145]

[145] BEA data on the trade in services in 2008 indicate that 59 percent was travel, transport, royalties, and education related, while the remaining 41 percent was business services.

The surge in the imports of manufactured goods—more than 100 percent from 1997 to 2007—reflects both an increase in the import share of goods for final consumption as well as the import share of intermediate inputs. According to the BEA, the import share of intermediate material inputs used by manufacturers increased from under 17 percent in 1997 to 25 percent in 2007.[146] Figure 1 plots this substantial shift in the sourcing of intermediates from domestic to foreign suppliers.

Also in Figure 1 the imported intermediate materials are classified by type of source country—developing, intermediate, and advanced. We classify countries with less than 20 percent of U.S. per capita GDP in 2008 as developing, and with a few exceptions, countries with per capita GDP equal to or exceeding two-thirds that of that in the United States as advanced. The remaining countries are classified as intermediate.[147] Developing countries accounted for half of the growth in foreign materials inputs, with much of that growth coming from China. Intermediate countries, such as Mexico, accounted for about a third of the growth.

How has the manufacturing sector performed given the growth of imports from low-wage countries? In particular, has the substantial shift in sourcing "hollowed out" manufacturing or instead contributed to the emergence of a leaner, more efficient industrial sector? On the one hand, dramatic drops in employment are often taken to portray a sector in decline. The precipitous decline in manufacturing employment since the late 1990s is evident in Figure 2 and is coincident with the rise in foreign sourcing. Employment never rebounded after the 2001–2002 recession as it had following previous downturns. Indeed, in the decade leading up to the current recession, manufacturing employment declined by 20 percent, while manufacturing's share of employment in the economy fell from 14 percent in 1997 to 10 percent in 2007 (Figure 3). Reflecting plant closures that accompanied the employment declines, the net number of manufacturing establishments fell by 10 percent from 1998 to 2007. At the same time, the nominal share of manufacturing value added in GDP fell from 15.4 percent in 1997 to 11.7 percent in 2007.

Statistics on manufacturing production, however, paint a much more favorable picture of the sector. From 1960 to 2009, the average annual rate of change in real nonfarm business output was 3.5 percent, only slightly higher than the 3.2 percent average annual change for manufacturing.[148] More recently, from 1997 to 2007, the average annual growth rate of real manufacturing production was 3 percent, almost the same as the 3.1 percent growth for all

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[146] Government surveys do not explicitly track the destination of imports to final and intermediate uses. In the data we employ within this paper, the BEA assumes that an industry's use of a specific import is in proportion to its overall use of that commodity in the economy, i.e., the import comparability or proportionality assumption.

[147] The main exceptions are Middle Eastern oil producers, which we classify as intermediate countries.

[148] Although the average growth of manufacturing has been fairly close to that of the economy as a whole, the sector has typically exhibited greater cyclical swings. As a result, the sector tends to make outsized contributions to changes in GDP growth during economic turning points (Corrado and Mattey 1997). In addition, the relatively faster gains in manufacturing productivity have resulted in lower relative goods prices, which, in combination with inelastic demand for goods (on average), has led to a decline in manufacturing's share of nominal output.

private industry.[149] Moreover, cross-country comparisons show larger production gains in U.S. manufacturing relative to other advanced industrial countries, according to OECD data.

The divergent trends of employment declines and plant closures, on the one hand, and rapid growth in real value added, on the other, are primarily reconciled through the lens of productivity. The steadily increasing series displayed in Figure 3 shows the ratio of output per hour in manufacturing to output per hour in all nonfarm business since 1960; the series indicates that labor productivity grew considerably faster in manufacturing throughout the period. Indeed, the average annual growth rate of labor productivity in manufacturing during 1997 to 2007 was 4.1 percent compared to 2.7 percent for all nonfarm business. Manufacturing labor productivity also grew substantially faster in the United States than in most other major industrialized countries during that decade (see BLS 2009). The rapid growth in labor productivity has more than offset the declines in labor input and has permitted firms to sustain robust growth in real value added.

Analysts have pointed to the robust output and productivity growth to argue that the manufacturing sector is relatively healthy.[150] Our work, however, suggests the story is more complex. The aggregate numbers are unrepresentative of the trends in most of manufacturing. Moreover, we find that the performance of U.S. manufacturing has been overstated to some extent in the official statistics because of offshoring.

EVIDENCE OF OFFSHORING BY MANUFACTURERS

We begin our analysis by examining the sources of the growth in manufacturing. Toward this end, we utilize a standard growth accounting framework in which output is defined as manufacturing shipments adjusted for price changes—termed real gross output. We decompose growth into the parts resulting from the growth of inputs to production—capital, labor, services, energy, and materials inputs—and MFP growth, which is computed as a residual. In other words, MFP growth is the part of output growth that cannot be accounted for by the growth of factor inputs, and therefore represents the returns to all factors of production.[151]

As mentioned, a novel feature of our analysis is that we distinguish between domestically sourced and foreign materials inputs. Specifically, we use unpublished BEA data on the value of

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[149] With the BEA's May 2010 comprehensive revision to the annual industry accounts, manufacturing output now expands at a slightly faster rate during this period. The analysis throughout this paper is based upon the previous vintage of these data published in 2009.

[150] This perspective is illustrated by Executive Office of the President (2009), which emphasizes the strength of output and productivity and growth of U.S. manufacturers vis-à-vis the aggregate economy and manufacturers in other industrialized countries and which largely attributes employment declines to productivity growth. Recent articles in the popular press also have advanced this view (e.g., *Economist* 2005; Murray 2009).

[151] See Jorgenson, Gollop, and Fraumeni (1987) and Hulten (2009) for more on the growth accounting methodology, its early development, and current applications. The industry-level data for output, materials, energy, and services come from the BEA's GDP-by-industry accounts. Capital services inputs for are derived from the BEA's fixed asset accounts. The labor input is based on industry-level hours worked from the national income and product accounts, adjusted for changes in the worker composition effects using wage data from the Census Bureau's county business patterns.

imports and imported input prices at a detailed commodity level to distinguish between the growth of domestic and imported materials inputs.
Using these data, we compute MFP growth for manufacturing as the growth in real gross output ($\hat{Q}$) less a weighted average of the growth rate of labor ($\hat{L}$), capital ($\hat{K}$), energy ($\hat{E}$), services ($\hat{S}$), domestic materials ($\hat{M}^D$), and foreign materials ($\hat{M}^F$) inputs:

(1) $$\widehat{MFP} = \hat{Q} - \left[w^L \hat{L} + w^K \hat{K} + w^E \hat{E} + w^S \hat{S} + w^{m^D} \hat{M}^D + w^{m^F} \hat{M}^F \right]$$

The weights (*w*) on each input represent the input's share of total input costs. Any error in the measurement of input growth—including errors that result from biased price indexes used to deflate the inputs—will directly result in an error in the measurement of productivity growth.

Equation (1) can be rearranged to obtain an identity in which output growth is decomposed into MFP growth and contributions from the growth of factor inputs. Table 1 provides the results of this decomposition for manufacturing and selected industry breakouts from 1997 to 2007. Note that the figures in column (1), which represent the average annual real output growth rate over the period, equal the sum of the figures in columns (2) through (8), which represent the contributions to output growth from MFP and from the growth of the indicated inputs.

Several striking findings emerge from this table. One is the strong MFP growth. The contribution to real output growth from MFP actually exceeds real gross output growth, indicating that MFP can account for *all* of the growth in real gross output over the decade. Capital, purchased services, and materials all play important, albeit more modest, roles, while the contribution of labor is negative and large, reflecting the steep employment declines during the period.[152]

Columns (7) and (8) in Table 1 provide a clear picture of the rapid pace of structural change currently under way in U.S. manufacturing. During the period, the contribution of domestically supplied materials inputs fell, while that of imported materials inputs greatly expanded, reflecting the substitution of foreign for domestic intermediate inputs. The growth of imported intermediate inputs, to some degree, will also reflect the direct substitution of imported goods for domestic labor and capital. To see this, consider the case in which a firm previously produced an intermediate input and final product internally, but now sources that input from a foreign supplier. In this instance, gross output will not change, but imported materials inputs will rise and the labor and capital previously used to produce the input will fall.

For all manufacturing, the contribution of imported materials inputs to output growth was greater than that of any other factor of production and was more than double the contribution from capital. For manufacturing excluding the computer industry, imported materials account for 60 percent of the growth during this period.

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[152] The growth accounting results in Table 1 reflect the authors' calculations and rely on a different methodology than what is used by the BLS. However, these two salient features of the data are also observed in the BLS estimates. A full reconciliation of the two approaches appears in Houseman et al. (2010).

Another striking result in Table 1 is that computer and electronic products manufacturing—which includes computers, semiconductors, and telecommunications equipment—accounts for most of the output and productivity growth in manufacturing over the period.[153] Output and productivity growth in the computer industry averaged 7.4 and 6.8 percent per year, respectively, compared to growth of only about 0.5 percent for output and 0.7 percent for MFP in the rest of manufacturing. The extraordinary productivity and output growth in computers reflects, to a large degree, technological improvements of the products produced and output price deflators that, when properly adjusted for product improvements, are often falling rapidly.[154]

Throughout the decade, the computer industry's share of manufacturing value added remained relatively constant at around 10 percent. Because manufacturing output and productivity statistics are strongly affected by the computer industry, which represents such a small share of the sector, researchers should be cautious in drawing general inferences about manufacturing from the aggregate numbers. It also bears note that statistics on industry output and productivity growth should be interpreted in relation to growth in demand for the industry's products. Indeed, in spite of rapid value added and productivity growth of computers and electronic products manufacturing during the decade, the trade deficit within this product group greatly widened and substantial offshoring of components of the industry occurred (Brown and Linden 2005; Linden, Dedrick, and Kraemer 2009).

Because statistics on labor productivity, defined as output per hour worked, are widely used in research and policy analyses, it is also of interest to consider the relationship between labor productivity growth and offshoring. In the official BLS labor productivity release, manufacturing output includes imported intermediates but excludes intermediates sourced from within the domestic manufacturing sector. As a result, shifts in sourcing from a domestic to a foreign supplier do not offset each other, mechanically increasing labor productivity.[155] To this point, Eldridge and Harper (2009) find that imported intermediate materials explain 20 percent of the growth in manufacturing labor productivity from 1997 to 2006. We find that the contribution to manufacturing labor productivity from imported materials inputs significantly accelerated over the period.

Although Table 1 documents the substantial growth in offshoring during the period, it nevertheless likely *understates* the true magnitude of the phenomenon. Our focus below concerns the systematic upward bias in the price indexes used to deflate intermediate materials. We could not account for the measurement of two additional factors, which likely also impart an upward bias: 1) imported capital inputs, such as computers and machinery, have exhibited substantial gains in import penetration; and 2) imported services inputs (i.e., services offshoring) have accelerated in recent years, albeit from a very low level.[156]

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[153] Similar findings have been reported in other studies. See, for example, Jorgenson, Ho, and Stiroh (2008) and Oliner and Sichel (2000). See also Oliner, Sichel, and Stiroh (2007) and Syverson (2010) for more in-depth reviews of recent research on U.S. productivity.
[154] The BLS uses hedonic methods to adjust prices in the computer industry. For a review of these, see Wasshausen and Moulton (2006).
[155] This could also occur if a firm imports an intermediate input it previously produced internally. In this case, output will not change, but the labor input used to produce that intermediate input will fall.
[156] See Cavallo and Landry (2010) for a discussion of imported capital goods, and Eldridge and Harper (2009) and Yuskavage, Strassner, and Maderios (2008) and for estimates of services offshoring.

BIAS TO PRICE INDEXES FROM OFFSHORING

Understanding why offshoring likely results in biases to the price indexes used to deflate inputs requires some background on the relevant price programs. In addition to the Consumer Price Index (CPI), the BLS constructs separate price indexes for imports, exports, and domestically produced goods. Just as the BLS constructs the CPI to measure the rate of price change of goods and services purchased by consumers, the BEA constructs input price indexes to measure the rate of price change of inputs to production purchased by businesses. The BEA constructs industry-specific input price indexes using import and domestic price indexes in conjunction with information on each industry's input structure from the input-output tables. The import price data come from the BLS's International Price Program (IPP), which surveys importing establishments on the prices paid for imports of a detailed product. For domestic materials prices, the BEA primarily uses the Producer Prices Index (PPI) in which BLS surveys domestic producers on the prices they receive for a sample of products.[157]

The BLS takes great care to ensure that it is pricing the same item over time, and thus that price indexes are based on "apples-to-apples" comparisons. Each observation used in the construction of a particular price index represents the period-to-period price change of an item as defined by very specific attributes and reported by a specific establishment. These methods mean, however, that price indexes neither capture the price changes associated with the entry of a low-cost supplier nor the level differences in prices which drive its subsequent market share expansion. As mentioned, this problem has been studied extensively in the CPI literature, where it has been dubbed "outlet substitution bias" (Diewert 1998, Hausman 2003, and Reinsdorf 1993).

Figure 4 presents a stylized depiction of the problem in the context of offshoring. The BLS measures the price change from period t to $t+1$ of a specific imported product at a specific importer in the IPP, and it measures the price change from period t to $t+1$ of a specific product produced by a specific domestic producer in the PPI. Neither the IPP nor the PPI captures the price drop (d) that occurs when businesses shift from a high-cost domestic to a low-cost foreign supplier. The input price index is, in essence, a weighted average of period-to-period changes measured in the IPP and the PPI, and thus the price drop from offshoring is missed.[158]

To further illustrate how offshoring can impart a bias into the input price index, Table 2 provides a hypothetical numerical example. Suppose that pharmaceutical companies purchase a common chemical compound, "obtanium," from a domestic supplier at $10 per ounce. A Chinese supplier enters the market and sells obtanium for $6 per ounce. As the new, lower-cost source becomes known, its reliability is established, and contracts with the domestic supplier expire, U.S. pharmaceutical companies begin shifting their purchases to the Chinese supplier. For simplicity, we assume that the domestic and foreign dollar prices of obtanium remain the same throughout the period.[159] Even if the BLS picks up the Chinese import of obtanium in its import prices

[157] For more information on the BLS price index computations, see Chapters 14 and 15 in BLS (2009).
[158] Although our empirical focus is on the substitution of imported for domestic inputs, a bias would also occur with the entry and market share expansion of a new low-cost domestic supplier.
[159] Because prices are often contractually set for periods of time, this simplifying assumption of price stickiness is not unrealistic. Nakamura and Steinsson (2009) document that 40 percent of prices on imported items never change for the entire duration they are in the BLS sample.

sample without a lag, it will not capture the input price drop enjoyed by drug manufacturers at the time of the switch.

The input price index, as computed by the statistical agencies, is a weighted average of the domestic and import index, and, in our example, does not change. The correct index, however, would capture the period-to-period change of the average price that U.S. companies pay for obtanium and falls by 12 percent. More rapid introduction of new suppliers into the BLS sampling frame or more frequent sampling of prices—common suggestions for improving price statistics—will not address this particular problem.

The bias to the price index arises because neither the U.S. producer nor the U.S. importer can report the price drop that buyers experience when they shift their purchases from domestic to foreign suppliers. To address this problem, the BLS has proposed that an input index be constructed based on a survey of purchasers (Alterman 2009).[160] In theory, the buyers could accurately report the period-to-period changes in the price they pay for specific inputs, irrespective of source.

Diewert and Nakamura (2010) characterize the bias to the input price index resulting from a shift in input suppliers. The upward bias (*B*) to the rate of inflation in the input price index ($1+i$) is proportional to the share captured by the low-cost supplier over the period (*s*) and the percentage difference in the prices of the low- versus the high-cost supplier—or discount—(*d*):

$$B = (1+i)sd \qquad (2)$$

Returning to our obtanium example, over the period there is no measured inflation (i.e., *i* equals zero), the low-cost supplier captures a 30 percent market share, and the discount from the low-cost supplier is 40 percent. Whereas the measured rate of price change is zero, the true rate of price change for that input is -0.12, or negative 12 percent. The characterization of the bias to the input price index in Equation (2) is identical to the characterization of the bias to the CPI (Diewert 1998). It is the same problem manifested in a different index.[161]

As shown in Figure 5, the problem is evident in the input price indexes used by the BEA to deflate intermediate materials inputs. If price indexes were accurately capturing the cost savings to businesses that presumably underlie the recent share growth of imported intermediates, then the growth of the import price index should be *slower* than the domestic price index, indicating a fall in the price of imported relative to domestic inputs. Instead, the foreign price deflator for intermediate materials rose *faster* than the domestic deflator. The differential between foreign and domestic materials price deflators is especially apparent beginning in 2002, coincident with the rapid rise of imports from China.

[160] The proposed input cost index is still at the concept and design stage at the BLS.
[161] Although the goods in this model are treated as homogeneous, Diewert (1998) provides a simple extension to where the goods are different qualities. In this case, the discount represents the price differential adjusted for quality.

EVIDENCE OF COST SAVINGS FROM OFFSHORING

No comprehensive evidence exists on the magnitude of the cost savings from shifts in sourcing—i.e., the discount, *d*, in Equation (2). A few case studies, however, provide some evidence for selected products and industries. Byrne, Kovak, and Michaels (2010) find sizable cross-country differences in the prices of semiconductor wafers with identical specifications. On average, they find that, compared to prices of semiconductor wafers produced in U.S. foundries, prices were on average about 40 percent lower in China and about 25 percent lower in Singapore. Klier and Rubenstein (2009) find that offshoring aluminum wheel production to Mexico lowered overall costs by 19 percent and processing costs by 36 percent.

The different samples in the IPP and PPI do not permit a direct comparison of prices for domestic and imported items. However, such a comparison is possible among imported products originating in different countries. Products from intermediate and, especially, developing countries were gaining market share not only vis-à-vis the United States but also other advanced countries. On the grounds that production cost structures are likely to be more similar between the United States and other advanced countries, systematic import price differentials between products from advanced versus developing and intermediate countries may be informative about the size of the discount relative to U.S. goods.

Figure 6 shows the average percentage differences between imported products from advanced and developing countries and between advanced and intermediate countries as recorded in the BLS microdata underlying the IPP. The position of each bubble represents the size of the discount for a single North American Industry Classification System (NAICS) 4-digit category in manufacturing. The size of each bubble is proportional to the gain in U.S. market share for developing and intermediate countries within each category. In almost all cases, the discounts are negative, indicating lower prices in developing and intermediate countries compared to advanced countries. In many cases, these discounts appear to be quite sizable. Further, the size of a discount is negatively correlated with a gain in market share, indicating that the larger the developing or intermediate country's price differential, the greater the U.S. market share captured. Products on the left side of the figure (i.e., food, beverages, textiles, and apparel) are characterized by smaller discounts and share gains, whereas products to the right (i.e., machinery, electronics, semiconductors, and transportation) are characterized by larger discounts and share gains.

An important caveat to this figure is that even within very detailed product codes there may be considerable heterogeneity that may explain at least some of the price differentials. Returning again to our example in the previous section, if obtanium is a differentiated product and the Chinese version is of a lower quality than that from Japan, then Chinese obtanium should trade at a discount relative to a variety that is not strictly comparable. We adopt various methods to control for possible heterogeneity. In particular, one method restricts the import price sample to cases in which there is a newly observed price for an incumbent importing firm within the same detailed product code. In this way, we are able to narrow the sample to instances in which an importer appears to be switching sources of a specific product from a supplier in an advanced country to one in a developing or intermediate country. The observed price differentials are somewhat smaller but still sizable when we limit our sample in this way.[162]

The evidence from case studies and from comparisons of import prices is consistent with reports of large discounts in the business literature. For example, in 2004 *Business Week* reported that prices of imported goods from China typically were 30 to 50 percent lower than the prices for comparable products produced in the United States, and that the discounts were sometimes higher (Engardio and Roberts 2004). Similarly, a McKinsey & Company (2006) study cited cost savings from production of electronic equipment in China of between 20 and 60 percent. Estimates of the savings from offshoring auto parts production to Mexico are generally in the range of 20 to 30 percent (see discussion in Kinsman 2004). In sum, although no systematic data exist, a variety of evidence points to large cost savings from offshoring.

The above-mentioned price differentials could be the result of numerous factors, such as labor costs, industrial policy, or disequilibrium in exchange rate markets. For instance, the Manufacturers Alliance of the National Association of Manufactures provides estimates of manufacturing labor costs, adjusted for productivity, for major U.S. trading partners as compared to the United States. Their estimates of large labor cost savings—58–72 percent lower in China and 22–62 percent in Mexico from 2002 to 2009—are consistent with the large product discounts reported in research and in the business press (Leonard 2008). Also consistent with the evidence of cost savings from offshoring are estimates that the Chinese *renminbi* may be significantly undervalued relative to the dollar, perhaps by as much as 40 percent (Bergsten 2010, Cline and Williamson 2010).

BIAS TO PRODUCTIVITY AND VALUE ADDED FROM OFFSHORING

We implement the bias correction to input prices in Equation (2) and simulate the effects of the bias on MFP and value-added growth. Figure 7 illustrates what the bias to industry-level materials deflators would be if the true import discounts match those derived from the full sample of import price microdata. The vertical distance between each point and the 45 degree line represents the size of the bias. For all manufacturing, if the true import discount can be approximated by the IPP microdata, then the cumulative price growth of 20 percent between 1997 and 2007 would overstate the bias-corrected inflation rate by a full 9 percentage points. Thus, once we account for offshoring bias, the materials costs faced by U.S. manufacturers would only have risen at *half* the rate reported in official estimates. This, in turn, would imply that the real use of materials by U.S. manufacturers was twice as large as reported. With more production being generated by purchased materials, both productivity and value added would be diminished. Also shown in Figure 7 are the implied industry-level cumulative price changes under this set of assumptions about import price discounts.

[162] Houseman et al. (2010) describe this approach in greater detail. We also attempt to account for unobserved differences in product characteristics using an econometric model informed by estimates of product-level quality from Mandel (2010). We find that the price dispersion across source countries decreases but remains substantial. In short, it is unlikely that product differentiation accounts for the large, persistent price differences across countries.

By how much might the productivity statistics be overstated from failing to account for offshoring? The top panel of Table 3 presents alternative estimates of MFP growth based upon different assumptions about the import discount. Column (1) restates our baseline MFP results from Table 1, while column (2) presents estimates in which all commodities—both domestic and imported—have been deflated with domestic deflators provided to us by the BEA. Since our alternative materials deflators are derived by adjusting domestic commodity prices (primarily PPIs), the estimates in column (2) should be viewed as the appropriate reference or "jumping-off" point for gauging the extent of offshoring bias. In other words, they show what MFP would be if the rate of price inflation for imported commodities was the same as for their domestic counterparts. This assumption in Equation (2) is maintained in order to hone in on the impact of the level difference in prices between imported and domestic commodities.

For the entire manufacturing sector, deflating imported materials with domestic prices reduces MFP growth by a bit less than 0.1 percentage point, from 1.30 percent in our baseline scenario to 1.23 percent. Almost all of this change owes to differences in the price deflators used for imported and domestic semiconductors. In other words, prices for imported semiconductors—a product used heavily by the computer and electronic products industry—fell less rapidly than their domestic counterparts. The discrepancies are especially evident in the early years of our data and appear to be the result of inconsistent adjustment of imported and domestic semiconductor prices for quality improvements. Although not the focus of our paper, the drop in MFP between columns (1) and (2) likely represents an additional modest bias.[163]

Columns (3) and (4) present MFP estimates that have been adjusted for offshoring using our micro evidence on the import discount. We report estimates using product-level discounts based on the entire microdata sample ("full sample") and on a sample limited to instances where importers appear to shift from suppliers in advanced counties to ones in developing or intermediate countries ("switchers"). In columns (5) and (6), we estimate MFP using import discounts informed by the business press and available case study evidence, applying these discounts uniformly across commodities. The column labeled "50/30" assumes discounts of 50 percent for developing countries and 30 percent for intermediate countries, whereas the column labeled "30/15" assumes discounts of 30 percent for developing countries and 15 percent for intermediate countries. These represent discounts on the high and low end, respectively, of those found in the case study and business literature.

On balance, for the entire manufacturing sector, we find that adjusting for offshoring lowers MFP growth by an additional 0.1–0.2 percentage point, which implies average annual productivity growth is reduced between 6 and 14 percent. These numbers are fairly significant, as a 0.1 percent average annual growth rate for MFP roughly equals the average annual contribution of the capital stock to manufacturing growth during this period.

If we exclude the contribution of the computer and electronic products industry, correcting for offshoring results in larger percentage adjustments to MFP, which falls from 0.67 percent in

[163] Because of the high import penetration in semiconductors and other high-tech products, consistently adjusting domestic and import prices for product improvements is important for the accuracy of industry and national income statistics, though difficult owing to lack of product detail, particularly for imports. Addressing this problem has resulted in substantial revisions to the national accounts statistics in the past (Grimm 1998).

column (2) to between 0.52 percent (column 3) and 0.58 percent (column 4); in other words, the reduction in MFP widens to as much as 22 percent. The results for the case study scenarios shown in columns (5) and (6) are quite consistent with our results based on IPP microdata.

What about the likely range of bias to value added? Recall that value added nets out intermediate inputs from an industry's shipments, and therefore represents the additional product produced in an industry.[164] If, as suggested by Figure 7, the actual amount of intermediate materials used by U.S. manufacturers has been larger than what is contained in the official statistics, then value added has been overstated as well. This implies that a larger share of the sector's production has simply been final assembly, and relatively less of domestic manufacturing shipments are contributing value to the overall economy.

The BEA derives indexes for industry-level value added using the double-deflation method in which real value added is computed as the difference between real gross output and real intermediate inputs. We replicate this double-deflation procedure using our adjusted measures of real purchased materials. We therefore derive the implied value of real value added –associated with published measures of gross output, energy, and services and our adjusted measures of purchased materials inputs.

The bottom panel of Table 3 presents alternative estimates for value added based on our different assumptions on the import discount. Of note, the unadjusted average growth rate in value added for all manufacturing is about 3 percent, while the annual growth rate for manufacturing, excluding the computer sector, is less than one-third of this size—about 0.9 percent. The annual growth rate for the computer industry exceeds 20 percent. As shown in columns (3) through (6), our simulations indicate that value-added growth for all manufacturing was overstated by 0.2–0.5 percentage point, or about 7–18 percent of the growth. Excluding computers, real value-added growth for manufacturing is biased by 0.2–0.4 percentage point, which accounts for 21–49 percent of the growth. 165 The annual growth rate of real value added for manufacturing excluding computers falls under a half percent per year in some of our adjusted estimates, while that for nondurable goods turns negative for all of our adjusted estimates.

IMPLICATIONS FOR DATA AND RESEARCH

The above analysis focuses on biases to manufacturing productivity and value added from the substitution of lower-cost imported for domestic materials inputs. Such biases, however, may also arise from the offshoring of other inputs and affect statistics for other sectors and for the aggregate economy.[166] In the 2000s, sizable import penetration by developing countries occurred in computers and machinery products, which largely are treated as capital inputs in the industry accounts. Price drops accompanying the substitution of imported for domestic capital equipment

[164] Gross domestic product can therefore be derived as the sum of value added across all sectors of the economy.
[165] In addition to the "switchers" estimates, we attempted to adjust for unobserved differences within detailed product codes using econometric techniques. These estimates do not alter the qualitative results of our analysis, and imply bias adjustments to MFP and value added roughly in line with the "30/15" estimates in Table 3.
[166] Reinsdorf and Yuskavage (2009) examine pricing in selected consumer goods and provide preliminary evidence of biases to GDP from import growth. Biases to price indexes from offshoring and their implied biases to GDP growth also have been covered in the business press (see Mandel 2007, 2009).

would not be captured in capital price deflators, possibly leading to an understatement of the growth of capital services and an overstatement of growth in MFP and real value added.

The same problem arises from services offshoring. Collecting accurate price information on services trade is complicated by the fact that the level of detail in services sector data is quite limited (Jensen 2009, Norwood et al. 2006,Sturgeon et al. 2006,), and that the BLS international prices program does not cover business services imports and exports. If services offshoring were to expand rapidly in the near future, as some predict, the absence of accurate price deflators could impart significant biases in official statistics.

More generally, the Shumpetarian dynamic by which low-cost producers enter and capture market share from incumbents is an important mechanism by which prices change, but is a dynamic largely missed in price indexes. Although we have focused on the substitution of low-cost foreign for domestic inputs because of the recent empirical importance of offshoring, the entrance and market share expansion of low-cost domestic suppliers is an important aspect of firm dynamics in the United States and also would impart biases to price indexes.[167] As mentioned above, a proposal to construct an input price index based on a survey of purchasers, if implemented by BLS, would address the biases to the industry statistics from all shifts in sourcing (Alterman 2009).[168]

The growth of low-cost imports has spurred numerous studies to assess their effects on the U.S. economy and its workers. Biases to price indexes that arise from offshoring affect the accuracy not only of the industry statistics, but also of analyses based on them. Because such import growth will be understated in real terms and, to some degree, will be manifested as false productivity gains, studies may underestimate the true effects of import growth.

The pace of globalization is unlikely to abate in the near future, underscoring the need for reliable economic statistics to understand its effects and formulate policy responses. The biases to price indexes discussed in this paper are emblematic of a broader set of measurement problems that arise from the growth of globalization (Feenstra and Lipsey 2010, Houseman and Ryder 2010). Understanding the effects of globalization requires better data, including, quite critically, better price deflators.

[167] See Foster, Haltiwager, and Syverson (2008) for evidence that entrants, on average, have higher physical productivity and offer lower prices than incumbent firms.

[168] The proposed index, which would not distinguish source country, would capture price changes from shifts in sourcing among domestic suppliers, among domestic and international suppliers, and among international suppliers. Although the input price index would address biases in the industry statistics, it would not address biases in published statistics on GDP growth, which are based on expenditure, not industry value-added, data.

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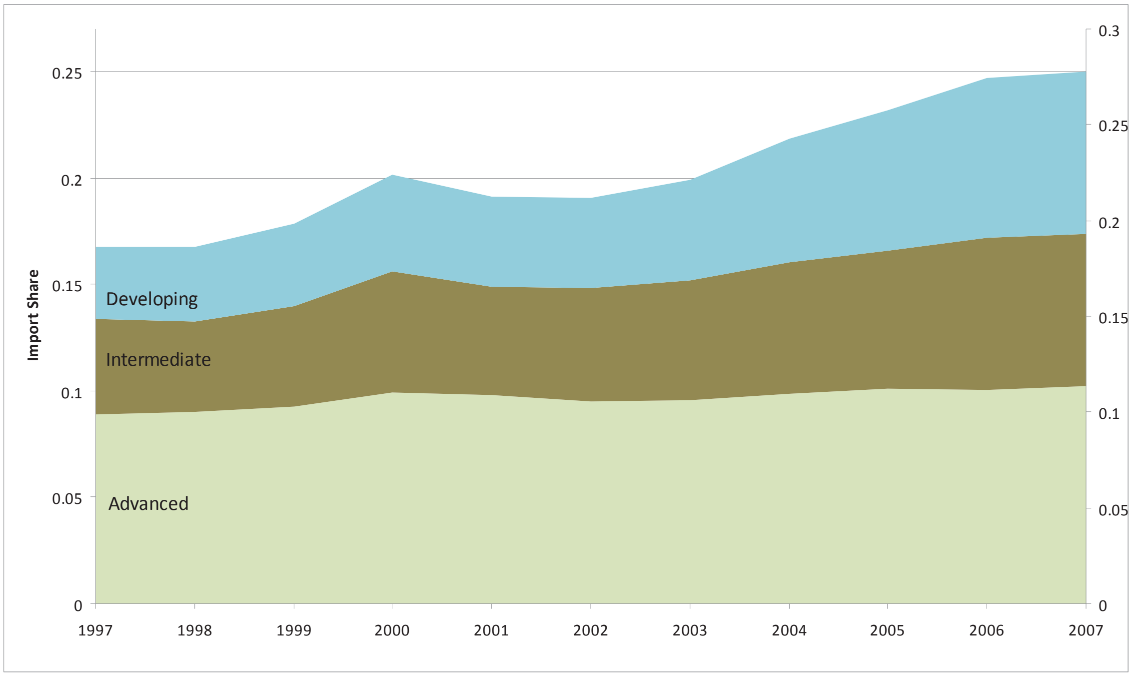
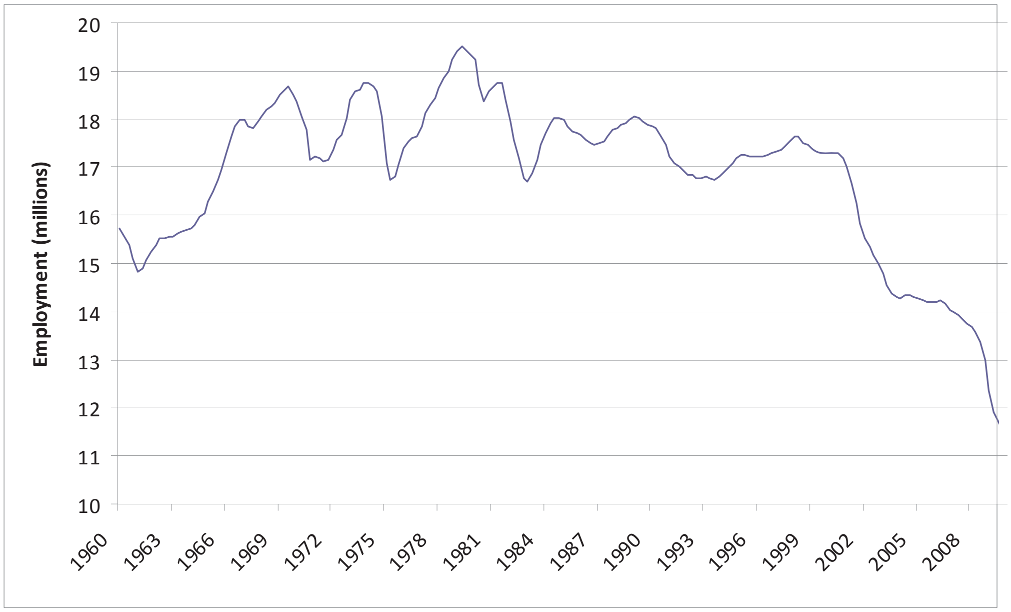
Figure 1: The Import Share of Material Inputs Used by U.S. Manufactures



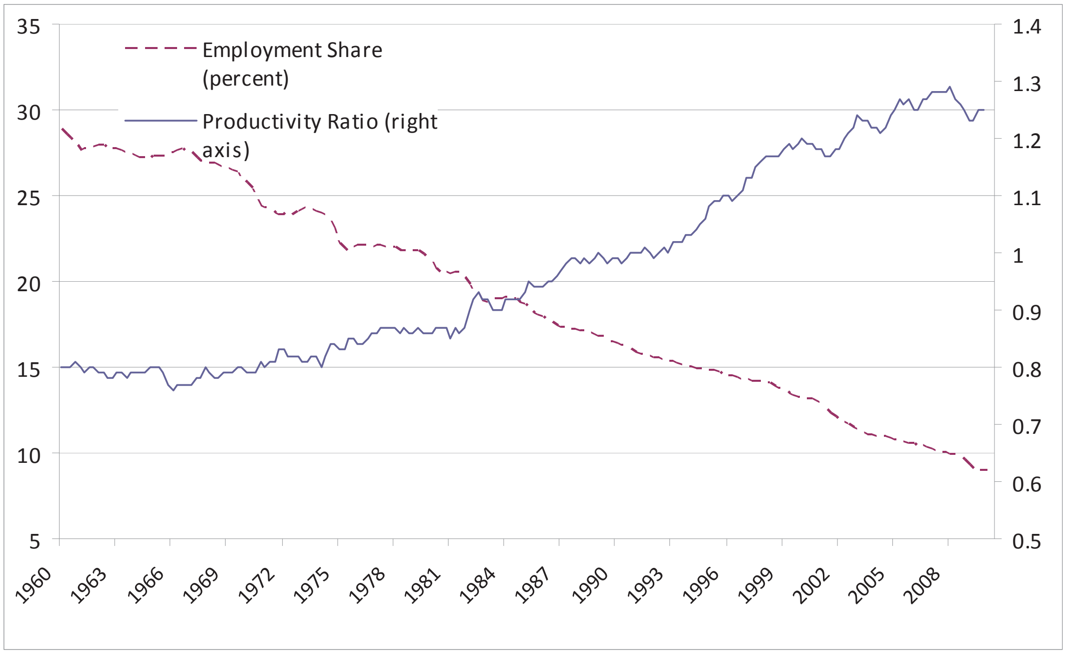
NOTE: Imported intermediates are decomposed into their source country of origin and plotted as their portion of the share of imported intermediate in total materials use by the manufacturing sector.
Source: BEA Annual Industry Accounts and Import Microdata

Figure 2: Manufacturing Employment, 1960-2009



Source: BLS

Figure 3: Manufacturing: Labor Productivity and Employment Relative to Total



NOTE: Productivity series is calculated as ratio of manufacturing output per worker as a fraction of total nonfarm business labor productivity. Employment share is ratio of manufacturing employment to total employment.
SOURCE: BLS

Figure 4

How Offshoring Biases an Input Price Index

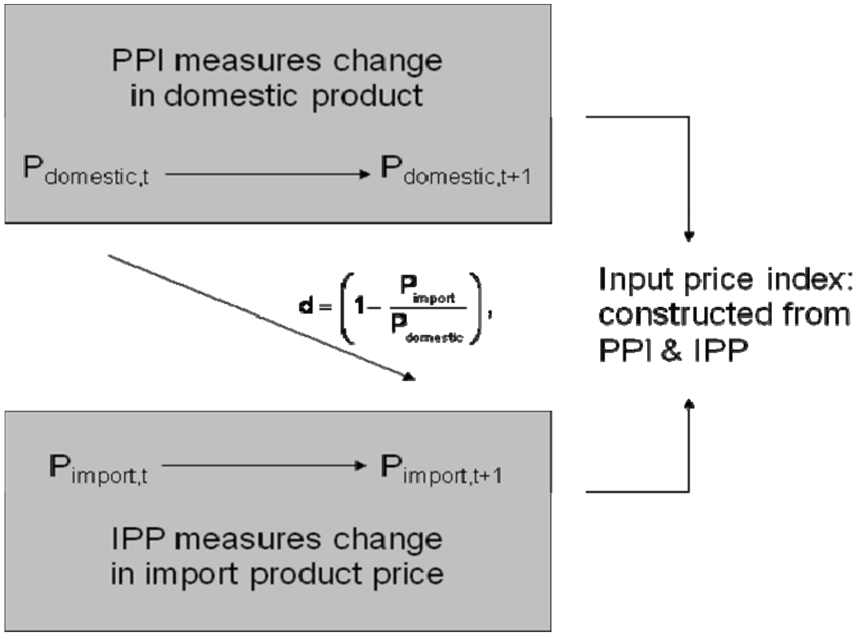
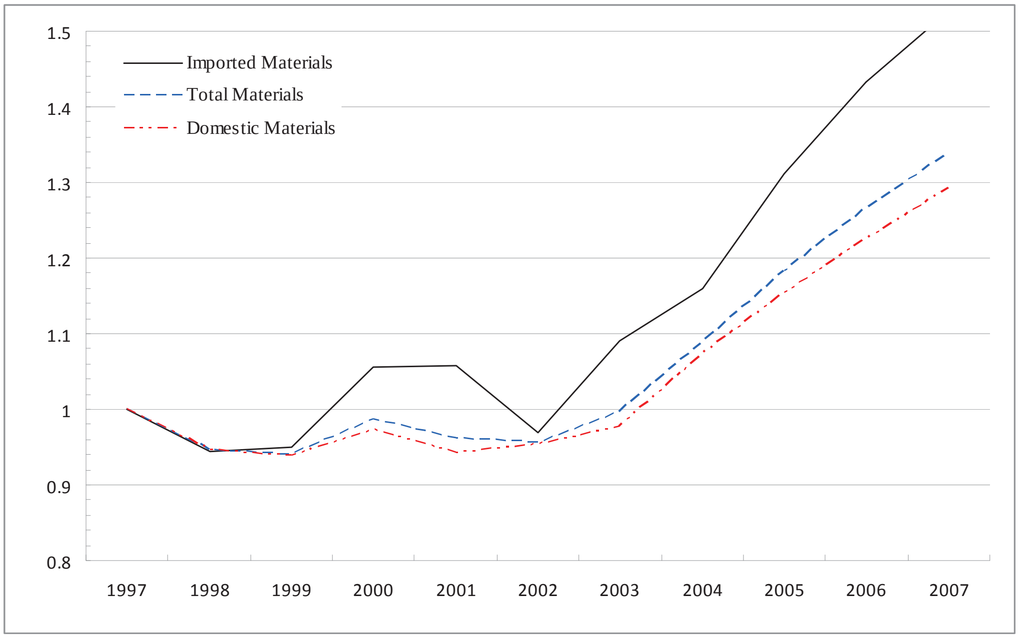
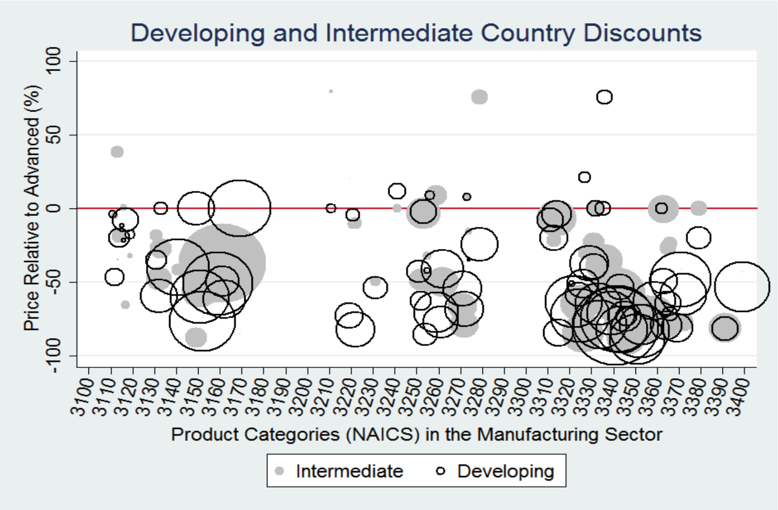


Figure 5: Baseline Input Price Indexes for the Manufacturing Sector



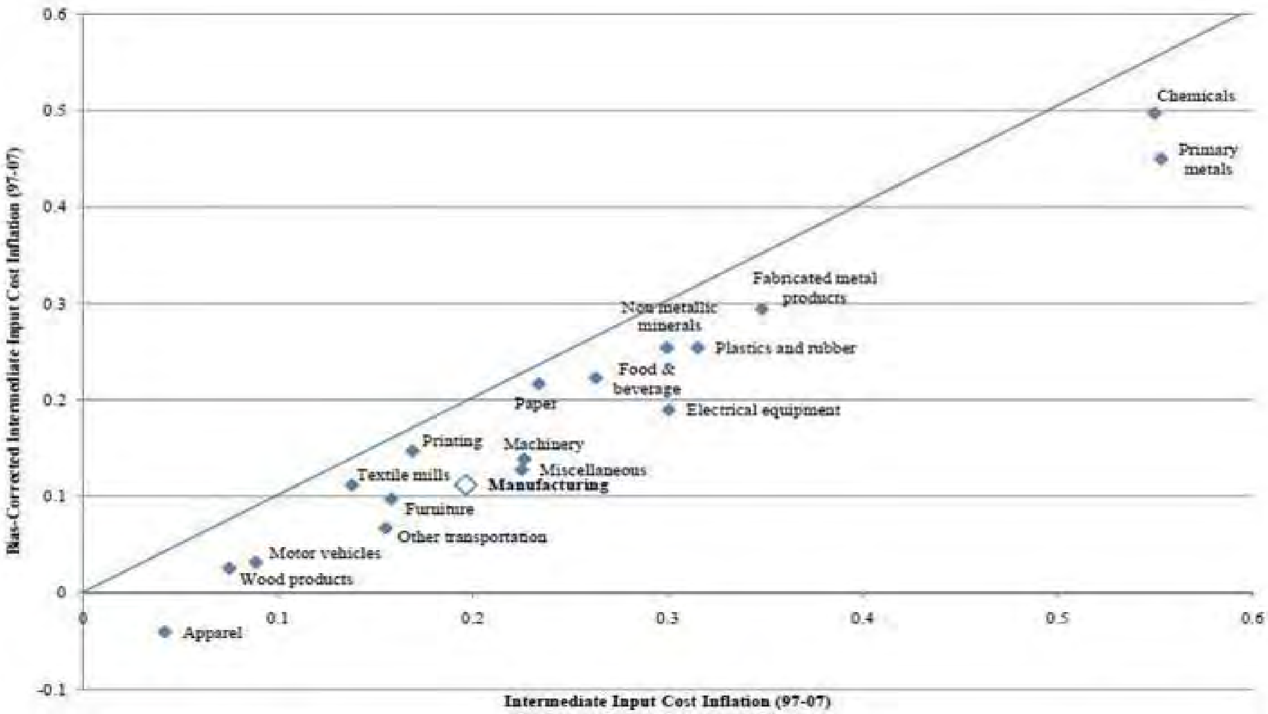
NOTE: The total materials deflator is from the BEA's Annual Industry Accounts, while the imported materials deflator is an aggregate of confidential BEA commodity price data. The implied domestic materials price deflator is computed from the total and imported materials price deflators.

Figure 6



NOTE: The import price discount for each NAICS category averages across many underlying detailed product groups classified according to the U.S. Harmonized System (HS 10-digit) for the months September 1993–May 2007. Within an HS group, the developing (or advanced) country discount is the average of individual item prices exported from developing (or advanced) countries relative to a geometric mean of advanced country transaction prices.
SOURCE: BLS

Figure 7: Materials Cost Inflation for U.S. Manufacturing Industries



NOTE: The figure contrasts the materials cost inflation as published by the BEA with an adjusted measure derived from IPP micro data and Census foreign trade shares. For each manufacturing industry, and manufacturing as a whole, cost measures are computed as the cumulative percent change between the published and hypothetical index values in 2007 and 1997. A cost inflation of 0.2, for example, represents a 20 percent increase in prices over the decade. Two industries, petroleum products, and computer and electronic components, were included in the overall manufacturing number but excluded from the charts. Petroleum products had cumulative input cost inflation of 137 percent and bias-corrected inflation of 134 percent. Computer and peripherals had input costs decline by 35 percent, 51 percent adjusted.

Table 1: Sources of Growth for U.S. Manufacturing Industries, 1997–2007[1]

	Gross Output (1)	MFP2 (2)	Capital3 (3)	Labor (4)	Energy (5)	Services (6)	Purchased Materials Domestic (7)	Purchased Materials Foreign (8)
1. Manufacturing	1.18	1.30	0.13	-0.53	-0.05	0.22	-0.19	0.28
2. Manufacturing excl. Computers and electronic products	0.46	0.69	0.11	-0.47	-0.05	0.13	-0.23	0.28
3. Durable goods:	2.00	2.02	0.17	-0.66	-0.05	0.30	-0.15	0.37
4. Computer and electronic products	7.35	6.82	0.25	-1.11	-0.05	1.05	0.04	0.35
5. Durable goods excl. Comp. & electr. products	0.77	0.95	0.15	-0.57	-0.05	0.12	-0.22	0.38
6. Nondurable goods:	0.16	0.45	0.07	-0.37	-0.04	0.14	-0.25	0.17

1. Average annual rate for period shown. Column (1) is percent change. For each row, columns (2) through (8) are percentage points that sum across columns to (1).
2. MFP is multifactor productivity. 3. Includes Non-IT equipment, IT Capital, (computers and peripheral equipment, software, and communication equipment), structures, and inventories

Table 2: Hypothetical Offshoring of "Obtanium"

	t	t+1	t+2	t+3
Domestic supplier price	$10.00	$10.00	$10.00	$10.00
Domestic quantity sold	100	90	80	70
Chinese supplier price	$6.00	$6.00	$6.00	$6.00
Chinese quantity sold	0	10	20	30
Average price paid for obtanium	$10.00	$9.60	$9.20	$8.80
Domestic input price index	100	100	100	100
Import input price index	–	100	100	100
Input index, as computed	100	100	100	100
True input price index	100	96	92	88

Table 3: Foreign Offshoring and the Bias to U.S. Multifactor Productivity and Value Added, 1997-2007

				Micro Evidence			
	Simulation:	Baseline (1)	IPP=PPI (2)	Full Sample (3)	Switching (4)	Dev50, Int30 (5)	Dev30, Int15 (6)
	Multifactor Productivity:						
1	Manufacturing	1.30	1.23	1.05	1.12	1.08	1.16
2	Manuf.excl. Comp. & electronic products	0.69	0.67	0.52	0.58	0.54	0.61
3	Durable goods:	2.02	1.87	1.64	1.73	1.67	1.77
4	Computer and electronic products	6.82	6.33	5.91	6.13	6.05	6.18
5	Durable goods excl. Comp. & electr. products	0.95	0.89	0.70	0.76	0.71	0.81
6	Nondurable goods:	0.45	0.45	0.36	0.40	0.38	0.42
	Value Added:						
7	Manufacturing	3.04	2.82	2.31	2.50	2.39	2.61
8	Manuf.excl. Comp. & electronic products	0.94	0.86	0.44	0.59	0.48	0.68
9	Durable goods:	5.25	4.86	4.19	4.44	4.27	4.57
10	Computer and electronic products	22.68	21.12	19.73	20.44	20.17	20.61
11	Durable goods excl. Comp. & electr. products	1.74	1.58	1.05	1.22	1.07	1.34
12	Nondurable goods:	0.07	0.08	-0.23	-0.10	-0.15	-0.03

NOTE: Figures represent average annual percent growth in real value-added. For "IPP=PPI," imported materials are deflated with domestic deflators. For "full sample," estimates are adjusted with product-level discounts from the entire IPP micro data sample. For "switchers," the import discount is based on a sample where importers appeared to shift from suppliers in advanced counties to ones in developing or intermediate countries. "50/30" assumes discounts of 50 percent for developing countries and 30 percent for intermediate countries, while "30/15" assumes discounts of 30 percent and 15 percent respectively.

Producing an Input Price Index

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November 2009

This paper is designed to address the need, and especially the feasibility, of producing an input price index at the U.S. Bureau of Labor Statistics (BLS). These price indexes would serve to provide more accurate estimates of several key indicators of the state of the U.S. economy, including gross domestic product (GDP), productivity, and inflation.

The current interest in these types of price indexes arose over concerns that the BLS does not adequately measure shifts in prices resulting from offshoring (or its corollary, onshoring) in its industrial price programs. The BLS has three indexes that cover the production of goods, the International Price Program's (IPP's) import price index (MPI) and export price index (XPI), and the producer price index (PPI). The MPI only covers goods that are being imported, the XPI only covers the export of goods, and the PPI only covers goods and services that are produced domestically. Thus, a good that had been domestically produced and repriced by the PPI, and has had its production sent overseas, will no longer be tracked in the PPI. Correspondingly, the MPI index will not begin to price that particular item until after it has become an import. Therefore neither program will directly show the price change that occurs when the item goes from domestic production to foreign (or vice versa).

An example of how the BLS constructs an import price index and a producer price index will help to illuminate the problem. Let us look at how both indexes might reflect price changes in the manufacturing of furniture. Below I've constructed a table showing prices for four different chairs. All chairs that are being produced domestically sell for $10, while all imported chairs sell for $5. Chair A is only produced domestically, while Chair D is only imported. During the year, the remaining two chairs shift from domestic production to being imported, Chair B in March and Chair C in May.

The PPI only tracks Chair A for the entire period, and Chairs B and C for the months that they are domestically produced. The MPI only tracks chair D for the entire period, and chairs B and C only for the months they are imported. Thus, the PPI and the MPI for chairs would both reflect no change during the entire reference period.

One suggested option was to combine the two indexes. However, since the indexes themselves are always unchanged, no amount of recombining or reweighting will produce anything other than an unchanged series. The only way to construct a price index that would show the price decline associated from the offshoring of chairs B and C would be to construct a price index that would directly track the price changes of items as they move from domestic to foreign and vice versa. This is not possible under the methodology (and concepts) currently in use in the BLS's two industrial price programs.[169] The PPI does currently construct output price indexes for wholesalers and retailers, which presumably includes data on both imported and domestically produced goods. However, these indexes are only gross margin indexes, and only represent the difference between their selling price of a good and the acquisition price for that same item. The data collected does not lend itself to delineating import goods from domestic goods.

[169] Note that the consumer price index *is* designed to pick up these price changes, and is reflected in prices paid by domestic consumers. In addition, the bureau has conducted a preliminary analysis of PPI data that provides some evidence that prices from domestic producers are influenced by the degree of import penetration in their industry.

		Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09
Chair A	Domestic	$10	$10	$10	$10	$10	$10
Chair B	Domestic	$10	$10				
Chair B	Imported			$5	$5	$5	$5
Chair C	Domestic	$10	$10	$10	$10		
Chair C	Imported					$5	$5
Chair D	Imported	$5	$5	$5	$5	$5	$5
PPI		100	100	100	100	100	100
MPI		100	100	100	100	100	100
Combined index		100	100	100	100	100	100
Input index		100	100	85.7	85.7	71.4	71.4

Although the BLS was aware of the potential data gaps between XPI, MPI, and PPI, it appeared that shifts over time between domestic and foreign production have been gradual enough that it was not evident that the limitation of the indexes was seriously biasing estimates of productivity as well as GDP figures and other components of the National Accounts. The potential shortcomings in the BLS indexes, however, were highlighted in an article in the summer of 2007 in *Business Week*, and by a study funded by the Sloan Foundation (Mandel 2007; Houseman 2009a). Presumably this potential gap in BLS data becomes more serious as the proportion of the U.S. economy tied into the global economy has grown, especially in conjunction with the perception that U.S. jobs are being lost to foreign competition.

In order to address this limitation, the BLS needs to develop an entirely new set of "input" price indexes, which would price goods and services that are inputs into a domestic company's production function. Indeed, the BLS itself recognized the need for this type of series over 30 years ago when the old "wholesale price index" was transformed into the more comprehensive and systematic output-based producer price indexes.

This paper will review both the concepts and uses of an input price index, as well as assess additional evidence centering on the need for these data. In addition, the paper will also focus on the practical aspects and limitations of attempting to produce such an index. This will include surveying the data sources necessary for drawing a sample of establishments and items to reprice, evaluating possible sources for appropriate weights in an input price index, determining a proper index estimation formula, and verifying the publication structure necessary to support the different uses of these series.

WHY AN INPUT PRICE INDEX IS IMPORTANT

As mentioned, an accurate estimate of the prices paid for inputs of both goods and services is crucial to a number of broad and critical measures of the economy. This includes estimates of GDP, inflation, and productivity. For example, in order to properly estimate GDP by industry, (constructed by the Bureau of Economic Analysis [BEA]) and industry productivity estimates (constructed by the BLS), these agencies must properly account for input costs. Although these data are available on a current dollar basis (though sometimes with a considerable lag), in order to estimate their "real" (that is, inflation-adjusted) values, they need to be deflated by changes in price levels. However, the appropriate price measures paralleling these input values are not currently being produced by the BLS. Consequently, the BEA and the BLS must make use of whatever price data are available. Generally this has required the agencies to make use of the PPI output price indexes and/or the IPP import price indexes. It has been speculated that using these next best sources may lead to significant mismeasurements in the economy. For example, the *Business Week* article (Mandel 2007) estimates that the increase in real GDP from 2003 to mid-2007 may have been overestimated by $66 billion. This article focuses on import prices not picking up price changes when a good goes from being domestically produced to being imported. It summarizes the example of the furniture industry and highlights the apparent contradictory behavior of consumer prices for furniture; those prices have been decreasing while the indexes for both domestic producer prices and import prices for this category have both been increasing.

Equally important, the article also infers that the lack of an input price index may lead to a significant overestimate of productivity in U.S. industry. A rise in a nation's productivity is considered the key factor in an economy's ability to improve its standard of living. It is further assumed that increases in real hourly earnings are often tied to gains in productivity. If, in fact, GDP and productivity are being overestimated, this implies that the gains from trade (that is, the terms of trade) are being underestimated, and that in real terms the value of imports is greater than currently measured.

RECENT WORK

A growing body of literature has now examined the increasing role of imports in intermediate inputs in the U.S. economy, as well as concerns associated with the methodology in constructing U.S. estimates of GDP and productivity. Kurz and Lengermann (2008) note that foreign inputs accounted for one-third of growth in the manufacturing sector between 1997 and 2005, while Yuskavage, Strassner, and Medeiros (2008) estimate that from 1997 to 2006 the import share of intermediate inputs increased from 13.5 to 20.0 percent. Feenstra, Reinsdorf, and Slaughter (2008) attribute a substantial portion of the apparent acceleration in productivity gains after 1995 to gains in the terms of trade and tariff reductions. Nakamura and Steinsson (2008) find limitation in the import and export price indexes associated with "product replacement bias." Finally, Houseman (2009b) states, "The measurement problem has broad implications not only for various aggregate and industry statistics, but also for the research that relies on them. Although the growth of imports from developing countries has spurred great interest in academic and policy circles about their effects on the U.S. economy and its workers, credible research into these issues cannot be conducted without accurate data on real import values."

Additional Evidence

In order to prove the need for a set of input price indexes that incorporates both domestic and foreign sourcing, I analyzed the most recent available data on the role of imports in domestic supply. In analyzing the data from the BEA, I estimate that not only has the contribution of imports to intermediate inputs in the United States increased, but that it increased at a faster rate during the past decade. In 1975, imports represented less than 7 percent of inputs into manufacturing. By 2007 that figure had climbed to almost 28 percent (see Figure 1). Equally important, between 1997 and 2007, the percent of imports in inputs increased by an average of over 0.4 percent a year, while in the prior decade, the percent had increased by less than 0.25 percent a year. This point is critical because it infers that there is an acceleration in companies shifting their products from domestic sourcing to foreign sourcing, making the need for additional data more critical. In addition, if the rate of change was consistent over time, it might have been easier to model a "discount" factor to apply to import prices in order to adjust for this shift.

Indeed, the speed of globalization is perhaps happening so quickly that the ability of traditional measures to capture these shifts has become increasingly problematic. For example, the household wood furniture manufacturing industry—the industry highlighted in the *Business Week* article—recorded a dramatic increase in the value of imports during the past decade, jumping from $13.2 billion in 1999 to $27.0 billion in 2007. Despite this increase, in 2006 the preliminary estimate from the Annual Survey of Manufactures for the household wood furniture sector recorded an increase in value of domestic production, up to $13.5 billion. However, when the final figures were revised the following year, the number was adjusted substantially downward to only $8.6 billion. This may be due in part to the difficulty of properly (and in a timely manner) coding companies to the correct NAICS (North American Industry Classification System) number when they shift from being a manufacturer to being essentially a wholesaler.

Limitations

It is important to point out that the construction of an input price index will not alleviate directly the potential mismeasurement issues associated with an *import* price index. This is important to note because GDP can be estimated using two different methods: It can be constructed by calculating the total of final sales in the U.S. economy and subtracting imports (the familiar $Y = C + I + G + X - M$), as well as by the value-added approach, where the total value added of each industry is aggregated ($Y = \quad VA_{j,}$ where VA_j = Sales for industry j – Purchases of materials and supplies by industry j. The current methodology in the United States focuses on the former.

In order to understand why the BLS cannot construct an import price index that directly registers these price changes, it helps to review the current methodology. The procedure for producing import price indexes starts out with a very robust frame from which to draw a sample. It includes nearly the entire set of transactions of all merchandise brought through U.S. Customs and into the United States. It categorizes it by individual shipments, product categories, and of course, companies. A sample of specific companies and the items they imported is then drawn from this frame, and the BLS attempts to collect prices on a monthly basis for these items. Note, however, that the sample only consists of goods that are already being imported. It is not practical to ascertain from an importer (who in many cases may only be an intermediary) if in the past he sourced an item domestically. It would also be hard to get the reverse, asking an importer who no longer imports if the sampled good is now produced domestically, and if so, what is the price. Presumably, constructing an input price index may potentially provide some indication of the magnitude of any differences in price trends being missed by import prices or producer prices as sourcing shifts from one to the other. This might be possible if, as the pricing data was being collected, the respondent was able to take note of whether the item was bought domestically or from a foreign source. From a practical standpoint, however, it is not clear if this information could be successfully incorporated into the index production process.

It should also be noted that an input price index will not alleviate problems arising from previously in-house-produced goods and services that are now being outsourced (either domestically or to a foreign source). This, too, is considered a growing phenomenon, but unless data on prices associated with the in-house cost of producing an item can be directly compared with the outsourced price, it is not clear how the BLS could evaluate shifts in prices associated with this phenomenon.

BLS AND INPUT PRICE INDEXES

The seminal 1961 report of the National Bureau of Economic Research Price Statistics Review Committee, the so-called *Stigler Report*, made a number of recommendations surrounding the wholesale price indexes, which was the name of the industrial price series then being produced by the BLS. One of the recommendations was that the BLS should rely on buyers' prices rather than sellers'. A second recommendation was for the creation of a set of conceptually rigorous input and output price indexes. The report also included an empirical study, which concluded that buyers' prices were more likely than list prices to accurately reflect prices of actual transactions.

Buyers' Prices

Prior to the *Stigler Report*, the PPI had evaluated the use of buyers' prices. In 1942, the PPI conducted a study of buyers' prices for eight selected items of steel mill products for six time periods and compared them to list prices. The results of the study showed that the buyers' prices moved differently than list prices for short periods of time, but longer-term list and invoice prices were comparable. Experiences with the study showed that purchases of an item by an individual company included many different transaction terms and detailed specifications.

In response to the *Stigler Report* and subsequent reports, the BLS commissioner as well as others expressed concerns that the cost of collecting buyers' prices would outweigh the likely benefits due to potential problems such as buyers' prices from an invoice sometimes not reflecting real transaction prices, difficulties capturing retroactive price adjustments based on cumulative volume, and financial assistance given by sellers to buyers for advertising and other expenses.

The BLS did agree that the project had merit on a selective basis to allow analysis of price trends in industries where transaction pricing was difficult.

A more detailed study looking into the advantages of buyers' prices was published in Stigler and Kindahl (1969), which pointed out the differences in price trends between buyers' and sellers' prices. As much of the concern with the then BLS wholesale price index focused on the use (or potential misuse) of so-called *list prices*, the BLS economists worked with the sellers who were participating in the price survey to encourage the reporting of actual transaction prices and made substantial progress in some industries in improving the quality of the received prices. In addition, the PPI also began the process of evaluating specific products where buyers' prices should be collected due to the unavailability of transaction prices from sellers. As a result of this study, in January 1972 the PPI began publishing a commodity index for aluminum ingot using buyers' prices from a judgmentally selected sample of reporters.

Building on this work, in 1974 the PPI attempted a systematic sampling approach to obtaining buyers' prices. This project was undertaken with the goal of determining the feasibility and cost of collecting prices directly from buyers in order to either calculate price indexes or evaluate the quality of the transaction prices being reported by sellers. The project identified highly weighted products where either sellers refused to provide transaction data or the quality of current transaction data was questionable, and where there were homogeneous products frequently purchased by buyers in consistent quantities. The project focused on titanium forgings because the PPI was able to create an unrefined frame and document the typical transaction characteristics of buyers in this product area. After significant resources were spent on this project, pricing issues remained, and a process had not been defined to refine and systematically sample from the frame. As a result, the project was dropped and the program reverted to obtaining good transaction prices from sellers even in these more difficult cases. No further work was done on buyers' prices, and in 1980, when indexes calculated using sellers' transaction prices were introduced from the systematic sample for the primary aluminum industry output index, the buyers' price commodity index for aluminum ingot was dropped.

Input/Output Indexes

In response to the *Stigler Report*, the PPI also began examining approaches to creating input and output (price) indexes for industries. For example, in the early 1960s the PPI built output Industry-Sector Price Indexes (ISPI) for some industries by combining the judgmentally sampled data collected for the commodity indexes using different classification structures and weighting. In the mid 1970s, however, the PPI began a comprehensive revision in order to plan and implement many improvements that had been recommended over the years, including those in the *Stigler Report*. The long-term goal of the revision was to expand the PPI's coverage to every industry in the private economy and to publish a system of price indexes that included

- industry output indexes,
- industry input indexes,
- detailed commodity indexes, and
- industry based stage of processing indexes.

In the late 1970s the PPI began systematically sampling industries, and in 1980 began introducing industry output indexes on a regular basis.[170] Throughout the years, the PPI continued to expand the number of industry output indexes and now covers 82 percent of all in-scope production.

As an attempt to fulfill the recommendations of the Stigler report, and as a component of its stage of processing indexes, the BLS did publish a set of input price indexes from 1988 to 2003. These indexes were calculated by reweighting output prices using input weights, which allowed the use of output price indexes at a great level of detail. However, these indexes did not include imports, nor did they directly account for substitution from a buyer's perspective. Thus, they assumed that sellers' prices are a good proxy for buyers' prices, and that prices for imports and domestic production move similarly. These series were discontinued in 2003, but the BEA and the BLS still used them as a method for constructing input price indexes where necessary (see Table 1).

Note that the BLS *does* have extensive experience with constructing an input price index, because both the import price and consumer price indexes are constructed from buyers' prices.

CURRENT USES AND USERS OF THE DATA

The fundamental question facing the BLS, of course, is, can the BLS produce an input price series that will meet the needs of its primary users? To answer this question, one must first delve into the intricacies of the construction of the outputs of the two primary potential users of these data, the Office of Productivity and Technology (OPT) at the BLS, and the Industry Sector Division of the BEA.

The BLS

We will start with the OPT, which publishes two types of productivity measures: 1) labor productivity, or output per hour of labor; and 2) multifactor productivity, or output per unit of combined inputs. Labor productivity indexes and multifactor productivity indexes are produced in two different divisions in the BLS.

Labor productivity

Measures of labor productivity are produced in two divisions of the OPT: the Division of Major Sector Productivity (DMSP) and the Division of Industry Productivity Studies (DIPS). The estimates of labor productivity (and unit labor costs) for major sectors are published quarterly, while estimates for industries are published annually. Labor productivity estimates do *not* explicitly measure shifts in the quantity (or constant dollar value) of material inputs, and therefore do not require estimates of the changes in the prices of those inputs, be they domestically sourced or imported. Note that outputs *are* adjusted for inflation.

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[170] While the practical work focused on an output price index, work did proceed on the theory of an input price index, culminating in a BLS working paper by Robert Archibald in 1975.

Multifactor productivity

Multifactor productivity measures are also produced in both the DMSP and DIPS. The DMSP publishes, albeit with little detail, multifactor productivity estimates for the private business and private nonfarm business sectors of the economy. These series represent 77 percent of U.S. GDP. In calculating these series, outputs are measured on a value-added basis, which are then compared to just two inputs, capital and labor. The value of material inputs is excluded from these calculations. However, staff uses detailed price indexes to deflate capital expenditures. Physical capital, as measured by the DMSP, consists of 42 types of equipment and software, 21 types of nonresidential structures, 9 types of residential capital, inventories (manufacturing available for 3 stages of fabrication), and land. Deflation of each capital expenditure category is actually done at the detailed 5- or 6-digit input-output (I-O) level. (The actual derivation of value-added by sector entails adjusting the value of inputs to account for changes in prices. This work, however, is done at the BEA.)

The DMSP also publishes annual multifactor productivity measures for total manufacturing and 18 broad 3-digit NAICS manufacturing industries, comparing sectoral output (total output excluding intraindustry or intrasector transactions) to a broad set of inputs, including capital, labor, energy, materials and business services (KLEMS) inputs. (Note that on a value-added basis, manufacturing represented 12 percent of GDP in 2007.) In the manufacturing sector of the economy and in individual industries, intermediate purchases constitute the largest component of inputs. The nominal dollar and constant dollar values of energy, materials, and services used by the DMSP are derived by the BEA.

DIPS publishes more detailed annual multifactor productivity measures for 86 4-digit NAICS manufacturing industries, plus air transportation and line-haul railroads. These productivity measures also compare industry sectoral output to a broad set of combined inputs. DIPS publishes estimates of intermediate purchases, capital, and labor for each of the detailed manufacturing industries. The index of intermediate purchases for each industry is constructed by combining separate quantities (or constant dollar costs) of electricity, fuels, materials, and purchased services. In order to deflate nominal dollar cost inputs for each industry, weighted deflators for materials and services are calculated by combining detailed price indexes using weights derived from the cost of commodities consumed by each industry, as shown in the detailed benchmark I-O tables produced by the BEA. I-O commodities from the benchmark I-O tables generally relate to the primary products of 6-digit NAICS industries, or occasionally a combination of industries. For materials commodities that are heavily imported, DIPS combines PPIs and import price indexes using weights from the BEA's import matrix. DIPS also uses PPIs to create weighted deflators to deflate annual fuels purchases of each industry and capital expenditures. Price deflators for each equipment asset category are constructed by combining detailed PPIs with weights from the BEA capital flow tables at the roughly 6-digit level. For the DIPS detailed manufacturing industry measures, physical capital consists of 25 categories of equipment, two categories of structures, three categories of inventories, and land.

Note that the BLS makes use of product-specific data in constructing deflators for a set of input price indexes for a given industry's material costs. Ideally, an input price index would be industry-specific, but that may prove cost-prohibitive.

Since industry MFP calculations are based on annual data, the nominal input values are adjusted by annual PPIs (average of 12 monthly price indexes).

The BEA

The Industry Sector Division at the BEA is responsible for producing the annual industry accounts and the benchmark input-output accounts. These accounts, which shed critical light on the relationships between U.S. industries, take a value-added approach to and are consistent with the BEA's flagship GDP estimates. Although the BEA does not publish detailed annual real input-output estimates, they do publish annual price and quantity indexes for 65 detailed industries, including 19 manufacturing industries, which do require data on the real value of inputs.

As in the work at the BLS, the BEA attempts to make its adjustments at the most detailed level possible. For example, at the BEA, the effort to construct updated values for intermediate inputs of goods and services entails making adjustment to approximately 3,500 different items, of which roughly 2,300 represent categories of goods. Ideally, and like the BLS, the BEA would like input price indexes *by industry* for each of the 1,179 6-digit NAICS level of detail. In practice, since the cost of producing that many separate price indexes could be prohibitive, the BEA, like the BLS, would accept a set of *product-based* input price indexes. In addition, at a minimum, category definitions should be consistent with the 12 expense categories recently added to the Census Bureau's ASM forms (most of which are services inputs). While the BEA currently only produces annual estimates of GDP-by-industry, there has been growing interest in providing these estimates on a quarterly basis.

In sum, although superficially the level of publication required to produce the currently published set of economic data is comparatively high, in actuality the detail necessary to properly support these estimates may be considerably more disaggregated.

STEPS TO PRODUCE AN INPUT PRICE INDEX

While there is little dispute over the potential advantages of adding an input price index to the family of price indexes produced by BLS, there is the fundamental question of both feasibility and cost of producing a usable and comprehensive set of indexes.

Developing a Sample

From a practical standpoint, the first and perhaps the biggest hurdle in developing an input price index is developing a frame from which to draw a sample of establishments; the bureau does not currently have access to data on the expenses and purchases of individual companies necessary to produce a representative sample. Without these data, a BLS field agent attempting to initiate a respondent into a survey would have no information on what that establishment buys in order to produce its outputs. While, in theory, the establishment might be able to supply these data, in practice it is expected that this type of data collection would be very problematic given the voluntary nature of BLS programs.

All is not lost, however, as the Census Bureau does collect detailed data on purchases by individual establishment. In particular, in the Economic Census, which the agency conducts every five years, all manufacturing firms are asked to include detailed data (by 10-digit NAICS code) on their cost of materials, parts, and supplies consumed in the reference year. The most recent data available cover the calendar 2007 Economic Census and became available in mid-2009. The dataset includes information for 340,000 manufacturing establishments in the United States, and the Census Bureau records the total cost of materials purchased by these establishments as approximately $2.5 billion in calendar 2007. Table 2 is part of the collection form for the MC-33702 Manufacturing, Household Furniture and Wood Housings sector, where establishments report on their material costs. In addition, Table 3 has an example of the type of data that is publically available from the census. For NAICS 333111, one can find data on the number of companies and their total purchases and expenses, as well as an indication of their relative size. Table 4 shows data on cost of materials by type of material for that same industry, while Table 5 reflects the total purchases for all manufacturing industries of a given commodity.

In addition, the less comprehensive but timelier Annual Survey of Manufacturing, which is based on a sample of 50,000 manufacturing establishments, includes a limited amount of data on purchases, providing one category for total cost of materials, parts, containers, packaging, etc.

One shortcoming of these surveys is that, while data on capital expenditures is also collected, it is only split three ways: 1) motor vehicles, 2) computers, and 3) other. Another potential shortcoming of this source of data is its timeliness, or lack thereof. Since the detailed data is only collected once every five years, it may be that by the time the BLS is able to draw a sample and initiate these establishments into a market basket, the establishments and/or the products that they buy may be out of date and no longer reflective of their current market.

Although much of the focus has been on the manufacturing sector, it should be recalled that the manufacturing component only accounts for a small and shrinking sector of the economy; services represent nearly two-thirds of GDP. The amount of detailed cost data collected by the census for the service industry surveys is more limited. In general the collection forms include some detailed data on purchased services, but only limited data on purchased equipment and materials.[171] Interestingly, while the census collects very little detailed data on material costs in the noncensus years for manufacturing industries, the level of detailed data collected for the cost of business services, though limited, is roughly the same, whether it is for an annual survey or the every five-year census. In general, the surveys break out the purchases of business services into five categories: computer services, communication services, advertising and related services, professional and technical services, and repair and maintenance services.

Due to the more detailed cost of materials data available for the manufacturing sector, much of the current assessment of a potential sampling frame has focused on this sector. Unfortunately, because many of the datasets at the Census Bureau have data that has been commingled with

[171] For example, in contrast to the forms for the furniture manufacturing industries, the collection form for the parallel furniture wholesale (Table 6: WH-42305) sector does not provide the same level of detail on material costs, while the collection form for the retail furniture industry (Table 7: RE-44201) does not collect *any* information on the cost of materials.

federal tax return information data from the Internal Revenue Service, getting access to the necessary data has been somewhat problematic. Work has continued for several years on what is referred to as companion legislation.[172] Regardless, BLS staff have recently been able to access these data at the Census Research Data Center in Suitland, Maryland, and have begun the process of assessing the utility of using these data to draw samples that would permit the publication of input price indexes for the 471 6-digit NAICS manufacturing industries. One concern is that a large percentage of the cost of materials purchased is in a miscellaneous purchase category.

Assuming BLS is able to use the census data, this would allow the BLS, using establishment sampling methodologies with which the bureau is already quite familiar, to construct a sample of establishments, and detailed product areas within the given establishment, that the bureau would need to collect the necessary pricing data. The selection of the actual item that the bureau would need to reprice on a periodic basis would normally be done by a BLS field economist during a so-called initiation visit to the establishment. This procedure is one that is already done by staffers when collecting data for the bureau's PPI and IPP industrial price programs, and involves a number of trade-offs. Ideally the selection would be based on a probability proportionate to how much of a given item a company purchases within the selected category. Thus, if a company buys a certain amount of varying types of steel, the field economist, using data hopefully supplied by the respondent, would be able to select a specific steel product on which the BLS would attempt to collect data. In practice, however, these procedures would likely have to take into account the fact that the selected item may not be purchased on a regular basis, or the respondent may not have any data available on how much of each different type of steel the company purchased in a given period. Since the BLS already has experience with these types of issues in its current programs, developing an appropriate fallback procedure does not necessarily present a problem. However, it does lead in to what is perhaps the key issue, which is the ability of the program to reprice the same item month after month, quarter after quarter or year after year, from the same source.

Pricing

Maintaining a constant set of items to reprice over time may prove to be the most intractable barrier to constructing a comprehensive set of input price indexes. While on the output side, companies tend to ship their goods (or offer their services) every month, it is not clear if they buy the same item on a regular basis, especially for capital equipment such as computers. This may place a heavier burden on the imputation method chosen for valuing prices in missing periods.[173] Alternatively, the BLS may have to use an altogether different approach, such as combining prices from different respondents (in cases where the item specifications are identical). A related question is how to handle changes in the pricing specifications. For example, if the product is the same but the supplier is different, do we continue to price it as the same item? What is our

[172] Legislation to modify the IRS tax code was proposed by the last Administration, with interagency support from the Departments of Treasury, Commerce, and Labor, in 2002–2003 and in 2008. Conversations have begun on the development of an official Obama Administration proposal, with the Office of the Under Secretary of Commerce for Economic Affairs taking the lead on this effort.

[173] In constructing a sample for the import price index, the International Price Program has the advantage of accessing the universe of import transactions from the Customs Service, which allows for drawing a sample only of those items and importers who trade consistently over the course of a year.

general approach toward quality adjustment when a buyer switches products and/or suppliers? That is, in an ideal situation where we can get the exact information that we desire, what would we ask for? What are the acceptable fallbacks if we can't obtain the desired information? What if, in fact, the buyer uses multiple suppliers? Do we select a specific supplier or use some sort of average? If we select one, how and when do we switch to a price from a different supplier? Should the price include or exclude transportation costs? If other services are bundled with the product (e.g., installation), how do we handle those situations? Do we want to include government purchases? If so, how would we sample for them since they wouldn't be included in data at census? How do we coordinate requests for buyers prices with requests for sellers prices within the same firm?

In order to answer these and similar questions, the BLS will most likely need to make some effort to collect information from a sample of representative companies. A final decision on some of these issues will probably entail balancing the requirements of a price index with the reality of the agency's sometimes limited ability to collect data voluntarily from private industry.

Estimation Formula

With one exception, compared to the questions associated with sampling and repricing, the issues surrounding the estimation formula are comparatively easy. Weights can either be derived from the sampling frame, from the respondents themselves, or from some combination thereof. One concern with using the weights derived from the sampling frame is the age of the data. Since the detailed data are collected only once every five years, the data may be out of date by the time they are actually used in the calculation of the indexes. A comparison of these values from one census to the next may shed light on the volatility of these figures.

There are various questions associated with the actual formula to use, such as using an arithmetic formula versus a geomeans formula, but they do not present intractable barriers. One interesting aspect of the formula relates to theoretical differences between the price index formula for the output from a production function versus the index formula for the price index for inputs into a production function. The theory assumes that a firm will attempt to maximize profits by minimizing costs while maximizing revenue. On the output side, theory tells us that an establishment will attempt to shift sales to its goods or services that over time are becoming relatively more expensive compared to its other outputs. In contrast, the firm would attempt to shift costs toward its expense categories that are becoming relatively cheaper. Consequently, a price index of firms' outputs would tend to show at least no decline in the relative quantity of the more expensive goods being sold, while on the cost side, the index should in theory reflect at least no increase in the goods or services that are more expensive. Interestingly, these assumptions are based on partial equilibrium models where the model is only looking at one side of the equation. But, of course, one establishment's sales are another establishment's purchases, and in a general equilibrium model, there is no a priori theory of exactly what constitutes the correct direction of substitution.[174]

The one notable difficulty in estimating these indexes relates to how one goes about constructing industry-specific price indexes. While a product-based input price index would use every

[174] For further elucidation, see Kim and To (2009)

establishment's purchases of a specific good (or service), an industry-specific input price index would only use goods or services purchased by establishments in that specific industry. For example, presumably all establishments must purchase energy, be it electricity, gas, petroleum products, etc. Would the BLS attempt to calculate a separate energy index for each industry, or would it combine all energy data into one generic input energy index? The answer may ultimately be decided on practical grounds, (i.e., do we have enough data for separate energy series, or do each of the different energy series trend nearly the same?) Of course, a proxy for an industry-specific input price index could be constructed using individual product-level price indexes, but aggregating them using the proportions appropriate for a particular industry's purchasing patterns.

Next Step: Reality Check

As previously mentioned, the preliminary step in this effort to produce an input price index is to develop a set of questions for a limited set of respondents who in the past have proven cooperative to the BLS industrial price programs. The questions would be designed not to collect specific pricing data from the establishments, but to provide the BLS with some insight into how respondents are likely to react to any such data collection requests. For example, some companies have refused to provide BLS with data, citing confidentiality concerns. Thus, one question might be designed to ascertain whether companies would be more likely, less likely, or equally as likely to supply data on costs as they are willing to supply output or import or export price data. Another basic question to ask respondents would be to ascertain if they even keep good data on the cost of their purchases, and if so, what the periodicity of their purchasing is.

Developing a Pilot

A longer-term effort to produce input price indexes can be broken down into four phases, based on availability of data. This effort will require additional approvals and funding as well. The four phases include input indexes covering 1) manufacturers material costs, 2) manufacturers capital equipment costs, 3) manufacturers business services costs, and 4) service industries material, capital equipment, and business services costs.

Ideally, each phase would start with a pilot prior to going into production. For each pilot, BLS will conduct research and develop the methodology, procedures, and systems associated with each of the following activities:

- Obtain permission from the OMB.
- Select a set of industries for the pilot.
- Evaluate the data sources that are available for a sampling frame. Due to the potential for detailed cost data from the Census of Manufactures, the first phase would focus on input indexes of cost of materials for manufacturing industries.
- Develop the collection materials and procedures and train staff.
- Select a sample of establishments for the pilot.
- Conduct the pilot test and evaluate the results.

- Evaluate the feasibility of producing an input price index for the given phase and develop the requirements for producing an input price index, including publication goals, required sample size, expected burden, and estimated resources and timeframe for publication.
- Based on available resources, develop and maintain a production set of indexes for that particular set of input indexes.

Cost

Assuming the methodological and data collection issues can be resolved, and assuming the BLS is able to collect the necessary data from respondents, there remains the question of the cost of developing and maintaining these new indexes. On the one hand, the collection, review, and verification of data for inclusion in price indexes still has a significant labor-intensive component, usually requiring a substantial level of expertise in economics and/or statistics. On the other hand, a significant (but unknown) amount of the necessary resources, both in human capital as well as data processing applications, may be shared with the bureau's other industrial price programs, the IPP and the PPI. Any bureau effort to produce an input price index past the research phase would require resources sufficient to cover collecting approximately 15,000 items and publishing approximately 600 6-digit material codes (which are similar to NAICS codes). The process for developing these series would extend over several years. Extending the set of indexes to cover the three additional phases would entail an additional annual cost.

Table 1

Table 11. Producer price indexes and percent changes for net material inputs to industry stage of process and final demand, not seasonally adjusted

(June 1987=100)

Grouping 1/	Relative importance Jun. [illegible]	Unadjusted index 2/ Mar. 1996 2/	Jun. 1996 2/	Jul. 1996 2/	Percent changes: 11 months ending Jul. 1996	3 months ending-- Oct. 1995	Jan. 1996	Apr. 1996	Jul. 1996	Jun. 1996 to Jul. 1996
Net material input to:										
Primary processors	100.000	122.5	[illegible]	121.7	7.7	-0.3	6.6	2.9	-2.3	0.3
Foods and agricultural products	18.575	154.5	176.9	182.1	47.4	6.2	13.7	[illegible]	9.2	2.9
Crude food and agricultural products	12.516	166.6	196.3	205.2	56.5	6.6	15.1	[illegible]	11.2	2.9
Processed foods	6.[illegible]	138.9	148.7	156.8	29.5	6.3	11.8	[illegible]	5.9	0.7
Energy	35.[illegible]	111.9	[illegible]	100.5	16.1	-1.7	17.4	[illegible]	-3.9	[illegible]
Other than food and energy	47.[illegible]	132.3	131.7	129.[illegible]	-2.2	-1.0	-2.5	[illegible]	-1.9	[illegible]
[illegible]	4.232	117.9	[illegible]	[illegible]	-5.7	-2.3	-5.5	[illegible]	[illegible]	[illegible]
[illegible]	32.[illegible]	132.8	129.0	128.5	-0.5	-0.0	-3.8	[illegible]	[illegible]	[illegible]
[illegible]	14.091	134.4	134.9	134.0	-1.3	-1.1	-0.9	[illegible]	[illegible]	[illegible]
Semifinished processors	100.000	119.4	121.[illegible]	121.[illegible]	-0.7	0.3	-0.7	-0.6	1.3	-0.2
Foods and agricultural products	24.61[illegible]	109.3	[illegible]	109.0	11.2	[illegible]	[illegible]	[illegible]	2.0	1.5
Crude food and agricultural products	22.86[illegible]	99.1	[illegible]	107.[illegible]	11.[illegible]	[illegible]	[illegible]	[illegible]	2.6	[illegible]
Processed foods	1.743	119.4	[illegible]	122.[illegible]	11.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Energy	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other than food and energy	[illegible]	127.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	113.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	30.612	138.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	16.[illegible]	135.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	100.000	122.[illegible]	[illegible]	[illegible]	-0.4	0.2	0.2	0.0	0.2	-0.2
Foods and agricultural products	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Crude food and agricultural products	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Processed foods	[illegible]	129.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Energy	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other than food and energy	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-1.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Final demand	100.000	124.1	[illegible]	125.5	2.8	0.4	0.7	1.1	0.6	-0.2
Consumers	74.[illegible]	125.5	127.5	127.5	3.4	0.2	0.2	1.4	0.9	-0.2
Foods and agricultural products	25.[illegible]	123.[illegible]	125.[illegible]	124.9	5.1	1.5	1.8	0.7	1.9	[illegible]
Crude food and agricultural products	2.[illegible]	168.9	152.[illegible]	155.2	19.5	4.4	12.6	3.6	-1.8	-4.7
Processed foods	27.[illegible]	126.8	[illegible]	125.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Energy	14.[illegible]	141.5	139.7	139.2	5.4	-3.4	2.1	6.3	0.9	-2.3
Consumer goods less food and energy	34.[illegible]	127.[illegible]	128.[illegible]	128.2	1.6	1.0	0.3	0.8	0.2	-0.2
[illegible]	0.[illegible]	122.[illegible]	120.7	120.6	-2.9	0.3	1.1	-0.5	1.7	-0.1
[illegible]	19.910	135.[illegible]	135.[illegible]	134.[illegible]	1.6	0.5	[illegible]	-0.1	0.6	0.0
[illegible]	16.[illegible]	120.3	120.4	120.1	1.5	1.6	0.2	-0.1	-0.2	-0.2
Capital investment	25.332	121.3	121.1	121.0	0.9	0.9	0.2	-0.1	-0.2	-0.1
Special groupings:										
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] 4/	[illegible]	128.9	[illegible]	120.5	5.9	7.4	[illegible]	[illegible]	2.9	-0.1
[illegible] 4/	[illegible]	120.9	[illegible]	120.1	2.7	-0.2	0.7	1.7	0.3	-0.2
[illegible] food and energy 4/	[illegible]	131.1	[illegible]	134.7	5.1	-1.1	1.1	2.5	6.7	-0.2

[1] The indexes in this table are derived from the product indexes in table 5. These indexes are composed of the goods used by the industries in each of the industry stage of process output indexes as shown by the 1977 input/output

[2] The indexes for March 1996 have been recalculated to incorporate late reports and corrections by respondents. All indexes are subject to revision 4 months after original publication.

Table 2
2007 Economic Census: MC-33702 Manufacturing, Household Furniture and Wood Housings

17 DETAILED COST OF MATERIALS, PARTS, AND SUPPLIES

Materials, parts, and supplies (0634)	Census material code (0630)	Consumption of purchased materials and of materials received from other establishments of your company — Cost, including delivery cost (freight-in) (0631) $ Bil.	Mil.	Thou.
Wood furniture frames	337215 00			
Lumber, rough and dressed				
Hardwood	321000 25			
Softwood	321000 31			
Plywood, hardwood and softwood	321000 91			
Hardwood veneer	321211 04			
Particleboard (wood)	321219 02			
Medium density fiberboard (MDF)	321219 06			
Hardboard (wood fiberboard)	321219 09			
Hardwood cut stock and dimension (excluding furniture frames)	321912 03			
Furniture and builders' hardware, including cabinet hardware, casters, glides, handles, hinges, locks, etc.	332510 01			
Coated and laminated fabrics, including vinyl coated	313320 06			

Table 3
NAICS 333111
Farm Machinery and Equipment Manufacturing

Companies	Establishments with 100 employees or More	Total Value of Shipments ($1,000)	Total Capital expenditures ($1,000)	Total Cost of, Purchased materials ($1,000)
1,079	104	$21,181,238	$348,399	$9,903,172

Table 4
NAICS 333111
Farm Machinery and Equipment Manufacturing
(Cost of Materials)

Material Code	**Description**	**Delivered cost ($1,000)**
971000	Materials, ingredients, containers, and supplies, nsk	2,718,394
970099	All other materials/components/parts/containers/supplies	967,152
33000019	Engines (diesel/semidiesel/gasoline/carburetor-type/etc.) & parts	680,000
33000067	Fluid power products, hydraulic and pneumatic	607,834
33100022	Steel sheet and strip (including tinplate)	586,586
33200046	Other fabricated metal products (excl. Forgings/castings etc.)	504,553
32621103	Pneumatic tires and inner tubes	389,781
33635003	Transmissions and parts	288,496
33100025	Steel struct shapes & sheet piling (excl castings/forgings/etc.)	286,917
33361200	Mechanical speed changers, gears, & ind. high-speed drives	281,122
33120092	All other steel shapes/forms (exc. castings/forgings/etc.)	280,209
33151001	Iron and steel castings (rough and semifinished)	268,893
33632200	Engine electrical equip. (incl. spark plugs/magnetos/etc.)	226,547

Table 5
Expenditures on Fluid Power products (Material Code 33000067) by Industry

NAICS Code	Description	Delivered cost ($1,000)
333111	Farm machinery and equipment manufacturing	607,834
333112	Lawn and garden equipment manufacturing	218,356
333319	Other commercial and service industry machinery manufacturing	422,091
333512	Machine tool (metal cutting types) manufacturing	66,118
333513	Machine tool (metal forming types) manufacturing	43,371
333516	Rolling mill machinery and equipment manufacturing	12,355
333518	Other metalworking machinery manufacturing	29,007
333611	Turbine and turbine generator set units manufacturing	4,687
333618	Other engine equipment manufacturing	284,283
336312	Gasoline engine and engine parts manufacturing	268,662
336330	Motor vehicle steering and suspension parts	89,222
336340	Motor vehicle brake system manufacturing	47,397
336350	Motor vehicle transmission and power train parts manufacturing	237,914
336399	All other motor vehicle parts manufacturing	405,854

Table 6
2007 Economic Census: WH-42305 Wholesale, Furniture and Home Furnishings

11–15 Not Applicable.

16 SELECTED EXPENSES

		Mark "X" if None	2007 $ Bil.	Mil.	Thou.	Dol.
A. Operating expenses *(Include payroll. Exclude cost of goods sold and interest expense.)*	0140	☐				
B. Purchases of merchandise for resale, net of returns, allowances, and trade and cash discounts *(Include amounts allowed for trade-ins.)*	1160	☐				

C. For the value reported on line B, were any of these goods ordered over an Internet, Extranet, Electronic Data Interchange (EDI) network, electronic mail, or other online system?

0441 ☐ Yes

0442 ☐ No

0443 ☐ Do not know

Table 7
2007 Economic Census: RT-44201, Retail Furniture Stores

Form RT-44201 (12/01/2006)

If not shown, please enter your 11-digit Census File Number (CFN) from the mailing address.

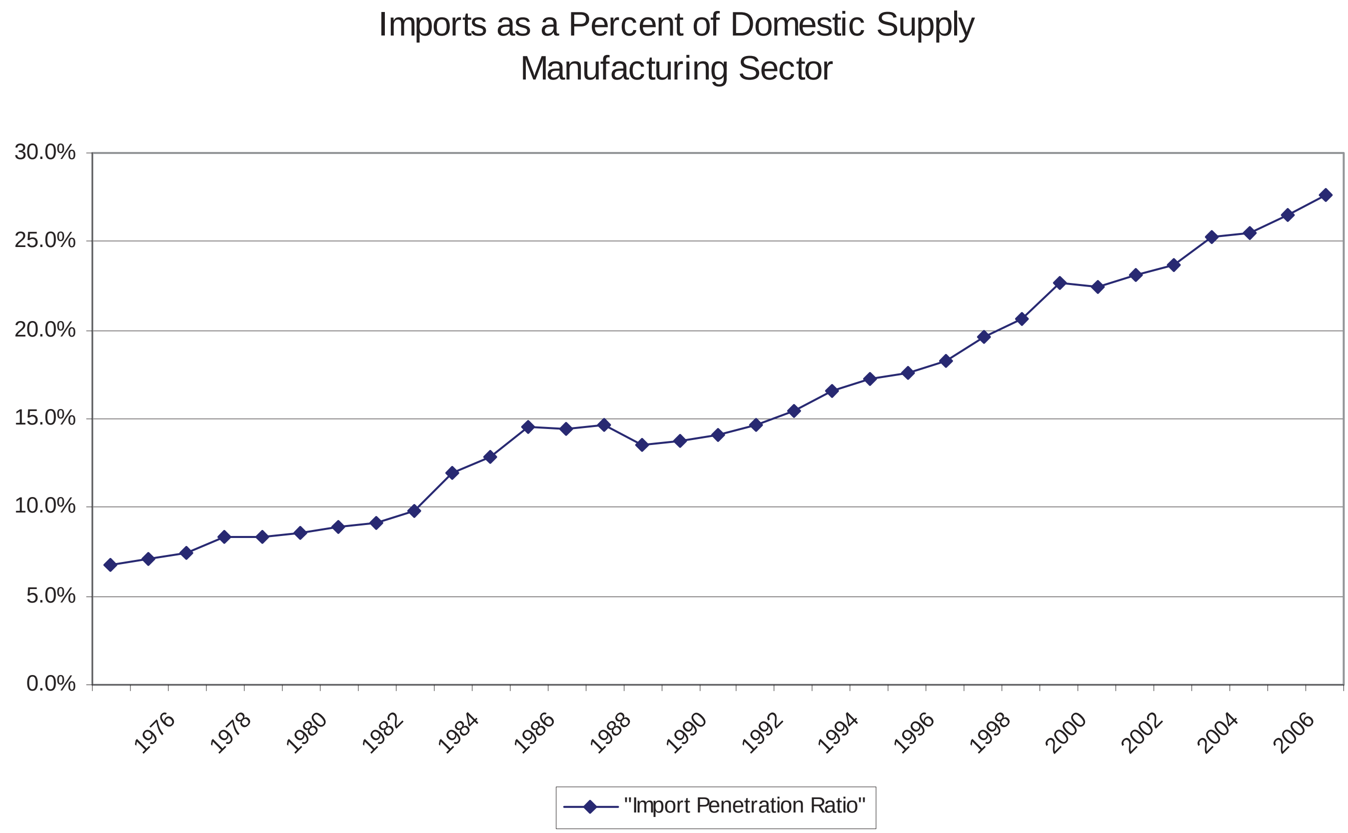
8–18 Not Applicable.

19 KIND OF BUSINESS

Which ONE of the following best describes this establishment's principal

(Mark "X" only ONE box.)

Figure 1


Imports as a Percent of Domestic Supply
Manufacturing Sector
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
"Import Penetration Ratio"

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SESSION 7: MEASUREMENT OF IMPORT PRICES AND IMPORT USES: EVIDENCE OF BIASES

CHAIR: Carol Corrado (Conference Board)

Imported Inputs and Industry Contributions to Economic Growth: An Assessment of Alternative Approaches, Erich Strassner, Robert Yuskavage and Jennifer Lee (Bureau of Economic Analysis)

Evaluating Estimates of Materials Offshoring from U.S. Manufacturing, Robert C. Feenstra (University of California-Davis) and J. Bradford Jensen (Georgetown University and Peterson Institute for International Economics)

DISCUSSANT: William Milberg (New School for Social Research)

Errors from the "Proportionality Assumption" in the Measurement of Offshoring: Application to German Labor Demand, Deborah Winkler and William Milberg (Schwartz Center for Economic Policy Analysis, The New School for Social Research)

Imported Inputs and Industry Contributions to Economic Growth: An Assessment of Alternative Approaches

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Paper prepared for the NAPA/Upjohn conference
"Measurement Issues Arising from the Growth of Globalization"
Washington, DC
November 6–7, 2009

Imported Inputs and Industry Contributions to Economic Growth: An Assessment of Alternative Approaches

Over the past decade imports have become an increasingly important source of supply for both U.S consumers and producers, partly due to changes in the relative prices of imported and domestic goods. From 1997 to 2007, imports as a share of all goods and services consumed in the United States increased from 18 percent to 23 percent. This aspect of globalization has affected the size and structure of the U.S. economy, especially the manufacturing sector, but it has also complicated the task of measuring economic growth and industry performance. Policymakers and researchers are concerned that increased outsourcing to lower-cost offshore suppliers has affected key economic measures such as output, value added, and labor input. Difficulties in measuring price change for imported goods can affect measured growth in real gross domestic product (GDP). Similarly, problems identifying outsourcing-related activities could affect measures of industry contributions to economic growth and productivity in manufacturing and other sectors.

For several decades, imports have been the major source of U.S. supply for final consumer goods such as apparel, toys, shoes, motor vehicles, and consumer electronics, and for certain kinds of business investment goods. More recently, the import share has increased for final goods such as furniture and other household products, with important implications for the measurement of domestic consumption prices. Another recent trend has been strong growth in the use of imported intermediate materials by U.S. manufacturing industries, partly at the expense of domestic goods. A significant portion of this trade occurs among affiliated parties within U.S. multinational companies. This form of offshore outsourcing—substitution of imported for domestic materials—has raised questions about the measurement of real value added by industry and its impact on real GDP growth.

Limitations in the measurement of imports have somewhat different implications for the various approaches typically used by statistical agencies to measure GDP.[175] Only the final expenditures approach and the production approach provide measures of both nominal and real GDP. Because imports are subtracted using either approach, import growth has important measurement implications. In the final expenditures approach, which is featured in the United States, real GDP is an aggregate of personal consumption expenditures, private equipment and structures, government consumption and investment, and exports less all imports, both final and intermediate. In the production approach, which is the featured approach in many other countries, real GDP is an aggregate of the real value added originating in all industries, including government. Value added equals gross output less intermediate inputs, which include imported inputs. As a result, under the production approach, only the imports consumed in intermediate uses are subtracted. In recent years, intermediate goods and services have accounted for slightly more than 50 percent of all imports.

[175] The three major approaches are the final expenditures approach, the income approach, and the production approach.

Economists have expressed concern that substitution by U.S. consumers and producers toward lower-priced imported goods from developing countries may not be fully reflected in the official import-price indexes used for calculating real GDP based on the final expenditures approach, and that as a consequence, growth in real GDP and productivity may be overstated (Mandel). This potential bias can be explored using both the expenditure and production approaches to measuring real GDP. To the extent that the recent growth in lower-priced imported goods has affected intermediate and final uses assessing the impact using the production approach may be revealing.

Data from the Bureau of Economic Analysis's (BEA) annual industry accounts can be used to identify not only the uses of imported goods (intermediate vs. final) but also the overall importance of imported products by measuring their value relative to the value of comparable domestically produced goods. For this paper, we use data from the BEA's annual industry accounts and from the BEA's surveys of multinational companies (MNCs) to determine how growth in imported intermediate inputs has affected growth in real value added by industry (real GDP growth), and to assess the impact of alternative assumptions about the use of imports and the behavior of import prices.

In this paper, we calculate real value added by industry and real value added for all industries (real GDP) using alternative assumptions about industry use of imports and the behavior of imported input prices. In the current (baseline) methodology, the allocation of imports to industries is based on an "import comparability" assumption. This assumes that the portion of intermediate inputs attributable to imports is calculated as a percentage of the total purchase value, using the economy-wide ratio of commodity imports to the total domestic supply of the commodity. Alternative assumptions about the use of imports by selected industries are based on the BEA's data on imports by the U.S. parents of foreign affiliates and unaffiliated parties. For the deflation of imported intermediate inputs, the current methodology relies primarily on import-price indexes compiled by the Bureau of Labor Statistics (BLS). Alternative assumptions about import-price change are made to determine a threshold required for import price biases to impact real GDP, the manufacturing sector, and selected manufacturing industries.

The remainder of this paper is presented in four sections. The next section provides background on how the industry accounts can be used to measure outsourcing and the role of imported inputs at the industry level, how the BEA's import-use tables are compiled, and how imported inputs are used in constructing real value added by industry. After that we briefly describe the BEA's International Economic Accounts, including the MNC data, and explain how the MNC-based import-use tables are compiled. The following section presents empirical results that compare the current (baseline) estimates from the annual industry accounts with results from the MNC-based import-use tables. This section also describes results based on different assumptions about the behavior of import prices. We conclude with a brief summary and recommendations for improving data on imported inputs by industry and import-price indexes.

ANNUAL INDUSTRY ACCOUNTS

The annual industry accounts are a useful analytical framework for simulating the impact of alternative assumptions about imports for several reasons. These accounts provide an annual time series of nominal and real gross output, intermediate inputs, and value added for 65 industries defined according to the 1997 NAICS) (Moyer et al. 2004). They provide an internally consistent set of industry production accounts that are integrated conceptually and statistically with final expenditures and GDP from the national income and product accounts (NIPAs).

The annual industry accounts are estimated within the framework of balanced make and use tables, which allows for integrated analysis of industry output, inputs, employment, final demand, and imports. The annual input-output (I-O) accounts provide a time series of detailed, consistent information on the flows of goods and services that both comprise industry production processes and that are included in final expenditures. Estimates of the supply of commodities are prepared at nearly the same level of detail as in the benchmark I-O accounts and are then aggregated to the higher publication level used for the annual industry accounts. The GDP by industry accounts feature estimates of nominal and real value added by industry. Value added is defined as an industry's gross output (sales or receipts and other operating income) minus its intermediate inputs (energy, materials, and purchased services). Intermediate inputs are acquired from either domestic or foreign sources (imports). Price and quantity indexes of gross output, intermediate inputs, and value added are published for industries, industry groups, and broad sectors in the GDP by industry accounts.

Significant improvements in the measurement of intermediate purchases in the 1997 benchmark made the annual industry accounts more suitable for identifying and measuring outsourcing and the role of imported inputs than in the past.[176] A broader set of purchased services was collected for establishments in the manufacturing, mining, and construction sectors, and more detailed data on purchased services for more industries in the trade and services sector were collected from an expanded Business Expenses Survey.[177] Estimates of materials and energy inputs by industry were also based on detailed economic census data for manufacturing and on broader input category data for nonmanufacturing industries.

The expansion of the annual industry accounts in 2005 to provide additional information on the composition of intermediate inputs by industry made these accounts more analytically useful to study trends in the use of energy, materials, and purchased services inputs (Strassner, Medeiros, and Smith 2005). The balanced I-O use table provides the product detail needed to aggregate estimates of intermediate inputs into cost categories useful for economic analysis.[178] Each cost category includes both imported and domestically produced goods and services, and each

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[176] The 1997 benchmark I-O accounts were based almost entirely on detailed data on outputs and inputs collected by the Census Bureau in the 1997 Economic Census. For more information, see Lawson et al. (2002).

[177] As a result of the expansion in source data, a much larger share of total intermediate purchased services was based on economic census data than in past benchmarks.

[178] These estimates are prepared by applying a KLEMS production framework to the BEA's estimates of industry production.

category is valued in purchasers' prices, which include domestic transport costs, wholesale trade margins, and sales and excise taxes.

On an annual basis, a wide array of source data is used to update the benchmark estimates for the annual time series. Nominal value added by industry estimates are available annually for the compensation of employees, taxes on production and imports less subsidies, and the gross operating surplus. Annual survey data are available from the Census Bureau for updating industry gross output for all of the manufacturing industries and for most of the services industries, including the industries that provide outsourcing-related services. Annual data are also available from the NIPAs for updating estimates of final expenditures.

Data, however, are not available annually to update estimates of intermediate inputs by industry. Instead, the BEA's procedures for annual updates of intermediate inputs rely partly on the assumption that the real (constant-price) use of intermediate inputs relative to the industry's real gross output has not changed from the prior year.[179] An industry's real intermediate inputs are initially updated based on changes in its real gross output. The nominal value of its intermediate inputs for the current year is further adjusted based on price changes for the detailed commodity inputs. Balancing constraints are imposed to ensure that the use of commodities by all industries equals the supply of commodities, after accounting for final uses from the NIPAs.[180] These procedures are used for each year's set of accounts. Updated KLEMS estimates by industry are likewise based on the updated commodity input estimates.

An important step in updating the annual industry accounts is the development of import-use tables to allow for the separate deflation of domestic and imported inputs in the calculation of real value added.[181] Intermediate inputs at a detailed product level are disaggregated to obtain the domestic and imported portions of intermediate inputs included in each KLEMS input cost category. For each detailed commodity used by an industry, the portion attributable to imports is calculated as a percentage of the total purchase value, using the economy-wide ratio of commodity imports to the total domestic supply of the commodity.[182] Although this assumption is necessary, the import content of specific types of goods and services could vary by industry as a result of factors such as affiliation status, location, product mix, relative prices, or technology. The BEA uses this approach because of the lack of actual data on the use of imports by industry[183]

This distinction between domestic and imported inputs allows for differences in the behavior of prices for imported and domestic products to be accounted for when separate price indexes are

[179] This is often described as the "constant industry technology" assumption.
[180] The annual I-O accounts use final expenditure categories from the NIPAs as controls during the biproportional balancing of the use tables. An additional balancing constraint is that the sum of nominal value added across all industries must equal GDP.
[181] Fisher-ideal index number formulas are used to prepare chain-type indexes for gross output, intermediate inputs, and value added by industry, and for higher-levels of aggregation. For more information, see the technical appendix in Moyer et al. (2004).
[182] For example, if imports represent 35 percent of the domestic supply of semiconductors, then the estimates in the import-use table assume that imports comprise 35 percent of the value of semiconductors in each industry that uses semiconductors.
[183] This "import comparability assumption" is often used in studies of the impact of imports on intermediate inputs.

available.[184] For domestic materials and for energy, the price indexes are mostly BLS producer price indexes (PPIs), Department of Energy implicit price deflators, and price indexes from other sources that are considered reliable. Many of the services input-price indexes are also obtained from BLS PPIs, but some are based on other sources that are not as reliable, either because of quality change or due to assumptions about labor productivity.[185] Price indexes for imported materials are largely based on the BLS International Price Index program. Price indexes for imported services are much more limited in their coverage.

International Accounts

The BEA's international transactions accounts (ITAs) provide monthly, quarterly, and annual estimates of transactions between the United States and foreign residents.[186] ITAs include a current account, a capital account, and a financial account. The two major components of the current account are 1) exports of goods and services and factor income receipts, and 2) imports of goods and services and factor income payments. The difference between these two components, plus net unilateral current transfers, equals the balance on the current account. The capital account includes capital transfers such as debt forgiveness. The two major components of the financial account are 1) changes in net U.S.-owned assets abroad, and 2) changes in net foreign-owned assets in the United States. These components are the major source of change in the United States'net international investment position.

The BEA also produces comprehensive statistics on U.S. direct investment abroad and foreign direct investment in the United States that are required for compiling ITAs and for analysis of MNCs. The BEA's data on MNCs are potentially very useful for assessing assumptions about the use of imported goods by industries because these companies account for about 60 percent of U.S. imports of total intermediate inputs. While imports of goods in ITAs are based primarily on data compiled by the Census Bureau from import shipping documents, the data on imports of goods reported to BEA on the MNC surveys conform well to Census Bureau concepts and definitions. Imports of services in ITAs are estimated from a variety of sources, primarily the BEA's surveys of U.S. and foreign MNCs and the BEA's surveys of U.S. international services transactions between unaffiliated parties. For this study, we used annual data on U.S. imports of goods and services shipped to the U.S. parents by both their foreign affiliates and other unaffiliated parties.

The BEA's surveys are mandatory and collect selected data for transactions between the U.S. parents of MNCs and both their foreign affiliates and unaffiliated parties and transactions between the U.S. affiliates of foreign MNCs and both their foreign parent companies and certain other affiliated foreign firms. These data play an important role in compiling ITAs and in providing additional detail on cross-border trade in services and on services provided by the affiliates of MNCs. Because U.S. MNCs are typically very large firms, the combined data for U.S. parents and U.S. affiliates of foreign MNCs account for a significant share of domestic

[184] Domestic prices are used to deflate imported inputs in cases where import prices are unavailable.
[185] Expansion of the BLS PPI program in the services sector during the 1990s has resulted in better coverage and improved quality, but gaps and limitations remain.
[186] Transactions between the United States and its territories, Puerto Rico, and the Northern Mariana Islands are not treated as foreign transactions in ITAs.

economic activity, especially in the goods-producing sector of the economy. These combined company data, when classified by industry, provide valuable insights into the industry distribution of imports.

For this paper, alternative import-use tables were constructed using data from the BEA's surveys of MNCs.[187] Companies in these surveys are classified according to the International Survey Industry (ISI) classification system, a system developed by the BEA that is based on the NAICS. The MNC surveys provide information on total imports by U.S. parent firms (from both affiliated and unaffiliated parties) classified by the U.S. parents industry, and imports by U.S. parent firms from foreign affiliates classified by the foreign affiliate's industry. For the "benchmark" survey years, additional product information on imports is provided. These broad product categories are listed below:

- Food, live animals, beverages, and tobacco
- Crude materials, inedible, except fuels
- Mineral fuels, lubricants, and related materials
- Chemicals and related products
- Industrial machinery and equipment
- Office machines and automatic data processing machines
- Telecommunications, sound equipment, and other electrical machinery and parts
- Road vehicles and parts
- Other transportation equipment
- Other products

Linking the foreign affiliate to its U.S. parent provides the basis for a commodity and industry classification for the import-use framework. Industry classification is based on the ISI industry of the U.S. parent and commodity classification is based on the ISI industry of the foreign affiliate. To develop this mapping, imported products from the foreign affiliate were compared to the ISI industry of the foreign affiliate. In most cases, the ISI industry of the foreign affiliate aligns well with the product imported. For example, a foreign affiliate classified in pharmaceuticals and medicines manufacturing (ISI 3254) ships products categorized in chemicals and related products (NAICS 325). Because industry classifications are not available for unaffiliated parties, imports from unaffiliated firms are assumed to resemble those of affiliated firms. The import-use tables based on ISI industry categories were converted to the 1997 NAICS-based structure used for the Annual Industry Accounts. Import shares for commodities purchased by each industry were calculated as the ratio of the commodity import value for that industry and the total import value for that industry. In total, the MNC-based

[187] The estimates are based on special tabulations prepared by the BEA's Direct Investment Division (DID). The DID provided access to databases that allowed the authors to identify and tabulate imported goods and services directly.

imports accounted for about 60–65 percent of all imported intermediate inputs presented in the annual industry accounts.

EMPIRICAL RESULTS

The existing framework and methodology for the annual industry accounts was used to prepare a set of baseline estimates that can be compared with the results of simulation exercises that incorporate alternative assumptions about import use and prices. These results focus on industries that are the largest users of imported goods, such as computers and electronic products and chemicals manufacturing. Assumptions about both the use of imports and the behavior of import prices are important because an industry's real value added is calculated as the difference between real gross output and real intermediate inputs.[188]

Table 1 shows that, in the aggregate, the import comparability assumption provides results that are largely consistent with actual data on the use of imports by industry from the BEA's MNC surveys. These results indicate that the assumptions underlying the industry distributions of imported inputs in the annual industry accounts give reasonable results at aggregate levels, but that improvements are possible at more detailed industry levels. Some differences in the results at detailed levels are attributable to the fact that the data from the International Accounts are classified by industry on an enterprise basis, whereas data from the annual industry accounts are classified by industry on an establishment basis. Within both the goods- and services-producing sectors, some large share differences for industry groups are offset at higher levels of aggregation, suggesting the possibility that the differences are attributable largely to differences in classification.

[188] Estimates of real value added by industry are affected by both the source of the inputs and the import price indexes used for deflation. For example, if the computer manufacturing industry uses more imported semiconductors than assumed and if import prices are falling faster than domestic prices, or if the actual price of imported semiconductors is falling faster than the official import price index, then real intermediate input is understated and real value added is overstated in the computer manufacturing industry.

Table 1. Import Shares by Industry, 2002
(Comparison of International Accounts and Annual Industry Accounts Import-Use Tables)

(Percent)

Industry Group	International Accounts	Annual Industry Accounts
Manufacturing	20.7	16.8
Distributive services/1/	3.3	7.0
Information	4.2	5.3
Finance, insurance, real estate, rental, and leasing	0.9	5.0
Professional and business services	2.3	3.9
Other industries/2/	6.5	6.4
Addenda		
Private goods-producing industries/3/	17.7	14.9
Private services-producing industries/4/	3.5	5.4

/1/ Consists of w holesale trade; retail trade; transportation and w arehousing
/2/ Consists of agriculture, forestry, fishing, and hunting; mining; construction; educational services; health care and social assistance; arts, entertainment, and recreation; accommodation and food services; and other services, except government
/3/ Consists of agriculture, forestry, fishing, and hunting; mining; construction; and manufacturing.
/4/ Consists of utilities; w holesale trade; retail trade; transportation and w arehousing; information; finance and insurance; real estate and rental and leasing; professional, scientific and technical services; management of companies and enterprises; administrative and w aste management services; educational services; health care and social assistance; arts, entertainment, and recreation; accommodation and food services; and other services, except government.

Over the period 1999–2006, import shares of materials for manufacturing based on the MNC data are consistently higher than those constructed for the industry accounts using the import comparability assumption; however, the pattern of growth between the two series is similar (Chart 1). On average, the MNC data suggest that the annual industry accounts understate import shares of materials inputs by about 4 percentage points per year for manufacturing.

Chart 1. Imported Materials Inputs as a Share of Total Intermediate Inputs for Manufacturing, 1999-2006

Within manufacturing, the composition of imported inputs for materials shows some variation. Table 2 presents import shares for manufacturing at the commodity level constructed for the annual industry accounts compared with those constructed using MNC data. There are notable differences in import shares across the board. For 10 of the largest annual industry accounts' publication-level commodities within manufacturing, the largest differences are shown for oil and gas extraction and computers and electronic products. Most other commodities show much smaller differences.

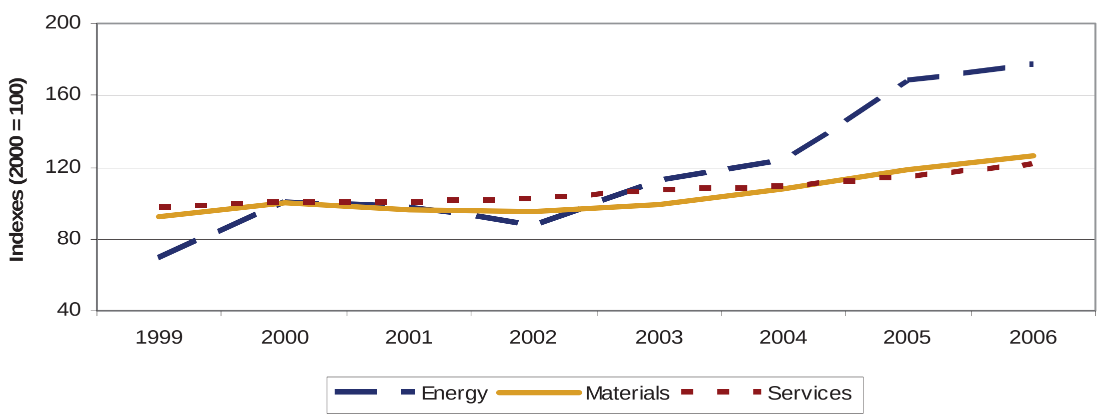
Table 2. Imported Input Shares for Manufacturing Commodities, 2002
(Comparison of International Accounts and Annual Industry Accounts Import-Use Tables)

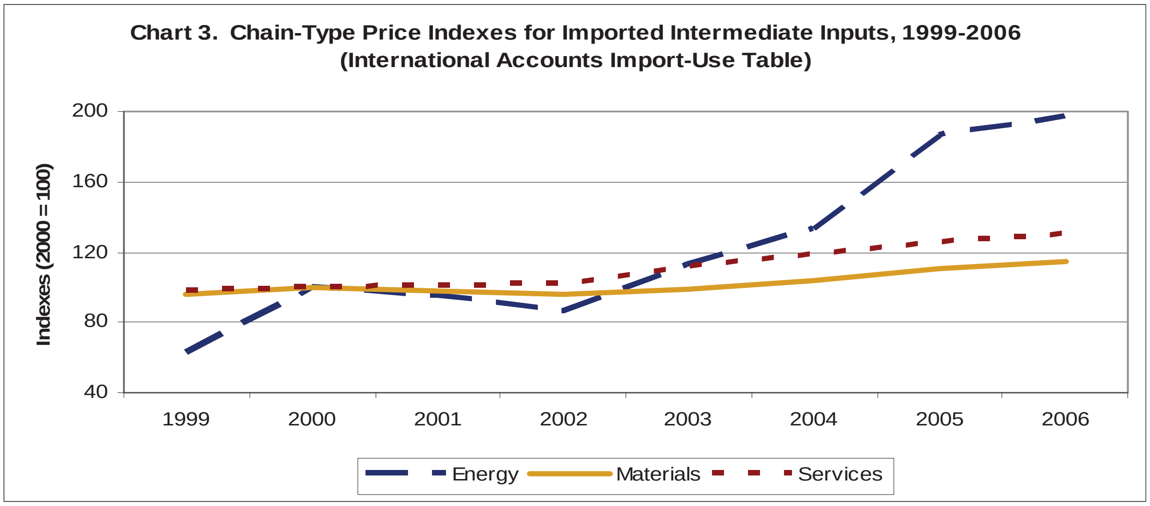
(Percent)

Commodity	International Accounts	Annual Industry Accounts
Oil and gas extraction	36.9	63.6
Computer and electronic product manufacturing	70.6	42.9
Primary metal manufacturing	8.5	20.7
Chemical manufacturing	26.4	13.4
Machinery manufacturing	26.2	29.0
Fabricated metal product manufacturing	3.8	10.2
Paper manufacturing	2.6	13.8
Electrical equipment, appliance, and component manufacturing	24.7	35.2
Food manufacturing	9.9	12.2
Wood product manufacturing	16.2	24.0

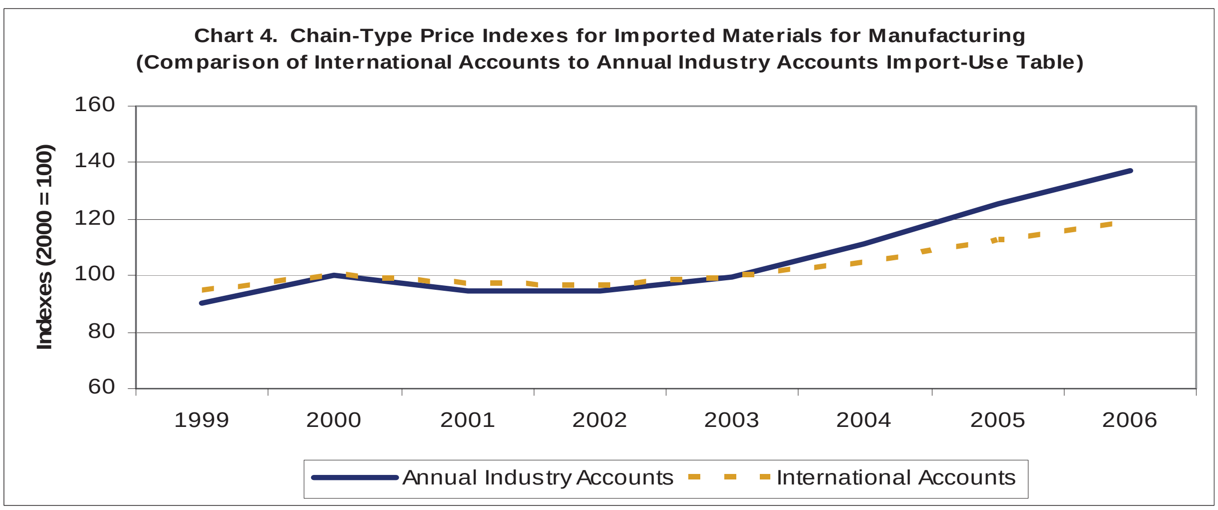
One would expect that changing the mix of intermediate inputs sourced from domestic versus foreign production could lead to important differences in price growth for imported intermediate inputs. Charts 2 and 3 show chain-type price indexes for economy-wide energy, materials, and purchased services inputs based on import shares developed for the annual industry accounts and those based on the MNC data. Price growth for imported energy inputs and purchased services inputs increases at a slower pace using data from the annual industry accounts; price growth for materials inputs increases at a faster rate.

Chart 2. Chain-Type Price Indexes for Imported Intermediate Inputs, 1999-2006
(Annual Industry Accounts Import-Use Table)





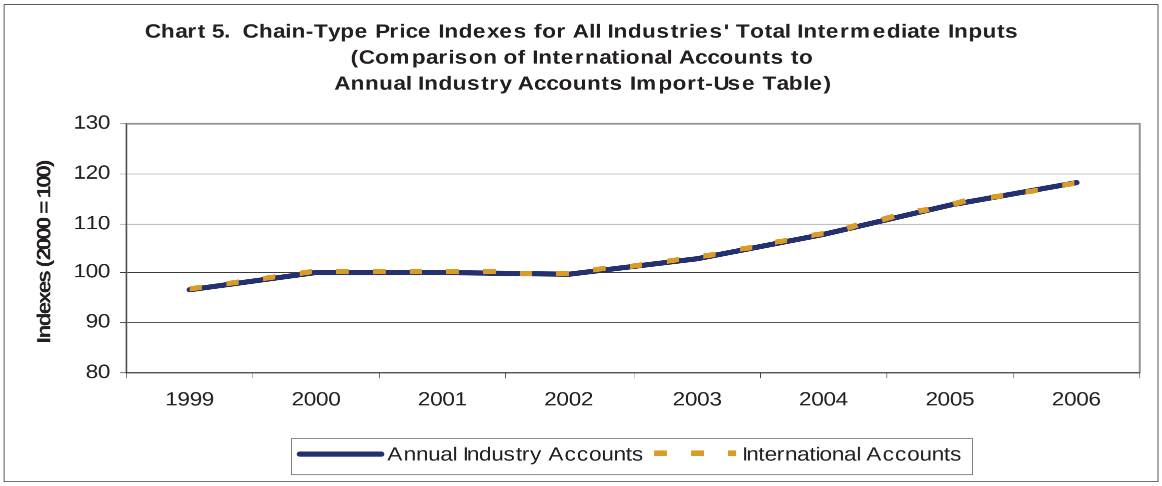
Within manufacturing, the trend for materials inputs is more focused. Over 1999–2006, price growth for imported materials inputs for manufacturing increases at a faster pace using data constructed for the annual industry accounts than that based on the MNC data (Chart 4). The slower materials price growth resulting from higher overall import shares for materials constructed with MNC data, coupled with BEA's existing import prices, suggest real intermediate inputs in the annual industry accounts may be understated and, therefore, that real value added for manufacturing is overstated.[189]

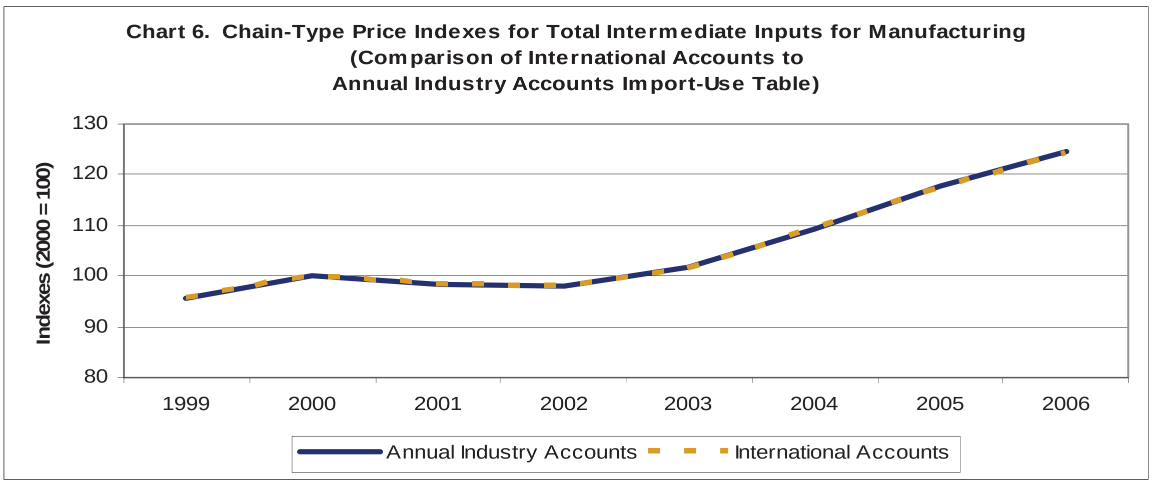


However, because existing import price data is incomplete, changing the sourcing mix for intermediate inputs does not impact the price indexes for intermediate inputs for all industries or, even, the manufacturing sector (Charts 5 and 6). Some differences do exist for high-import

[189] In addition to materials inputs, real intermediate inputs growth is a function of the source and price mix for energy and purchased services inputs. Therefore, compositional effects within intermediate inputs would have to be examined to determine how real intermediate inputs have changed. Nevertheless, manufacturing is a high importer of materials inputs relative to imports of energy and purchased services inputs.

industries, such as computer and electronic products, where existing good-quality import-price data is used to deflate the import content of intermediate inputs.





The limited availability of import-price data, overall, is the primary reason that changing the mix of import shares does not impact the aggregate growth rates. There are 1,028 item-level building blocks used to deflate imported intermediate inputs in the annual industry accounts, but only 57 percent have import prices available for use in the separate deflation of intermediate inputs. The remaining item-level goods and services are deflated with domestic price indexes. The mix of import-price coverage also differs by sector, with about 58 percent coverage for the Goods sector and 50 percent for the Services sector. Finally, import-price coverage does not necessarily imply a good match, as many of the item-level building blocks covered are deflated with an aggregate import-price index.

Given data limitations for import-price indexes available from the U.S. statistical system, we conducted several simulations to determine the threshold of import price biases that are required to affect real value added growth across all industries (real GDP), manufacturing, and a selected number of manufacturing industries. As a first step, we adjusted the domestic prices used to deflate the import content of intermediate inputs by applying the average price differential that exists for item-level detail when both domestic and import-price indexes are available. This difference averaged about 0.4 percent per year.

This bias adjustment translates into notable differences in price growth for imported intermediate inputs for All industries and manufacturing. Over the period 1999–2006, price growth for economy-wide imported intermediate inputs increases at an average annual rate that is about 1.5 percentage points slower when import shares are based on MNC data instead of the annual industry accounts. Price growth is about 3 percentage points slower for manufacturing (Charts 7 and 8). The impact, however, on real GDP growth and real value added for manufacturing is negligible: real GDP grew at an average annual rate of 2.5 percent using MNC-based import data, compared to 2.6 percent for the annual industry accounts, and real value added growth for manufacturing grew 1.9 percent and 2.0 percent, respectively.

Chart 7. Chain-Type Price Indexes for All Industries' Imported Intermediate Inputs with 0.4 Percent Import Price Bias Adjustment

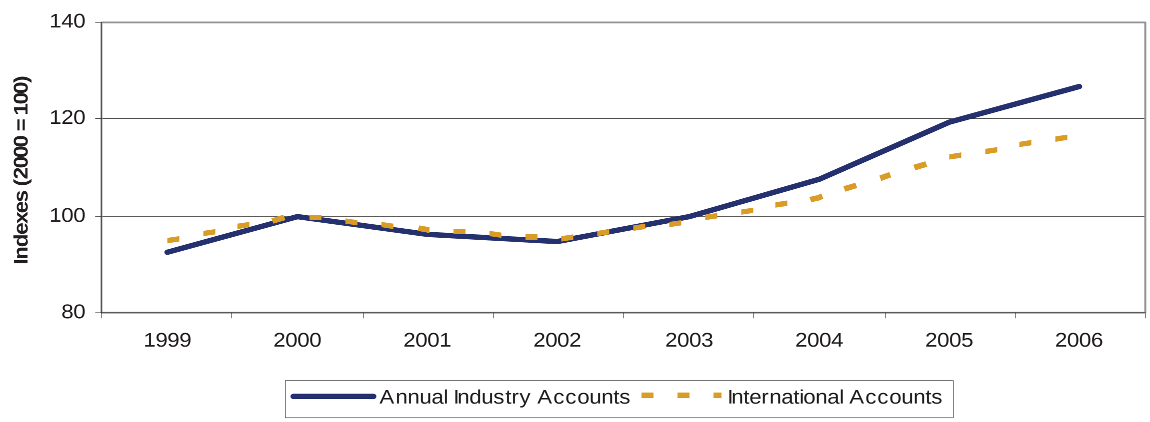
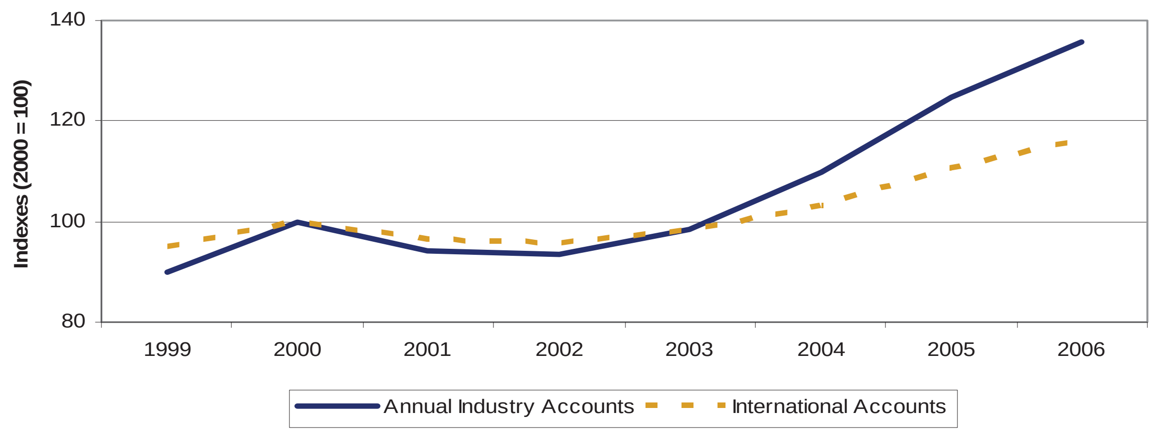


Chart 8. Chain-Type Price Indexes for Manufacturing's Imported Intermediate Inputs with 0.4 Percent Import Price Bias Adjustment



Finally, we applied a series of bias adjustments, ranging from a 1 percent to 5 percent overstatement of import prices, to determine the thresholds required to affect real GDP growth, and real value added growth for manufacturing, computer and electronic products, chemical manufacturing, and machinery manufacturing. The 1–5 percent bias adjustments were applied to all existing import prices and to the domestic prices that are used to deflate the import content of imported intermediate inputs for goods and services that do not have import price coverage.[190] The results in Table 3 show average annual growth rates for real value added based on the various bias adjustments applied to the existing annual industry accounts import-use tables and those constructed using MNC data.

Overall, each 1percent bias adjustment to import prices led to an average annual decrease of 0.08 percentage points for all industries, 0.33 for manufacturing, 0.46 for computer and electronic products, 0.22 for chemicals, and 0.24 for machinery manufacturing, when using import shares based on the annual industry accounts. One percent bias adjustments, when using import shares based on MNC data, led to an average annual decrease of 0.08 percentage points for all industries, 0.39 for manufacturing, 0.60 for computer and electronic products, 0.27 for chemicals, and 0.18 for machinery manufacturing.

Table 3. Average Annual Growth Rate for Real Value Added by Industry with Price Adjustments, 1999 - 2006
(Comparison of International Accounts and Annual Industry Accounts Import-Use Tables)

(Percent)

Industry	Baseline	0.04%	1%	3%	5%
All Industries					
Annual Industry Accounts	2.6	2.6	2.5	2.4	2.2
International Accounts	2.6	2.5	2.5	2.3	2.2
Manufacturing					
Annual Industry Accounts	2.2	2.0	1.8	1.2	0.5
International Accounts	2.0	1.9	1.6	0.9	0.1
Computer and electronic products manufacturing					
Annual Industry Accounts	17.2	17.1	16.8	15.8	14.9
International Accounts	17.2	17.1	16.8	15.6	14.4
Machinery manufacturing					
Annual Industry Accounts	1.4	1.3	1.2	0.7	0.2
International Accounts	1.4	1.3	1.2	0.9	0.5
Chemical manufacturing					
Annual Industry Accounts	2.6	2.6	2.4	2.0	1.5
International Accounts	2.5	2.4	2.2	1.7	1.1
Oil and gas extraction					
Annual Industry Accounts	-3.4	-3.5	-3.5	-3.7	-3.8
International Accounts	-3.2	-3.2	-3.3	-3.4	-3.6

SUMMARY AND CONCLUSION

In the annual industry accounts, imports of intermediate inputs are constructed using the import comparability assumption for purposes of separately deflating domestic and imported intermediate inputs in the calculation of real value added. An analysis of import shares for the

[190] Each bias adjustment decreased import prices used in the deflation by 1–5 percent.

annual industry accounts compared to import shares constructed using actual source data from the International Accounts shows that the import comparability assumption provides a good approximation of imported intermediate use. Differences at detailed levels, however, may be the result of using MNC company data rather than establishment-based data. In addition, while MNC imports account for about 60–65 percent of total imported intermediate inputs in the annual industry accounts, it is possible that import usage differs among the smaller firms that account for the remaining 35–40 percent. The possible impact of this coverage difference may be worth examining more closely.

Most notably, data from the international accounts suggest that growth in real imported materials inputs is likely understated in the annual industry accounts. However, this understatement does not currently lead to large differences in real value added growth for all industries (real GDP) or for manufacturing because of the limited availability of import-price data used to deflate the import-content of intermediate inputs. A simulation of a range of bias adjustments for import prices used in deflation suggests that better import-price measurement will improve the accuracy of real value added by industry; however, the overall magnitude of the bias adjustments would need to be about 6.5 percent to affect real GDP growth by at least one-half of a percentage point, irrespective of whether import shares are from the annual industry accounts or based on data from the international accounts.

Further study is required to develop a better understanding of how imported inputs affect industry output, employment, real value added, and contributions to GDP. More research is also needed to determine the sensitivity of these results to the assumptions used by the BEA for the annual industry accounts with respect to the classification of imported goods and services, the distribution of goods and services by using industry, and the behavior of import prices. The BEA will continue to review these assumptions and will further investigate company-based data from the international accounts that could help evaluate the assumptions underlying the industry distributions. The BEA is also interested in working with the BLS International Price Program to try to develop improved price indexes for the deflation of imported intermediate inputs in both the NIPAs and annual industry accounts. The BEA is also interested in the idea of input-price indexes that are proposed by the BLS. These input-price indexes could be used to deflate total intermediate inputs without concern for the sourcing mix. Input-price indexes, in conjunction with domestic price indexes, could be used to calculate import price indexes, allowing for the continued study of imported intermediate inputs.

The BEA plans to investigate these differences in more detail with the goal of obtaining improved industry distributions of imported intermediate inputs in the annual industry accounts. Better grounding of these assumptions is important not only for understanding the role of imported inputs in the U.S. economy, but also for developing more reliable quantity and price indexes for intermediate inputs and value added by industry.

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Evaluating Estimates of Materials Offshoring from U.S. Manufacturing*

by

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When materials offshoring is measured by estimating imported intermediate inputs, a common assumption used is that an industry's imports of each input, relative to its total demand, is the same as the economy-wide imports relative to total demand: this is the so-called "import comparability assumption" (Houseman 2008, p. 9), or the "proportionality assumption " (OECD STAN database). That assumption was made by Feenstra and Hanson (1999), for example, and was critiqued by the National Research Council ([NRC] 2006) as being a significant limitation of current data collection and analysis. Recent work by Winkler and Milberg (2009) for Germany shows that this assumption does not hold up well when compared to the actual imports by industries. For the United States, too, it is highly desirable to move beyond this assumption to obtain a *direct* measure of imported materials by industry.

The goal of this project is to obtain such an industry-level measure of offshoring for the United States. We begin, however, with a smaller first step. In the first step, we explore alternatives to the Feenstra-Hanson (1999) measure of offshoring that still make use of the import comparability assumption. While that measure of offshoring was intended to reflect imported intermediate inputs, in practice it also included imported final goods. So in this first step, we recalculate the Feenstra-Hanson (1999) measure of offshoring while focusing on only imported intermediate inputs as defined by end-use classifications. This approach has been taken by several other recent authors, including Bergstrand and Egger (2008), Sitchinava (2007, 2008), and Wright (2009).

In the second step, we explore a different methodology for allocating imported inputs across industries using firm-level data on imports and production. We use information on imports from the Linked/Longitudinal Firm Trade Transaction Database (LFTTD), which links individual U.S. trade transactions to firms and information on materials used and products produced from the census of manufactures. We use the linked production and import data to construct firm-level input-output (I-O) tables and then aggregate these to the industry level to derive imported input intensity by industry and compare our results with those obtained by the BEA using the "import comparability" assumption. Our focus is on imports of intermediate inputs, so we again use the end-use classification to exclude from the analysis products identified at "final goods" by Wright (2009). We confront a number of technical and data issues and make several compromises as a result, all of which we describe in the paper. We describe differences between the import matrix constructed using firm-level import data and BEA's import matrix.

THE IMPORT COMPARABILITY ASSUMPTION

Our goal is to update the offshoring measure described in Feenstra and Hanson (1996, 1999), which is defined for any industry *k* purchasing inputs *j* as

$$\text{Industry } k \text{ share of intermediate inputs that are imported}$$

$$(1) \qquad = \frac{\sum_j (\text{industry } k \text{ purchases of good } j)\left(\dfrac{\text{imports of good } j}{\text{total domestic consumption of } j}\right)}{\sum_j (\text{industry } k \text{ purchases of good } j)}$$

The primary shortcoming of this measure is the use of good *j*'s share of imports in total domestic consumption, in the numerator, which is computed for the entire U.S. economy. Obviously, it would be preferable to measure this share by just using data for purchasing industry *k*, as we shall attempt to do in the second step of this project. As it is stated, Equation (1) essentially assumes that the economy-wide import share for good *j* is the same as the industry *k* import share for good *j*, which is the "import comparability" assumption.

Given this limitation of Equation (1), there are still some improvements that can be considered before using firm-level data. Specifically, we consider recalculating the measure of offshoring in Equation (1) while focusing more carefully on only imported intermediate inputs. Specifically, the inputs *j* that are used in Equation (1) are defined by the classifications used in I-O tables of the United States: either 4-digit SIC before 1996 or 6-digit North American Industry Classification System (NAICS) after 1996. For each of classifications, there will be multiple 10-digit Harmonized System (HS) imported products. Let us denote by $i \in I_j$ the set of 10-digit HS products within each 4-digit SIC before 1996 or 6-digit NAICS good *i*. Then a more accurate definition of the Feenstra and Hanson (1999) measure of materials offshoring is:

Industry k share of intermediate inputs that are imported

$$(1') \qquad = \frac{\sum_j (\text{industry } k \text{ purchases of good } j)\left(\dfrac{\text{sum over imports } i \in I_j}{\text{total domestic consumption } i \in I_j}\right)}{\sum_j (\text{industry } k \text{ purchases of good } j)}$$

A problem with this definition of offshoring is that some of the imported products *i* can be final goods rather than intermediate inputs. Imports of such final goods are often not what we have in mind with materials offshoring. To correct this problem we can restrict attention to HS goods with corresponding "end-use codes" that are indeed intermediate inputs. The end-use codes are used by the Bureau of Economic Analysis (BEA) to allocate goods to their final use, within the National Income and Product Accounts. Accordingly, U.S. imports and exports by Harmonized System are also allocated to end-use codes. As described by the Census Bureau, Guide to Foreign Trade Statistics:[191]

> The 1-digit level end-use categories provide data for the following broad aggregates: (0) Foods, feeds, and beverages; (1) Industrial supplies and materials; (2) Capital goods, except automotives; (3) Automotive vehicles, parts and engines; (4) Consumer goods (nonfood), except auto; and (5) Other merchandise.
>
> …The HTSUSA and Schedule B classifications are summarized into six principal "end-use" categories and further subdivided into about 140 broad commodity groupings. These categories are used in developing seasonally adjusted and constant dollar totals. The concept of end-use demand was developed for balance of payments purposes by the Bureau of Economic Analysis.

[191] Slightly amended from http://www.census.gov/foreign-trade/guide/sec2.html.

Based on the numbering system defined in the above quotation, food and other items begin with the digit 0, which include both final goods and intermediate inputs; raw materials and intermediate goods begin with 1; investment goods begin with the digit 2; automotive goods begin with 3, which include both final goods (finished autos) and intermediate inputs (parts); final consumer goods (nonfood) begin with the digit 4; and 5 is a miscellaneous category. In Appendix A we list the precise 5-digit end-use codes that are included within final goods (i.e., consumption and investment), while all other end-use codes are treated here as intermediate inputs or raw materials.[192]

Using this end-use classification, we consider a restricted set of HS codes within each SIC or NAICS industry *j*

$$\bar{I}_j \equiv \{\text{HS goods } i \text{ within the industry } j \text{ that are also intermediate inputs}\}.$$

Then the revised measure of materials offshoring is

$$\text{(2)} \qquad \frac{\sum_j (\text{industry } k \text{ purchases of good } j)\left(\dfrac{\text{sum over imports } i \in \bar{I}_j}{\text{total domestic consumption } i \in \bar{I}_j}\right)}{\sum_j (\text{industry } k \text{ purchases of good } j)}.$$

Note that the import share used in the numerator of Equation (2) restricts the set of goods used in both the numerator and the denominator, so we cannot tell how it compares with the import share used in Equation (1'). Specifically, the denominator of this import share is constructed as

$$\begin{aligned} &\text{total domestic consumption } i \in \bar{I}_j \\ &= \text{domestic shipments for } i \in \bar{I}_j + \text{sum over imports } i \in \bar{I}_j - \text{sum over exports } i \in \bar{I}_j . \end{aligned}$$

The import and export terms in this expression do not need any explanation: they are simply the sum over HS imports or exports within the SIC or NAICS industry *j*, that are also intermediate inputs (as defined by their end-use classification). But the domestic shipments term does require an explanation. Rather than use the total domestic shipments of industry *j*, we instead apportioned those domestic shipments into various HS products *i*, by assuming that the share of domestic shipments for each HS product *i* within industry *j* equals the share of U.S. exports in that HS product and industry. We then sum domestic shipments over just those HS products that are also intermediate inputs (as defined by their end-use classification).

Empirical Implementation

We construct the offshoring measure Equation (2) for all years between 1980 and 2006 within the manufacturing sector. We begin with measures of intermediates purchases by U.S. industries,

[192] We thank Marshall Reinsdorf, BEA, for providing the end-use classifications in Appendix A. As noted in the appendix, certain raw materials such as oil and minerals are always excluded from the offshoring calculation.

which are obtained from the economic census for benchmark years (1982, 1987, 1992, 1997, 2002). Prior to 1997, values are by 4-digit SIC codes and post-1996 values are by 6-digit NAICS. Each observation in the economic census benchmark dataset contains a purchasing industry, a corresponding intermediate industry which provides inputs, and a total value of purchases (inputs). To obtain purchases for all years for an industry from a particular intermediate industry, we simply interpolate and extrapolate the benchmark values linearly throughout the period 1980—2006.[193]

The next step is to construct the import share of intermediates in domestic consumption of intermediates. This industry share will be merged with the input-providing industries from the purchases data described above. First, we merge data on imports and exports from Feenstra (1996) and Feenstra, Romalis, and Schott (2002) with yearly data on total industry shipments, obtained from the Annual Survey of Manufactures. Again, prior to 1997 these data are by 4-digit SIC and post-1996 by 6-digit NAICS, so the merge is straightforward.

Now, in order to restrict the imports, exports, and shipments to intermediates only, we use the end-use categories that are matched to SIC and NAICS industries in the import/export datasets. The end-use categories that we excluded because they are "final goods" come from a list provided by the BEA, as shown in the appendix. We separate investment goods and most automobile categories from the list because these include many things that we think of as vulnerable to offshoring, such as automobile parts and machinery and equipment, and therefore we ultimately would like to include these items. For personal consumption expenditure (PCE) goods, a portion of the list is more subjective, with some categories split between intermediate and final goods. Here we simply remove all end-use categories that encompass *some* final goods, and since the categories that are problematic are primarily food items, which we don't generally associate with offshoring activities, this approach seems reasonable. In addition, we remove certain raw materials detailed in the appendix, such as petroleum products and various metals, whose value and import volumes are likely unrelated to offshoring activities.

Table 1 shows trends in the offshoring measure using the original method of Feenstra and Hanson (1990, equations [1] or [1']). We report both a broad and a narrow offshoring measure as in Feenstra and Hanson (1996, 1999), where the narrow measure restricts the final and intermediate industries to be within the same 3-digit NAICS categories. In comparison, Table 2 details trends in the revised offshoring measure, Equation (2), with and without inclusion of investment goods.

We have compared the original and revised offshoring measures to determine which industries show the greatest differences (averaged over years) and to obtain the results:

NAICS 339931: Dolls and stuffed toys, difference ≈ 0.85
NAICS 315991: Hats and caps, difference ≈ 0.35
NAICS 331316: Aluminum extruded products, difference ≈ 0.35
NAICS 311320: Chocolate and confectionary products, difference ≈ 0.29

[193] The 2007 benchmark will be available beginning in June, and we will be able to reduce error caused by the extrapolation of the 2002 benchmark.

NAICS 339941: Pens and mechanical pencils, difference ≈ 0.28
NAICS 339992: Musical instruments, difference ≈ 0.25

The industries with the greatest difference are simply consumer items that are imported directly to retail outlets, so these imports are clearly final goods and therefore are omitted from the revised offshoring measure.

ASSIGNING IMPORTED INPUTS TO INDUSTRIES USING FIRM-LEVEL DATA

In this section, we explore an alternative methodology to the "import comparability assumption" for allocating imported inputs across industries. This alternative methodology uses transaction data on firms' imports linked to production data at the firm and plant level to construct something analogous to firm-level I-O tables and then aggregates the firm-level I-O tables to produce an aggregate import matrix that allocates imported intermediate inputs (I-O commodities) across industries. This approach offers promise in that it provides a different perspective on the allocation of imported intermediate inputs across industries. Our objective in the remainder of the paper is to explain the alternative methodology, describe some of the challenges we faced in trying to produce this, and then attempt to characterize (within the limits of disclosure) how our alternative import matrix differs from the import matrix provided by the BEA.

Data Used and Assignment Methodology

We use information on imports from 1997 from the Linked/Longitudinal Firm Trade Transaction Database (LFTTD), which links individual U.S. trade transactions to firms (see Bernard, Jensen, and Schott [2009] for more details on the LFTTD). We use information on materials used and products produced from the 1997 census of manufactures. Because both datasets contain a firm-level identifier, it is possible to link imported inputs to production data (materials used and products produced) of the firms that import the intermediates. We will use this information to construct a firm-level I-O table that allocates imported inputs across the products (I-O industries) the firm produces.

The first limitation we confront is that the LFTTD contains firm-level identifiers for 80–85 percent of import value (roughly 10 percent of value is associated with transactions that have no Employer Identification Number). As a result, our estimates of total import value across commodities are systematically lower than the BEA's, and this difference varies across commodities. When we compare our allocation of imports across industries to BEA's import matrix, we will compare the shares of imports by industry (instead of levels) between the two methodologies to try to mitigate the impact of this problem.

The LFTTD contains information on products at the 10-digit Harmonized System (HS) classification level. We use publicly available concordances between 10-digit HS products and 6-digit BEA I-O commodities and assign 6-digit I-O commodity codes to all firm-level imports. We then have firm imports on an I-O commodity basis.

The next step is to allocate the firm's imports to the industries that use the imports in production. Our intention was to use information collected in the census of manufactures regarding materials used by manufacturing establishments as a way of allocating the use of imported intermediate inputs to industries. The information on materials used is contained in "material trailers" in the census of manufactures files and is classified using internal Census Bureau material codes. To use this information to allocate imported commodities, we needed a bridge between internal Census Bureau materials codes and I-O commodity codes. We obtained internal BEA concordances between census material codes and BEA I-O codes.[194] Using these codes, we were able to allocate materials used to I-O industries.[195] The assignment of materials used to industries identified another limitation of our methodology—the value reported in the material trailers accounts for only about 75 percent of the total materials used in the BEA I-O tables.[196]

Another complication we confronted in allocating imported inputs to industries is that the vast majority of trade value is mediated by large, multiunit, multiactivity firms (see Bernard, Jensen, and Schott [2009]). Many of these firms have establishments classified in a range of sectors, e.g., the manufacturing sector, the wholesale sector, and the retail sector. Allocating imports across industries within these firms proved difficult. One source of the difficulty is that the materials-used information is not collected in the same way for sectors outside of manufacturing, so we needed some way to allocate commodity imports across industries. We tried allocating based on the share of a firm's total sales each establishment accounted for but found we were allocating significant value for end-use commodities to manufacturing establishments owned by multisector firms. To mitigate this problem, we excluded from our analysis 10-digit HS products classified as "end use" by Wright (2009) and restricted our analysis to the manufacturing establishments of importing firms.

After excluding end-use products and nonmanufacturing establishments/firms, we were able to allocate 50 percent of total imported intermediate input value to manufacturing establishments using the material codes (i.e., imported intermediate inputs were assigned to an establishment's I-O industry if the establishment reported using the material); the remainder of imported intermediate value was allocated based on establishments' share of a firm's manufacturing output. Because we exclude establishments within a firm that are outside of manufacturing, it is possible that we overallocate imports to firms that have both manufacturing operations and import for wholesale or retail operations. This highlights another potential compromise in our methodology—that a significant share of imported intermediate value is imported by firms whose manufacturing establishments do not report using the material.[197]

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[194] We thank Belinda Bonds of the BEA for providing the internal version of the concordance.
[195] We used a concordance between NAICS industry classifications and BEA I-O industry classifications.
[196] The BEA uses other sources and methodologies for constructing the materials used in the I-O tables. Conversations with BEA staff suggested that our finding that the material trailers accounted for 75 percent of the I-O value was in the right ballpark. There is a high correlation across commodity-industry cells between our materials used values and the BEA I-O tables materials used.
[197] It is difficult to know how to interpret this fact. One possibility is that establishments under-report the materials that they use. An alternative explanation is that firms import a significant share of intermediate inputs that they do not use for production.

With the assignment of imported intermediate inputs (I-O commodities) to establishments that are classified by industry (I-O industry), we have essentially created firm-level I-O tables with I-O commodity by I-O industry cells. The final step is to aggregate these firm-level cells to obtain an import matrix for the manufacturing sector.

Comparison of BEA's Import Matrix to Our Alternative Import Matrix

In this section, we attempt to characterize whether the allocation of imported intermediate inputs differs between BEA's import matrix, which uses the import comparability assumption, and our alternative matrix, which uses firm-level data to assign commodities to industries—and, if so, where it differs.[198] Assessing whether the matrices differ in a meaningful way is obviously a bit subjective and would depend to some extent on the purpose for which the matrix would be used. We present descriptive statistics that attempt to quantify and characterize the differences between the matrices from the two methodologies.

We focus on the share of a commodity's import value assigned to a particular industry instead of the level of import value to mitigate the issue posed by the systematic underallocation of imported inputs in our data. To make the comparison, we exclude from BEA's import matrix industries that are outside of manufacturing and exclude products classified as end use (the same products we excluded from the import data).[199] For the manufacturing sector, we calculate the share of an I-O commodity's total imports that is allocated to each I-O industry within manufacturing. We compare the shares in these I-O-commodity I-O-industry cells.

We begin by examining the simple correlation between the share of each 3-digit commodity group's total import value assigned to a 3-digit I-O-industry cell in the two matrices. The simple correlation and BEA-value-weighted correlation are reported in Table 3. There is a high correlation between the share in both the simple correlation and the weighted correlation; the correlation is actually higher for the value-weighted correlation.

We also examine the distribution of the differences between the shares in the two matrices at the 3-digit I-O-commodity/I-O industry-cell level. Figure 1 exhibits the distribution of share differences for 3-digit cells. Most of the cells have very small differences in the share of the imported intermediate input (I-O commodity) across industries. This suggests that for most cells, the share of the commodity imports allocated to a particular industry is fairly close in many cells. The high correspondence may be due to the large number of cells for which both methods allocate zero imports.

We also examine the BEA import-value-weighted distribution of share differences to see whether we match the allocated shares as closely for I-O-commodity/I-O-industry cells with relatively large import values. Figure 2 shows the BEA-import-value-weighted distribution. The value-weighted distribution is obviously more dispersed. For I-O-commodity/I-O-industry cells with relatively high import values, the import matrices derived from the "import comparability assumption" method and our alternative method are more different. In contrast to the unweighted

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[198] Characterizing the differences at a detailed level is difficult because of the constraint of confidentiality.
[199] This excludes I-O commodities that the BEA allocates to I-O industries outside of manufacturing. I-O industries outside of manufacturing can account for a significant share of value of some I-O commodities.

distribution, significantly less mass is at zero or small share differences. While most value-weighted cells have differences below 50 percentage points, there is significant mass of the distribution that differs by 10 percentage points or more.

We also thought it would be useful to show the I-O-commodity/I-O-industry cells where the two methodologies have the largest share differences. We were constrained a bit by the disclosure prevention protocols but were able to release 15 cells from the 10 largest positive and 10 largest negative differences. The cells are listed in Table 4.

The results highlight some of the limitations and conceptual differences inherent in our alternative approach. For example, the I-O-commodity/I-O-industry cell in the first row of the top panel of Table 4 shows that our methodology allocated a significant share of I-O-commodity 337, Furniture imports, to I-O-industry 337, Furniture. The BEA had a much smaller share of furniture imports allocated to this I-O industry. The first row of the negative panel shows that the BEA allocated a large share of furniture imports to I-O-industry 321, Wood products. In fact, the BEA allocated very little in terms of import value to I-O-industry wood products, but instead allocated most of the value of furniture imports *outside of* the manufacturing sector. Our allocation methodology allocated furniture imports by furniture manufactures to I-O-industry 337, Furniture. In contrast, the BEA allocated the furniture imports to the Construction sector. It would require additional research, and in the end it might be infeasible, to determine whether the furniture importers that are furniture manufactures are adding value to the furniture imports or are merely acting as wholesalers. Yet, to determine which allocation method is more appropriate would require this type of investigation.

The 3-digit I-O-commodity/I-O-industry cells are a bit unsatisfactory because of the relatively high level of aggregation (but are necessitated by the disclosure prevention protocols). To provide some sense of how the matrices compare at a more detailed level, we report descriptive statistics for weighted and unweighted share differences at the 6-digit I-O-commodity/I-O-industry level. Table 5 reports the mean share difference (weighted and unweighted) for the I-O-commodity/I-O-industry cells in the 90–100th percentile and the 0–10th percentile. The unweighted share differences are relatively small—only about 2 percentage points—at both the high end and the low end. The BEA-import-value-weighted means tell a somewhat different story. The weighted-average at the low end is more than 50 percentage points different. There are some 6-digit cells with relatively large import values where the BEA allocates significantly more import value to the industry than the alternative measure does. At the other end of the distribution, the differences are smaller, about 16 percentage points different. While it would be desirable to provide more information on the share differences at a very detailed level, fortunately the aggregation to the 3-digit level does not seem to distort the overall story much.

In summary, this alternative methodology seems to offer promise and probably warrants additional investigation. The comparison of the import matrices derived from the alternative methodology to BEA's matrix highlight some of the data limitations confronted by the firm-level methodology and possibly point out some conceptual differences between the two methodologies. To resolve which allocation is more appropriate would require additional information. As such, the exercise points out some potential shortcomings in current data collection systems; of particular interest is additional work to resolve the issue of firms importing intermediate inputs that are not reported as being used in production.

CONCLUSION

In the first part of this paper, we explored alternatives to the Feenstra-Hanson (1999) measure of offshoring that still make use of the import comparability assumption. While that measure of offshoring was intended to reflect imported intermediate inputs, in practice it also included imported final goods. So in this first step, we recalculated the Feenstra-Hanson (1999) measure of offshoring while focusing on only imported intermediate inputs as defined by end-use classifications.

In the second step, we explored a different methodology for allocating imported inputs across industries using firm-level data on imports and production. We used linked production and import data to construct firm-level I-O tables and then aggregate these to the industry level to derive imported input intensity by industry. We compared the results of this alternative allocation methodology with those obtained by the BEA using the “import comparability” assumption. The comparison of the import matrices derived from the alternative methodology to the BEA’s matrix highlight some of the data limitations confronted by the firm-level methodology, and possibly point out some conceptual differences between the two methodologies.

Table 1
Offshoring Trends with original Feenstra-Hanson calculation (Equation 1)

Year	Narrow Measure	Broad Measure	Broad minus Narrow Measure
1980	0.047	0.071	0.024
1990	0.067	0.123	0.055
2000	0.103	0.228	0.124
2006	0.129	0.282	0.152

Table 2
Revised Offshoring Trends (Equation 2)

	With Investment Goods Included		**Without Investment Goods**	
Year	Narrow Measure	Broad Measure	Narrow Measure	Broad Measure
1980	0.032	0.066	0.032	0.065
1990	0.054	0.121	0.049	0.122
2000	0.091	0.197	0.083	0.204
2006	0.119	0.270	0.105	0.274

Table 3

Correlation between Import Value Share across 3-digit IO-Commodity IO-Industry Cells	
Unweighted	0.6803
Weighted (by BEA import value)	0.8717

Table 4

IO Commodity IO Industry Cells with Largest Share Differences

3-digit IO Commodity Group	3-digit IO Industry Group	Alt. Share	BEA Share	Share Difference
337 Furniture and Related Products	337 Furniture and Related Products	0.50	0.01	0.50
324 Petroleum and Coal Products	324 Petroleum and Coal Products	0.82	0.34	0.48
315 Apparel	316 Leather and Allied Products	0.46	0.00	0.46
326 Plastics and Rubber Products	326 Plastics and Rubber Products	0.56	0.18	0.38
323 Printing and Related Support Activities	334 Computer and Electronic Products	0.38	0.01	0.37
316 Leather and Allied Products	316 Leather and Allied Products	0.61	0.26	0.35
325 Chemicals	325 Chemicals	0.73	0.46	0.28
335 Electrical Equipment and Components	335 Electrical Equipment and Components	0.40	0.20	0.20
3-digit IO Commodity Group	3-digit IO Industry Group	Alt. Share	BEA Share	Share Difference
337 Furniture and Related Products	321 Wood Products	0.06	0.98	-0.92
114 Fishing, Hunting, and Trapping	311 Food	0.18	1.00	-0.82
323 Printing and Related Support Activities	323 Printing and Related Support Activities	0.12	0.73	-0.62
311 Food	312 Beverage and Tobacco Products	0.00	0.36	-0.36
324 Petroleum and Coal Products	325 Chemicals	0.13	0.46	-0.32
316 Leather and Allied Products	314 Textile Products	0.00	0.22	-0.22
316 Leather and Allied Products	323 Printing and Related Support Activities	0.00	0.22	-0.22

Note: This table lists the 3-digit IO Commodity IO Industry cells with the largest share differences (both positive and negative). The table lists 8 of the top 10 positive differences and 7 of the top 10 negative differences. The remaining cells were suppressed to prevent disclosure.

Table 5

Mean Differences in Shares for 6-digit level IO-Commodity IO_Industry Cells

	0 to 10th Percentile	90 to 100th Percentile
Unweighted	-0.021	0.020
Weighted (by BEA import value)	-0.543	0.165

Figure 1
Histogram of Difference in Commodity-Industry Cell Import Share

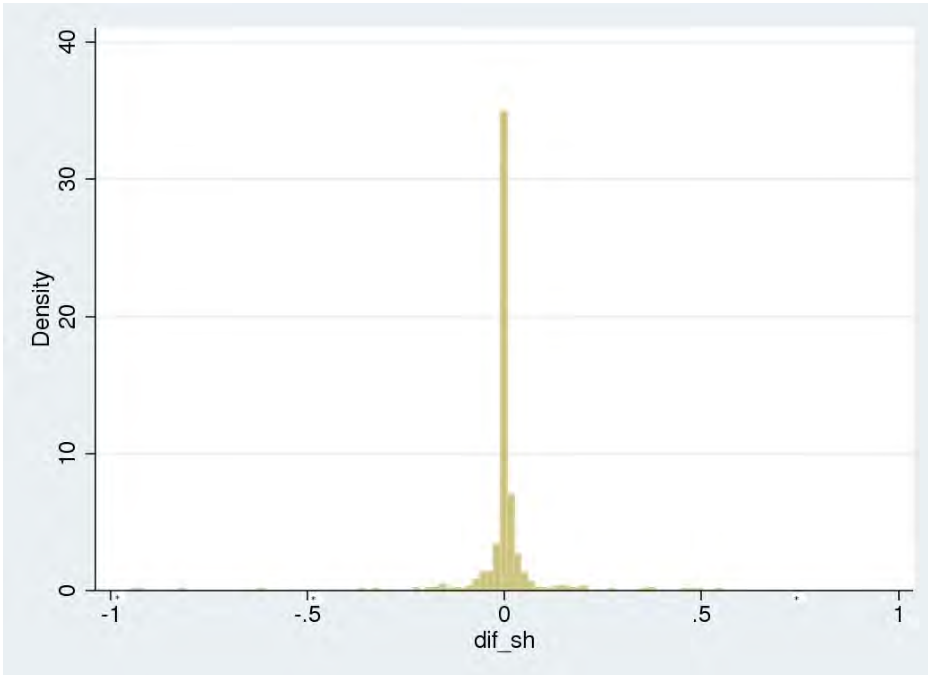
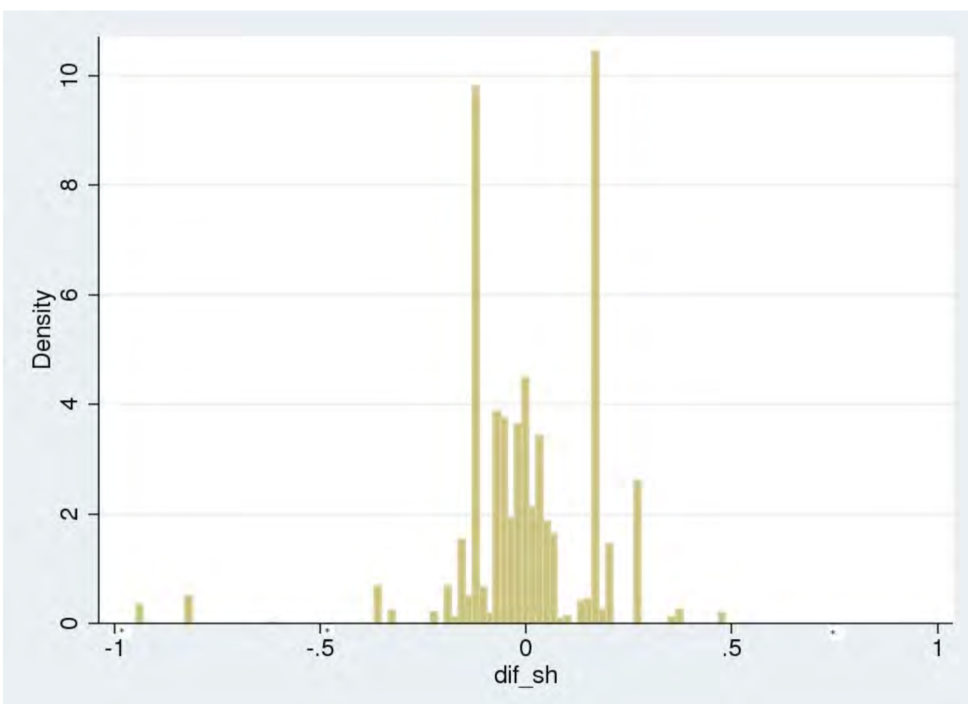


Figure 2
Histogram of Difference in Commodity-Industry Cell Import Share
(Weighted by BEA Import Value)



Appendix A: End-Use Final Goods

Personal Consumption Expenditure:

The following include both final and intermediate goods:

00020 Cane and beet sugar
00100 Meat products & poultry
00110 Dairy products & poultry
00120 Fruits & preparations including juices
00130 Vegetables & preparations
00140 Nuts & preparations
00150 Food oils & oilseeds
00160 Bakery products & confectionery
00170 Tea, spices, & preparations
00180 Agricultural foods, n.e.c.
00190 Wine & related products
01000 Fish and shellfish
01010 Whiskey and other alcoholic beverages
01020 Other nonagricultural foods & food additives
15200 Fabricated metal products
16110 Blank audio and visual tapes and other media

The following are final goods only:

40000 Apparel, & household goods--cotton
40010 Apparel, & household goods--wool
40020 Apparel, & household goods--other textiles
40030 Non-textile apparel & household goods
40040 Footwear of leather, rubber & other materials
40050 Sporting & camping apparel, footwear & gear
40100 Medicinal, dental, & pharmaceutical preparations includ. vitamins
40110 Books, magazines, & other printed matter
40120 Toiletries & cosmetics
40140 Consumer nondurables, n.e.c.
41000 Furniture, household items & baskets
41010 Glassware, porcelain, & chinaware
41020 Cookware, cutlery, house & garden ware & tools
41030 Household and kitchen appliances
41040 Rugs & other textile floor coverings
41050 Other household goods
41100 Motorcycles & parts
41110 Pleasure boats & motors
41120 Toys, shooting & sporting goods, including bicycles
41130 Photographic & optical equipment
41140 Musical instruments & other recreational equipment

41200 Television receivers, video receivers, & other video equipment
41210 Radios, phonographs, tape decks, & other stereo equipment & parts
41220 Records, tapes, & disks
413 Coins, gems, jewelry, & collectibles
42000 Unmanufactured goods
421 Unmanufactured diamonds

Investment *(final goods):*

20000 Generators, transformers, and accessories
20005 Electrical equipment and parts n.e.c.
21000 Oil-drilling, mining, and construction machinery
21100 Industrial engines, pumps, compressors, and generators
21110 Food- and tobacco-processing machinery
21120 Machine tools & metal-working machinery, molding and rolling
21130 Textile, sewing and leather working machinery
21140 Woodworking, glass-working & plastic- and rubber-molding mach.
21150 Pulp & paper machinery, bookbinding, printing & packaging mach.
21160 Measuring, testing, and control instruments
21170 Materials-handling equipment
21180 Other industrial machinery
21190 Photo- & service-industry machinery and trade tools
21200 Agricultural machinery and equipment
21400 Telecommunications equipment
21500 Other business machines
21600 Scientific, hospital, and medical equipment and parts
22000 Civilian aircraft, complete*
22010 Civilian aircraft, parts
22020 Civilian aircraft, engines
22100 Railway & other commercial transportation equipment
22200 Vessels (except military & pleasure craft) & misc. vehicles
22300 Spacecraft, engines & parts, except military

Automotive Vehicles, Parts, and Engines *(final and intermediate goods):***

30000 Passenger cars, new and used
30100 Complete and assembled

Raw Materials *(not final goods nor intermediate inputs):**

14200 Bauxite and aluminum
14220 Copper
14240 Nickel
14250 Tin
14260 Zinc
14270 Nonmonetary gold

14280 Other precious metals
14290 Misc. non-ferrous metals
10 Crude, Fuel oil, Other petroleum products, Coal, Gas, Nuclear fuel, Electric energy

* These classifications are always excluded from the offshoring calculation.
** This broad category include both final and intermediate goods. Those listed here are final goods and are excluded from the offshoring calculation.

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Errors from the “Proportionality Assumption” in the Measurement of Offshoring: Application to German Labor Demand

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Errors from the "Proportionality Assumption" in the Measurement of Offshoring: Application to German Labor Demand

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ABSTRACT

Offshoring—the importing of intermediate materials and services—has expanded rapidly in most industrialized countries, and its impact on the labor markets in these countries has been the source of enormous debate in both scholarly and popular circles. Since data on imported inputs at the sectoral level are not available for the United States and the United Kingdom, empirical research has relied entirely on a proxy-based measure offshoring, using what the OECD refers to as the "proportionality assumption." That is, every sector is assumed to import inputs of each material and service in the same proportion as its economy-wide use of that input.

German input-output data differentiate between domestically purchased inputs and imported inputs, which permits us to calculate a direct measure of sectoral imported input use. In this paper, we compare this measure to the proxy-based measure based on the standard proportionality assumption. We find that the direct measure differs significantly from the proxy-based measure for both services and materials offshoring. To assess the significance of using different measures, we substitute them for each other in standard labor demand equations focusing on German manufacturing between 1995 and 2004. We find that using the direct measure of offshoring gives very different results for labor demand—sometimes of opposite sign—compared to estimates using the proxy-based measure.

We perform a simple decomposition of the proxy-based measure and find that it fails to accurately capture the cross-sectoral variation in offshoring intensity because—as a result of the proportionality assumption—it is heavily influenced by the cross-sectoral variation in domestic input demand. The implications of our findings go beyond the case of Germany. They indicate that researchers must be cautious about drawing policy conclusions from estimates using the proxy-based measure of offshoring.

JEL No. F1, F2

Key Words: Services Offshoring, Offshoring Intensity, Labor Demand

Offshoring—the importing of intermediate materials and services—has expanded rapidly in most industrialized countries, and its impact on the labor markets in these countries has been the source of enormous debate in both scholarly and popular circles.[200] Since data on imported inputs at the sectoral level are not available for the United States and the United Kingdom, empirical research has relied entirely on a proxy-based measure offshoring, using what the OECD refers to as the "proportionality assumption" (Grossman and Rossi-Hansberg 2006). The U.S. Bureau of Economic Analysis, for example, collects data on input use, but does not break out imported from domestically produced inputs. Lacking information on a sector's imports of each input, researchers have instead applied the economy-wide import penetration ratio for a material or service input to approximate the imported input share of that material or service by all sectors. That is, every sector is assumed to import inputs of each material and service in the same proportion as its economy-wide use of that input. Without the information on imported input use, the proportionality assumption has been accepted in most major studies of the level and impact of offshoring.[201]

To date, there has been no way to assess the extent of error in measurement introduced by the use of the proportionality assumption, but recent data for Germany provide a test. German input-output data differentiate between domestically purchased inputs and imported inputs, which permits us to calculate a direct measure of sectoral imported input use. In this paper, we compare this measure to the proxy-based measure based on the standard proportionality assumption. We find that the direct measure differs significantly from the proxy-based measure for both services and materials offshoring. To assess the significance of using different measures, we substitute them for each other in standard labor demand equations. We find that using the direct measure of offshoring gives very different results for labor demand—sometimes of opposite sign—compared to estimates using the proxy-based measure. For example, using the proxy-based measure, services offshoring is found to have a positive and statistically significant effect on German employment. Using the direct measure, the estimated employment effect is significantly negative. This result is robust to a number of specifications and estimation techniques.

We perform a simple decomposition of the proxy-based measure and find that it fails to accurately capture the cross-sectoral variation in offshoring intensity because—as a result of the proportionality assumption—it is heavily influenced by the cross-sectoral variation in domestic input demand. The implications of our findings go beyond the case of Germany. They indicate that researchers must be cautious about drawing policy conclusions from estimates using the proxy-based measure of offshoring when we know, at least in the case of Germany for 1995–2004, that the direct measure gives a very different result.

This paper has five sections. First we discuss the alternative measures of offshoring—the direct measure and the proxy-based measure—differentiating between services and materials offshoring intensities, and present our calculations on these two measures for Germany in 1995 and 2004. We then look at the source of the apparent error in the proxy-based measure, followed by an

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[200] For a concise survey of the scholarly literature on employment and wage effects of offshoring, see Milberg and Schöller (2008). For a discussion of the parallels between the scholarly and popular debates, see Milberg (2008).
[201] The assumption was first used by Feenstra and Hanson (1996, 1999) and has been adopted in all major studies, for example, Hummels, Ishi, and Yi (2001), Amiti and Wei (2005, 2006), and Grossman and Rossi-Hansberg (2006). Further discussion of the proportionality assumption can be found in National Research Council (2006).

econometric analysis of offshoring and labor demand that uses the two measures and confirms the error of the proxy measure. In the final section we conclude with a discussion of the implications for future research and data collection.

OFFSHORING INTENSITY

In this section, we calculate the direct and proxy measures of services and materials offshoring intensity for Germany from 1995 to 2004. The analysis uses annual input-output data from the German Federal Statistical Office (FSO). Input-output tables focus "on the interrelationships between industries in an economy with respect to the production and uses of their products and the products imported from abroad. In a table form […] the economy is viewed with each industry listed across the top as a consuming sector and down the side as a supplying sector" (United Nations 1999, p. 3). **We extract a symmetric 43-sector matrix from the original input-output tables containing 71 sectors, including all 36 manufacturing sectors in the original tables and seven of the 27 services sectors. We drop the primary sector (sectors 1–3) and the sectors Mining and Quarrying of the secondary sector (sectors 4–8), as they generally have little or no offshoring activity. Total nonenergy inputs in Equations. (1) and (5) contain all 36 material inputs plus the 7 service inputs selected above. For a list of the 43 sectors covered, see Appendix A.**

In the following section, we use the term "inputs" when we refer to the supplying sectors. **The selection of the 7 service inputs out of 27 follows the aggregation of Kalmbach et al. (2005) and includes *tradable business activities*.** Business activities comprise Other business activities (sector 62), as well as the following 6 sectors: 1) Post and telecommunications; 2) Financial mediation (except insurance and pension funding); 3) Activities related to financial mediation; 4) Rental of machinery and equipment; 5) Computer and related activities; and 6) Research and development (sectors 54, 55, 57, 59–61). We exclude Wholesale, trade, and commission excl. motor vehicles services from the original definition, since in our view they do not represent typical offshoring services. Abramovsky, Griffith, and Sako (2004), for instance, classify them as nonbusiness services. **Consumer-related**[202] **and social services**[203] are also not considered, since the former in general do not represent typical offshoring services and the latter are not tradable.

Direct and Proxy Offshoring Intensity Measures

In this section we present the two measures of offshoring intensity: a direct offshoring intensity measure that uses direct information on imported input use and a proxy offshoring intensity measure that adopts the proportionality assumption that all sectors import an input at the economy wide rate. We explain the two different concepts by using the example of services offshoring intensity. These definitions can be applied analogously to materials offshoring intensity.

The *direct services offshoring intensity* (DOS) measures the share of imported service inputs s in total nonenergy inputs used by sector i at time t and is calculated as follows:

[202] Sectors within the classification of the FSO: 45, 47-53, 56, 58, 69–71.
[203] Sectors within the classification of the FSO: 63–68.

(1) $$DOS_{ist} = \frac{(imported\ input\ purchases\ of\ service\ s\ by\ sector\ i)_t}{(total\ non\text{-}energy\ inputs\ used\ by\ sector\ i)_t}$$

The direct services offshoring intensity across all service inputs *s* for sector *i* at time *t* is calculated by taking the sum over all DOS_{ist}:

(2) $$DOS_{it} = \sum_s DOS_{ist}$$

The sectoral services offshoring intensity DOS_{it} should not be confused with DOS_{st}, which represents the average offshoring intensity of a certain service input *s* across all sectors *i*. This is calculated by aggregating the respective DOS_{ist}, weighted by total sectoral nonenergy inputs INP , which is[204]

(3) $$DOS_{st} = \sum_i DOS_{ist} * (INP_{it} / INP_t)\text{, where } INP_t = \sum_i INP_{it}\,.$$

Summing DOS_{st} over all service inputs *s* yields the average services offshoring intensity DOS_t across all sectors *i* and all inputs *s* at time *t*

(4) $$DOS_t = \sum_s DOS_{st}\,.$$

The second measure is the *proxy services offshoring intensity* (POS), which uses a proxy for the proportion of the imported service input *s* used in home production, defined as follows (see e.g., Feenstra and Hanson [1996]:

(5) $$POS_{ist} = \left[\frac{(input\ purchases\ of\ service\ s\ by\ sector\ i)_t}{(total\ non\text{-}energy\ inputs\ used\ by\ sector\ i)_t}\right]\left[\frac{(imports\ of\ service\ s)_t}{production_{st} + imports_{st} - exports_{st}}\right]$$

The first bracket gives the share of the purchased service input *s* in total nonenergy inputs for sector *i* at time *t*, which we call the *sectoral input share*. However, the first ratio does not distinguish between domestically and foreign purchased inputs. Offshoring focuses solely on inputs purchased from abroad. Therefore, the second bracket gives an adjustment based on the share of total imported inputs *s* (the numerator) in the entire domestic disposability of this input *s* (the denominator), where the latter is composed of home production plus imports minus exports at time *t*. We call the second bracket of Equation (3) the *overall import share*.

The proxy services offshoring intensity POS_{ist} of service input *s* in sector *i* is equal to the product of the two ratios. The proxy measure is based on the assumption of the same import share of

[204] Other authors, e.g., Amiti and Wei (2005, 2006), use sectoral outputs as weights. Using total nonenergy inputs instead of output results in a more accurate overall offshoring intensity, as it directly refers to the denominator of the offshoring measure.

service input *s* for all sectors, irrespective of actual sectoral differences. In Germany, for instance, the overall import share of other business activities was 4.5 percent in 2004. Hence, an import share of 4.5 percent is assumed for each sector *i* in the calculation of the sectoral import intensities for 2004. POS_{it}, POS_{st} and POS_t are defined analogously to Equations (2), (3), and (4). We calculate direct and proxy materials offshoring intensities (DOM and POM) analogously to the services offshoring intensities.

The definition of offshoring intensity suffers from three related shortcomings; the first two concern both offshoring intensity measures, whereas the last one only holds for the proxy offshoring measure. First, the numerator underestimates the actual offshoring values, since import prices—used here for the calculation of the offshoring measure—are generally lower than the actual purchase prices of these inputs. Second, total nonenergy inputs only include purchased inputs, but not self-produced inputs used by sector *i*, which underestimates the denominator. Third, the application of the same import share of across all sectors in the proxy offshoring intensity is not accurate, since not every sector uses imports to the same extent. Thus, the offshoring intensity cannot be exactly measured (Amiti and Wei 2005).

The first two shortcomings are mutually offsetting and the direct offshoring intensities presents a good measure for the proportion of imported inputs being used by sector *i* at time *t*. However, the third shortcoming—the proportionality assumption that applies the same import share to all sectors *i* in the proxy offshoring intensity measures—could constitute a major problem, since much of the import-induced cross-sectoral variation gets lost. Because of lack of data on the direct import of intermediates, the proxy measured is used in all major studies of offshoring.[205]

German Offshoring Intensity Using Direct and Proxy Measures

Table 1 presents the direct and proxy measures of average services offshoring intensity (weighted by total nonenergy inputs) for each of the 7 selected service inputs *s* over all 43 sectors *i* in 1995 and 2004 as defined in Equation (3). For each service input we also show the (unweighted) mean and the standard deviation across the 43 sectors. The average services offshoring intensity measured directly, DOS_{st}, more than doubled from 1.37 percent in 1995 to 2.90 percent in 2004. At the service level, Computer and related activities grew on average from the third smallest share of 0.08 percent in 1995 to the fourth largest share of 0.39 percent in 2004. Average offshoring intensities of Research and development services increased from 0.13 percent in 1995 to 0.35 percent in 2004. Other business activities almost doubled their intensities from 0.53 percent in 1995 to 0.95 percent in 2004. These three service inputs are those that are typically associated with services offshoring and account for 58 percent of the total DOS_t in 2004.

The proxy measures of services offshoring intensity, POS_{st}, are shown at the bottom of Table 1. They are smaller than the direct measures. Applying the overall import share of a services category *s* to all sectors *i* thus seems to underestimate the real amount of imported service inputs. Average POS_t more than doubled from 0.88 percent in 1995 to 1.80 percent in 2004. Table 1 also shows that cross-sectoral standard deviations are generally much lower using the proxy measures compared to the direct measures. The corresponding measures of materials offshoring intensity

[205] For example, Feenstra and Hanson (1996, 1999); Amiti and Wei (2005, 2006); Grossman and Rossi-Hansberg (2006); and OECD (2007).

by type of materials input can be found in Appendix B. Note that analogously to subscript *s* in Equations (1) to (5), subscript *m* stands for material inputs. In the case of materials offshoring, we find the reverse: the proxy measures tend to be higher than the direct measures. Cross-sectoral standard variations, on the other hand, are higher for the proxy measure than for the direct measure which we will explain in section.

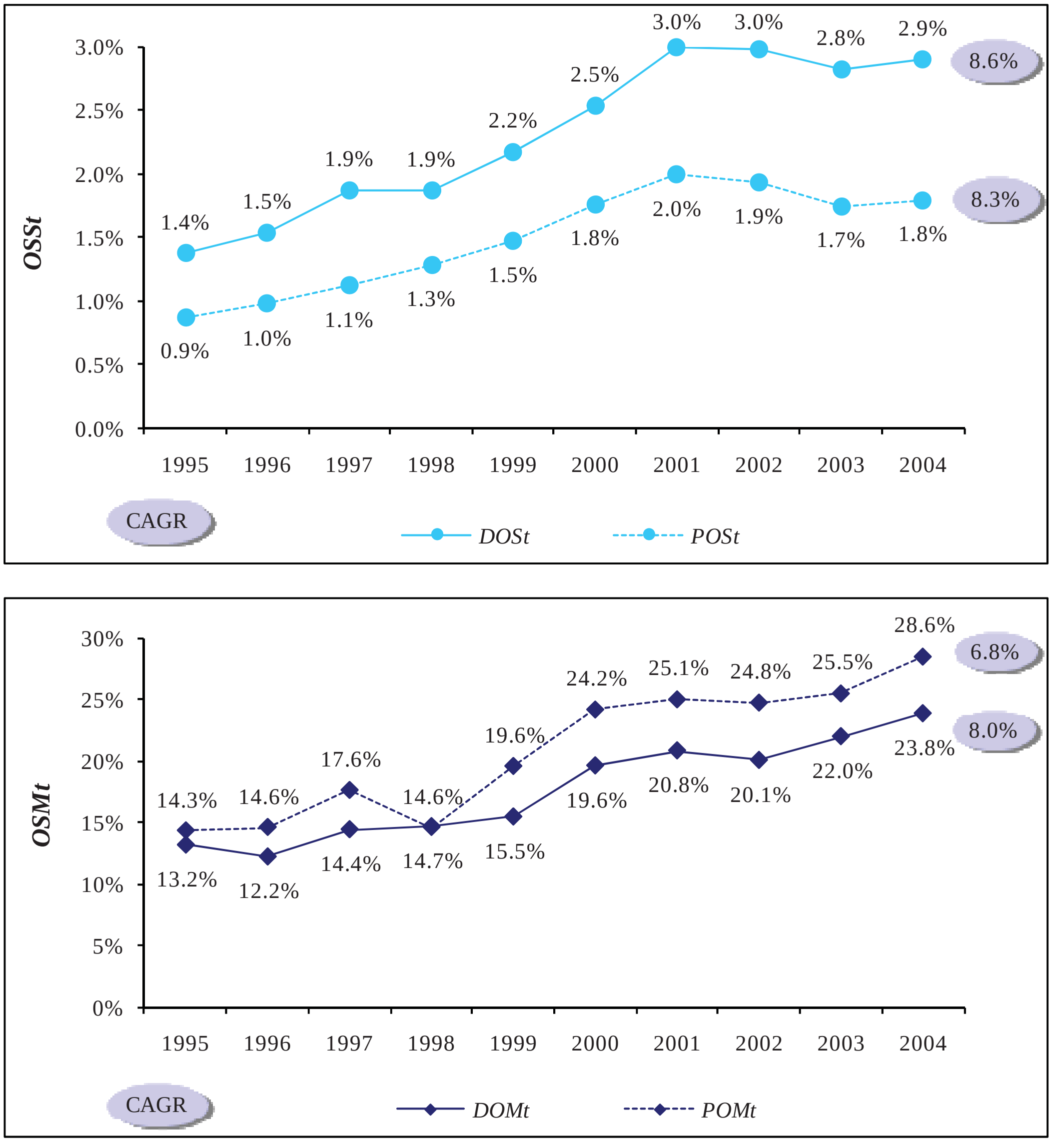
Table 6: Direct and Proxy Measures of Services Offshoring Intensity by Type of Service Input in Germany, 1995 and 2004

Service input *s*	Rank	DOS_s 1995 (weighted average)	Mean	Std Dev	Rank	DOS_s 2004 (weighted average)	Mean	Std Dev
Post and telecommunications	3	0.25%	0.25%	1.49%	2	0.52%	0.49%	3.04%
Financial intermediation	6	0.08%	0.06%	0.08%	6	0.19%	0.18%	0.10%
Activities related to financial intermediation	2	0.31%	0.19%	1.24%	3	0.51%	0.80%	4.71%
Renting of machinery and equipment	7	0.00%	0.00%	0.00%	7	0.00%	0.00%	0.00%
Computer and related activities	5	0.08%	0.13%	0.62%	4	0.39%	0.64%	2.07%
Research and development	4	0.13%	0.24%	1.00%	5	0.35%	0.64%	2.91%
Other business activities	1	0.53%	0.35%	1.03%	1	0.95%	0.73%	2.06%
Total DOS_t		**1.37%**	**1.23%**	**2.53%**		**2.90%**	**3.48%**	**6.98%**
Service input *s*	**Rank**	**POS_s 1995** (weighted average)	**Mean**	**Std Dev**	**Rank**	**POS_s 2004** (weighted average)	**Mean**	**Std Dev**
Post and telecommunications	3	0.09%	0.10%	0.11%	4	0.22%	0.21%	0.64%
Financial intermediation	5	0.05%	0.05%	0.10%	6	0.09%	0.09%	0.16%
Activities related to financial intermediation	2	0.22%	0.26%	1.19%	2	0.31%	0.38%	1.78%
Renting of machinery and equipment	7	0.00%	0.00%	0.00%	7	0.00%	0.00%	0.00%
Computer and related activities	6	0.04%	0.06%	0.20%	3	0.27%	0.40%	1.42%
Research and development	4	0.05%	0.10%	0.44%	5	0.16%	0.27%	1.06%
Other business activities	1	0.42%	0.45%	0.41%	1	0.75%	0.74%	0.63%
Total POS_t		**0.88%**	**1.03%**	**1.44%**		**1.80%**	**2.09%**	**2.78%**

Source: Own calculations, Data: FSO, revised input-output tables (1995 and 2004).

Figure 1 presents a plot of the development of the average services and materials offshoring intensities over all sectors in Germany as defined in Equation (4). The continuous lines represent the direct measures. Average direct services offshoring intensities DOS_t have grown considerably by on average 8.6 percent per year from 1.4 percent in 1995 to 2.9 percent in 2004, possibly due to the increased use of ICT. Direct materials offshoring intensities have risen by 8.0 percent per year from 13.2 percent in 1995 to 23.8 percent in 2004. The relatively strong annual growth rate of materials offshoring compared to services offshoring is somewhat surprising, as the process of materials offshoring started earlier and perhaps should have reached its limit. One explanation would be the collapse of communism in Eastern Europe, which was followed by significant German foreign direct investment in Central and Eastern Europe, and subsequent wave of re-imports back to Germany. Another explanation is the growing reliance on East Asian contract manufacturers.

Figure 5: Offshoring Intensities of Intermediate Inputs in Germany (1995-2004)



Source: Own calculations. FSO, revised input-output tables (1995-2004). Weighted average across all sectors *i* by total nonenergy inputs at time *t*.

The dashed lines in Figure 1 represent the average proxy measures POS_t and POM_t. Average services offshoring intensities POS_t are lower than the corresponding DOS_t measures. Nevertheless, the average annual growth rate is still 8.3 percent over the 1995–2004 period. On the other hand, the proxy measures of materials offshoring intensity POM_t are mostly higher than the corresponding direct measure DOM_t. The POM_t variable tracks the constant growth trend of the DOM_t measures with a lower CAGR of 6.8 percent. In sum, there is a clear difference in the average level and variation between the direct and proxy measures.

ERROR IN CAPTURING CROSS-SECTORAL VARIATION USING THE PROXY MEASURE

Loss of Cross-Sectoral Variation

In this section, we are interested how the proxy measure influences the *cross-sectoral variation* of offshoring, i.e., the variation across all sectors considered. In Equation (5), we distinguished between the "sectoral input share" (first bracket) and the "overall import share" (second bracket). Accordingly, we can attribute the cross-sectoral variation of the proxy measure in Equation (5) to the "input-induced variation," i.e., the variation in the first bracket across all sectors, and the "import-induced variation," i.e., the variation in the second bracket across all sectors.

Let us study the *import-induced variation* of the proxy measure compared to the direct measure in a first step. Applying the same overall import share for a service input *s* over all sectors *i* constitutes a major loss of cross-sectoral variation, which we will show in the following equation. Let us assume that a sector *i* only purchases two service inputs, s_1 and s_2. Then, the calculation of POS_{it} for a sector *i* at time *t* is given by

$$POS_{it} = \sum_{s=1}^{2} POS_{ist} = \left[\frac{(input\ purchases\ of\ service\ s_1)_{it}}{(total\ non\text{-}energy\ inputs)_{it}}\right]\left[\frac{(imports\ of\ service\ s_1)_t}{production_{s_1t} + imports_{s_1t} - exports_{s_1t}}\right] + \left[\frac{(input\ purchases\ of\ service\ s_2)_{it}}{(total\ non\text{-}energy\ inputs)_{it}}\right]\left[\frac{(imports\ of\ service\ s_2)_t}{production_{s_2t} + imports_{s_2t} - exports_{s_2t}}\right] \quad (6)$$

Now imagine the calculation of POS_{it} for a sector *j* (with $j \neq i$), which uses the same kinds of inputs as sector *i* at time *t*. We can see from Equation (6) that only the first bracket of each summand— i.e., the input-induced variation—differs from sector *i*, while the second bracket of each summand remains as in sector *i*— i.e. there is no import-induced variation across sectors. As a consequence, the cross-sectoral variation in offshoring intensities is solely determined by the input-induced variation. The application of the proportionality assumption thus lowers the import-induced cross-sectoral variation.

Influence of Domestically Purchased Inputs

We now analyze the *input-induced variation* of the proxy measure. As we have shown in the previous section, the cross-sectoral variation of POS_{it} is only determined by the input-induced variation because of the proportionality assumption. Note that the term input-induced variation in opposition to import-induced variation could be misleading, as it includes both the variation of domestically purchased inputs and the variation of imported inputs of *s*. In the following section we show that this can lead to a biased sectoral input share (first bracket in Equation 5), because the cross-sectoral variation is mainly determined by domestically purchased inputs.

The sectoral services offshoring intensities for the 36 manufacturing sectors using direct and proxy measures are plotted in Appendix C. One can see that the two measures differ for each sector. The cross-sectoral standard deviations per year (on bottom) are stronger for the DOS_{it}

measures. Consequently, the standard deviation of the DOS_{st} measures is also higher compared to that for POS_{st}, as already shown in Table 1. The category Other business services, for instance, shows a standard deviation of 1.03 percent in 1995 using the DOS_t measures, while the standard deviation is only 0.41 percent for the POS_t measures.

Similar differences between the direct and the proxy measure can be detected for materials offshoring intensity. Appendix D shows the sectoral materials offshoring intensities in manufacturing using both measures. Despite the loss in import-induced variation explained in the previous section, the cross-sectoral standard deviations of POM_{it} are higher than those for DOM_{it}. Likewise, the cross-sectoral standard deviations for the POM_{mt} measures are also higher compared to the DOM_{mt} measures (see Appendix B).

Why are there such differences in the standard deviation across sectors between the direct and proxy measures? In the following equation, we show the extent to which domestically purchased inputs as opposed to imported inputs influence the input-induced variation. To do this, we introduce two *domestic outsourcing variables* to reflect the amount of home-purchased service inputs and home-purchased material inputs. The domestic services outsourcing intensity *HPS* is calculated as follows:

(7) $$HPS_{ist} = \frac{(domestic\ input\ purchases\ of\ service\ s\ by\ sector\ i)_t}{(total\ non\text{-}energy\ inputs\ used\ by\ sector\ i)_t}$$

The domestic services outsourcing intensity HPS_{it} for sector *i* at time *t* is calculated by taking the sum over all HPS_{ist}: $HPS_{it} = \sum_s HPS_{ist}$. The domestic materials outsourcing intensity *HPM* is calculated analogously.

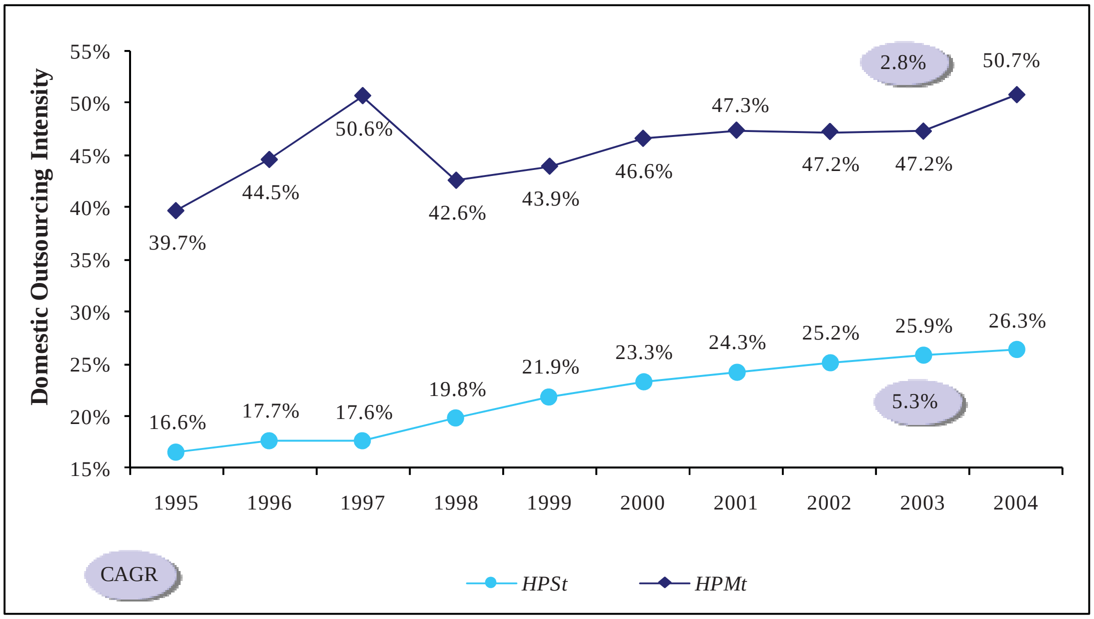
According to this definition, summing up Equations (7) and (1) yields the left bracket of Equation (5), i.e., the sectoral input share. Such domestic outsourcing is fully captured in the proxy measures, and is plotted in Figure 2 for the period 1995–2004. The average domestic outsourcing intensities are much higher than the offshoring intensities shown in Figure 2.[206] We thus expect domestic outsourcing to exert a stronger influence on the cross-sectoral input-induced variation. Between 1995 and 2004, domestic services outsourcing grew at an average rate of 5.3 percent per annum, (from 16.6 percent to 26.3 percent), while the overall domestic materials outsourcing intensity grew from 39.7 percent in 1995 to 50.7 percent in 2004, a compound annual growth rate of 2.8 percent.

The cross-sectoral correlations presented in Appendix E show that the sectoral POS_{it} measures have a very high correlation with the corresponding domestic services outsourcing intensities HPS_{it}, which is reflected in an average correlation of 0.9. This means that most of the cross-sectoral variation in POS_{it} is in fact determined by the domestic services outsourcing intensity and not by imported service inputs. Despite the fact that the POM_{it} measure shows an overall correlation with the *domestic materials outsourcing intensity* HPM_{it} of almost zero, the sectoral

[206] Note that the offshoring and domestic outsourcing measures for materials or services do not sum to 100 percent. The denominator in both measures is ‘total nonenergy inputs,’ which includes both material and service inputs, while the numerator includes only services or materials, depending on the measure.

data reveal that 22 sectors have a pairwise correlation of more than 50 percent. This is due to the fact that some sector pairs show positive and others have a negative correlation. We explain these differences by the fact that the ratio of domestic to imported inputs is much higher in services than in materials (see Figures 1 and 2). The influence of domestic outsourcing, and thus the error, would seem to be less severe for materials compared to services.

Figure 6: Domestic Outsourcing Intensity of Intermediate Inputs in Germany



Source: Own calculations. Data: FSO, revised input-output tables (1995–2004). Weighted average across all sectors *i* by total nonenergy inputs at time *t*.

We conclude that the input-induced variation is mostly determined by domestically purchased inputs, which is stronger in the case of service inputs. A high standard deviation of the domestic outsourcing variables thus influences the variation in the proxy measure. To support our hypothesis, we present the sectoral domestic outsourcing intensities and their standard deviations in Appendix E. The standard deviations of $HPS_{it.}$ and HPM_{it} are much higher than the respective standard deviations of DOS_{it} and DOM_{it}, which implies a strong influence of domestically purchased inputs on the variation of POS_{it} and POM_{it}. Moreover, the standard deviations of HPM_{it} (with 36 material inputs) across all sectors are higher than the standard deviations of HPS_{it} (with 7 service inputs).

To sum up: the use of proxy measures significantly influences the degree of cross-sectoral variation. First of all, the cross-sectoral variation of the proxy measure is only determined by the input-induced variation due to the proportionality assumption, since there is by assumption no cross-sectoral variation in the overall import shares. In general this implies less cross-sectoral variation in the proxy measure of offshoring. Second, the input-induced variation is to a large extent determined by domestically purchased inputs, which can have an upward or downward effect on the cross-sectoral variation, depending on the cross-sectoral variation in domestic input demand compared to that for imported inputs. In our specific case, we detected a lower cross-sectoral variation in the proxy measure for services, but a higher cross-sectoral variation for materials. This indicates a strong upward effect of the input-induced variation for materials on the cross-sectoral variation.

These two effects lead in general to erroneous measurement, and this error may be particularly important when the proxy measure is used in cross-sectoral analysis of offshoring. We test this hypothesis in the next section, where we measure the impact of services offshoring on labor demand in German manufacturing using both the direct and the proxy offshoring measures.

OFFSHORING AND LABOR DEMAND IN GERMANY

Empirical Model

We use a standard model of labor demand, following the labor demand specification of Hamermesh (1993). A firm's linearly homogenous production function *F* with constant returns to scale is described as follows:

$$(8) \qquad Y = F(L, K, S, M, T) \qquad \frac{\partial F}{\partial x_1} > 0,\ \frac{\partial^2 F}{\partial x_1^2} < 0,\ \frac{\partial^2 F}{\partial x_1 \partial x_2} > 0 \qquad \text{with } x_1, x_2 = L, K, S, M, T$$

where labor *L*, capital *K*, intermediate services *S*, intermediate materials *M*, and technology *T* are the input factors. The technology shifter, *T*=*T*(*OS*, *OM*), is a function of services and materials offshoring *OS* and *OM*.[207] *T* represents a change of the production function due to offshoring.

The corresponding linearly homogeneous cost function, conditional on the level of output *Y*, is the following:

$$(9) \qquad C = C(Y, w, r, p^S, p^M, p^T) \qquad \frac{\partial C}{\partial c_1} > 0,\ \frac{\partial C}{\partial c_1 \partial c_2} > 0 \qquad \text{with } c_1, cx_2 = w, r, p^S, p^M, p^T$$

where *w* designates wages, *r* the rental rate on capital, p^S, p^M, and p^T the prices for service, material, and technology inputs, and *Y* the constant output.

Using Shephard's Lemma,[208] the conditional labor demand function L^d is derived as follows:

$$(10) \qquad L^* = L^d(Y, w, r, p^S, p^M, p^T)$$

[207] We use *OS* and *OM* in the following, when the variables can represent the direct or the proxy measure.
[208] According to Shephard's Lemma (1953), factor demand is determined by the first partial derivative of the cost function with respect to the corresponding factor price, regardless of the kind of production function.

In log-linear form, we can write

(11) $$\ln L_{it} = \alpha_0 + \eta_Y \ln Y_{it} + \eta_L \ln w_{it} + \eta_K \ln r_{it} + \eta_S \ln p^S_{it} + \eta_G \ln p^M_{it} + \eta_T \ln p^T_{it}$$

In this form, the equation results in the employment-output elasticity η_Y, the price elasticity of demand for labor η_L, the cross-elasticity of demand for labor due to a change in the rental rate on capital η_K, the cross-elasticities of demand for labor due to a change in input prices for services, goods, and technology η_S, η_M, and η_T.

Wages are observed directly, but some choices must be made on the specification of the input prices. The rental rate on capital, *r*, is assumed to be the same for all companies and to be a function of time *r=f(t)*. *r* is not directly included in the estimation model, but will be captured by adding fixed-year dummies. The input prices for service and material inputs p^S and p^M can be subdivided into foreign input prices and domestic input prices (see Winkler [2009]). Following Amiti and Wei (2005), we use offshoring intensities as an inverse proxy for import prices of services as well as of materials. The lower the prices of imported services or material inputs, the higher the offshoring intensities should be. Therefore, we use the offshoring variables as inverse proxies for imported input prices.

Winkler (2009) uses the previously calculated domestic outsourcing intensities *HPS* and *HPM* as an inverse proxy for the prices of home-purchased service and material inputs. However, these variables can only be calculated using the domestic input matrices of the input-output tables. Unlike the offshoring intensity measures, we do not know an alternative proxy measure for domestic outsourcing intensities. Therefore, we do not include *HPS* and *HPM* in the regressions. This also makes our study more comparable with other studies that do not include domestic outsourcing intensities (e.g., Amiti and Wei [2005, 2006]). Finally, the input prices p^T of the technology shifter *T* need to be determined. Since adequate measures for p^T are not available and *T*=*T*(*OS*, *OM*), we use *OS* and *OM* as inverse proxies for the prices of technology p^T, because falling prices of technology inputs p^T are expected to be reflected in higher offshoring intensities.

Equation (11) thus reduces to

$$\ln L_{it} = \alpha_0 + \eta_Y \ln Y_{it} + \eta_L \ln w_{it} + \eta_{OS} \ln OS_{it} + \eta_{OM} \ln OM_{it} + \delta_t D_t + \varepsilon_{it}$$

Note that *OS* and *OM* have *two functions* in Equation (12). First, they are used as (inverse) proxies for other foreign input prices, and second, they are used as (inverse) proxies for the prices of the technology shifter *T*. Higher output is expected to be associated positively with labor demand, that is, $\eta_Y > 0$. Increasing wages are expected to be associated negatively, that is, $\eta_L < 0$. Concerning *OS* and *OM*, their net effects are not unambiguous as noted by Amiti and Wei (2006). Offshoring can influence employment in at least three ways. First, if input prices p^S and p^M fall, i.e., if *OS* and *OM* increase, labor is likely to be substituted for imported inputs. We call this the input substitution effect. Analogously, if input prices p^T decrease, i.e., if *OS* and *OM* rise, labor is likely to be substituted for technology in what we call the technology substitution effect. Second, offshoring could augment productivity via *T*, so that less labor is needed for the same amount of output (*productivity effect*). The substitution effect influences labor demand in a direct manner, whereas the productivity effect is indirect.

Besides these two negative effects, *scale effects* could influence labor demand positively. If productivity effects lead to lower prices, this would be expected to be associated with a greater quantity demanded, in turn increasing the demand for labor. Thus, the net effect of offshoring is not clear. If the negative substitution or productivity effects are larger than the positive scale effects, then $\eta_{OS} < 0$ and $\eta_{OM} < 0$. If the scale effects dominate the other effects for all variables, we would expect $\eta_{OS} > 0$ and $\eta_{OM} > 0$

Estimation Results

We estimate the effect of offshoring on labor demand using the consistent fixed effects estimator, which allows unobserved time-constant sector-specific effects c_i to be correlated with some explanatory variables x_{it}. All estimations produce standard errors robust to both heteroscedasticity (Huber-White sandwich estimators) and any form of intracluster correlation. Table 2 shows the results using the fixed effects estimator including all sectors, Table 3 shows the results excluding outliers 'pharmaceuticals' and 'recycling,' and Table 4 applies the instrumental variables two-stage least squares (IV 2SLS) estimator to control for potential endogeneity of the offshoring variables. The correlation matrix, summary statistics and data description can be found in Appendices G–I..

Table 7: Fixed Effects Estimations (1995–2004)

Dependent variable: lnL_t								
	Fixed effects using *DOS* and *DOM* measures				Fixed effects using *POS* and *POM* measures			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
lnY_t	0.3418***	0.1216**	0.2271**	0.1401**	0.3398***	0.1291**	0.1771**	0.0973
	(0.002)	(0.020)	(0.050)	(0.032)	(0.005)	(0.028)	(0.036)	(0.203)
lnY_{t-1}		0.2484***		0.0613		0.2277**		0.0503
		(0.010)		(0.470)		(0.014)		(0.402)
lnw_t	-0.5369***	-0.4414***	-0.4701***	-0.3499***	-0.5357***	-0.4395***	-0.4623***	-0.3621***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
lnw_{t-1}		-0.1250**		-0.1560***		-0.1300*		-0.1490***
		(0.037)		(0.005)		(0.053)		(0.008)
lnOS_t	-0.0403*	-0.0092	-0.0133	0.0121	0.0910*	0.0569	0.0860**	0.0577
	(0.059)	(0.653)	(0.313)	(0.549)	(0.064)	(0.133)	(0.030)	(0.132)
lnOS_{t-1}		-0.0406**		-0.0243**		-0.0068		0.0075
		(0.013)		(0.020)		(0.825)		(0.770)
lnOM_t	0.0095	-0.0051	0.0258	0.0116	-0.0128	-0.0026	0.0524	0.0444
	(0.672)	(0.769)	(0.367)	(0.596)	(0.844)	(0.955)	(0.253)	(0.327)
lnOM_{t-1}		0.0109		0.0376		0.0160		0.0616
		(0.665)		(0.137)		(0.737)		(0.108)
ln$(IM/Y)_t$			0.0209	0.0429			0.0195	0.0357
			(0.602)	(0.127)			(0.449)	(0.194)
ln$(IM/Y)_{t-1}$				-0.0396				-0.0368
				(0.295)				(0.235)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Joint significance tests:								
lnY_t + lnY_{t-1} = 0		p>F=0.0062		p>F=0.0970		p>F=0.0181		p>F=0.1650
lnw_t + lnw_{t-1} = 0		p>F=0.0000		p>F=0.0000		p>F=0.0000		p>F=0.0000
lnOS_t + lnOS_{t-1} = 0		p>F=0.0415		p>F=0.0641		p>F=0.2827		p>F=0.2751
lnOG_t + lnOG_{t-1} = 0		p>F=0.8727		p>F=0.3239		p>F=0.9273		p>F=0.1763
ln$(IM/Y)_t$+ln$(IM/Y)_{t-1}$ = 0				p>F=0.1973				p>F=0.3325
AIC	-855.8	-821.6	-849.8	-809.7	-834.9	-813.5	-879.3	-836.6
Observations	347	312	319	287	360	324	330	297
R-squared	0.64	0.65	0.66	0.66	0.62	0.63	0.68	0.68

Source: Own calculations. p*<0.1, p**<0.05, p***<0.001 (p-values in parentheses).

In each case we consider instantaneous effects and additional one-period lags of the independent variables. Employment is associated with income and wages in the predicted fashion under all estimation techniques, whether the estimation includes proxy or direct measures of offshoring. In all cases the income variable (contemporaneous and one-year lag) is positive and in most cases statistically significant. Similarly, the wage variable (contemporaneous and one-year lag) is always negative and in most cases significant. When lagged values of these variables were included, they were in all cases jointly significant with the contemporaneous value (see joint significance tests at the bottom of each table).

There are different results, however, for the offshoring variables depending on if they are measured in a direct or proxy fashion. In the fixed effects models (both with and without outliers), materials offshoring varies from positive to negative but is statistically insignificant in all models. In the IV 2SLS estimated with year fixed effects without outliers (Table 4), the direct measure of materials offshoring is negative and significant in columns (1) and (3) and insignificant in (2) and (4). The proxy measure of offshoring has a negative sign in all cases, and the effect is larger and statistically significant at a higher level in columns (5) and (7).

Table 8: Fixed Effects Estimations without Outliers (1995–2004)

Dependent variable: $\ln L_t$								
	Fixed effects w/o outliers[1] using *DOS* and *DOM* measures				Fixed effects w/o outliers[2] using *POS* and *POM* measures			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln Y_t$	0.3547***	0.1297**	0.2578**	0.1508**	0.2717***	0.1210**	0.1716**	0.0983
	(0.001)	(0.018)	(0.037)	(0.039)	(0.008)	(0.046)	(0.041)	(0.213)
$\ln Y_{t-1}$		0.2530***		0.0873		0.1628**		0.0406
		(0.009)		(0.334)		(0.029)		(0.503)
$\ln w_t$	-0.5627***	-0.4770***	-0.5007***	-0.3831***	-0.4770***	-0.4238***	-0.4959***	-0.3992***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$\ln w_{t-1}$		-0.1090*		-0.1477***		-0.0704		-0.1399**
		(0.067)		(0.008)		(0.266)		(0.017)
$\ln OS_t$	-0.0397*	-0.0097	-0.0139	0.0112	0.0591	0.0381	0.1102**	0.0744*
	(0.056)	(0.641)	(0.292)	(0.589)	(0.114)	(0.206)	(0.020)	(0.056)
$\ln OS_{t-1}$		-0.0398**		-0.0245**		-0.0106		0.0247
		(0.013)		(0.023)		(0.728)		(0.297)
$\ln OM_t$	0.0065	-0.0040	0.0160	0.0071	-0.0036	0.0060	0.0726	0.0708
	(0.788)	(0.825)	(0.629)	(0.780)	(0.957)	(0.902)	(0.109)	(0.112)
$\ln OM_{t-1}$		0.0039		0.0263		0.0133		0.0558
		(0.882)		(0.343)		(0.775)		(0.128)
$\ln(IM/Y)_t$			0.0388	0.0488			0.0368	0.0470*
			(0.398)	(0.136)			(0.112)	(0.054)
$\ln(IM/Y)_{t-1}$				-0.0231				-0.0281
				(0.560)				(0.385)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Joint significance tests:								
$\ln Y_t + \ln Y_{t-1} = 0$		p>F=0.0047		p>F=0.1121		p>F=0.0316		p>F=0.1960
$\ln w_t + \ln w_{t-1} = 0$		p>F=0.0000		p>F=0.0000		p>F=0.0000		p>F=0.0000
$\ln OS_t + \ln OS_{t-1} = 0$		p>F=0.0398		p>F=0.0708		p>F=0.3666		p>F=0.1098
$\ln OM_t + \ln OM_{t-1} = 0$		p>F=0.9643		p>F=0.6074		p>F=0.9588		p>F=0.0902
$\ln(IM/Y)_t + \ln(IM/Y)_{t-1} = 0$				p>F=0.2608				p>F=0.1069
AIC	-836.8	-803.3	-828.5	-786.3	-897.0	-845.5	-868.7	-828.5
Observations	337	303	309	278	340	306	320	288
R-squared	0.65	0.66	0.67	0.66	0.68	0.67	0.70	0.70

Source: Own calculations. p*<0.1, p**<0.05, p***<0.001 (p-values in parentheses).

1) Columns 1–4 exclude the outlier ‘pharmaceuticals’.
2) Columns 5–8 exclude the outliers ‘pharmaceuticals’ and ‘recycling.’

Table 4: IV 2SLS Fixed Effects Estimations without Outliers (1995-2004)

Dependent variable: $\ln L_t$								
	Instrumental Variables 2SLS: Fixed effects w/o outlier[1] using *DOS* and *DOM* measures				Instrumental Variables 2SLS: Fixed effects w/o outliers[2] using *POS* and *POM* measures			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln Y_t$	0.3537***	0.2368**	0.2549***	0.1439*	0.2825***	0.1893*	0.2545***	0.1083
	(0.001)	(0.048)	(0.002)	(0.059)	(0.003)	(0.082)	(0.001)	(0.161)
$\ln Y_{t-1}$			0.2424***	0.2361***			0.0676	0.1395**
			(0.001)	(0.006)			(0.276)	(0.023)
$\ln w_t$	-0.5509***	-0.5124***	-0.4750***	-0.4573***	-0.5419***	-0.4597***	-0.4760***	-0.4261***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$\ln w_{t-1}$			-0.1405**	-0.1078*			-0.1336*	-0.0722
			(0.029)	(0.073)			(0.070)	(0.267)
$\ln OS_t$	-0.0511**	-0.0298	-0.0625***	-0.0402	0.0911	0.1872	0.0439	0.1176
	(0.021)	(0.365)	(0.008)	(0.161)	(0.106)	(0.186)	(0.494)	(0.468)
$\ln OM_t$	-0.0815*	0.0376	-0.1181**	-0.0238	-0.2426***	-0.0216	-0.2201***	-0.0185
	(0.063)	(0.430)	(0.019)	(0.627)	(0.001)	(0.884)	(0.005)	(0.901)
Year fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Joint significance tests:								
$\ln Y_t + \ln Y_{t-1} = 0$			p>F=0.0002	p>F=0.0128			p>F=0.0040	p>F=0.0483
$\ln w_t + \ln w_{t-1} = 0$			p>F=0.0000	p>F=0.0000			p>F=0.0000	p>F=0.0000
First stage results:								
Shea Partial R-squared:								
$\ln OS_t$	0.5297	0.5092	0.5274	0.5066	0.3297	0.1923	0.3111	0.1802
$\ln OM_t$	0.4320	0.3142	0.4144	0.3173	0.4501	0.3247	0.4405	0.3274
Hanson J statistic[3] P-val.	$X^2(4)=0.05$	$X^2(4)=0.49$	$X^2(4)=0.05$	$X^2(4)=0.42$	$X^2(4)=0.04$	$X^2(4)=0.09$	$X^2(4)=0.03$	$X^2(4)=0.13$
AIC	-603.5	-649.6	-610.7	-666.8	-648.1	-692.8	-653.2	-711.2
Observations	235	235	235	235	238	238	238	238
R-squared	0.48	0.59	0.50	0.63	0.51	0.61	0.53	0.65

Source: Own calculations. p*<0.1, p**<0.05, p***<0.001 (p-values in parentheses).

1) Columns 1–4 exclude the outlier ‘pharmaceuticals.’
2) Columns 5–8 exclude the outliers ‘pharmaceuticals’ and ‘recycling.’
3) Overidentification test of all instruments.

The dramatic differences in the results between proxy and direct measures occur with services offshoring. In the fixed effect estimations (Table 2), the proxy variable has a positive and statistically significant coefficient in columns (5) and (7). The direct services offshoring measure has a negative sign in all cases and is significant in contemporaneous form in model (1) and in lagged form in models (2) and (4). A very similar result occurs when outliers are removed (Table 3). In the IV 2SLS fixed effects estimations (Table 4), the direct services offshoring variable is negative and significant when year fixed effects are not included (columns 1 and 3). By comparison, the coefficient on the proxy measure of services offshoring (models 5-8) is always positive and statistically insignificant.

CONCLUDING REMARKS

The proportionality assumption in the measurement of offshoring has been adopted in all the major empirical, input-output-based studies of offshoring. In this paper we provide a first assessment of the merits of that assumption. Since Germany collects imported inputs directly, we were able to construct a direct measure of offshoring to compare to the proxy measure, where the proxy measure was constructed with the proportionality assumption. We estimated the effect of offshoring on German labor demand for a sample of 36 sectors over the period 1995–2004 and found that the direct and proxy measures of offshoring give very different results, especially in the case of services offshoring. In many cases where the proxy measure gives a positive and insignificant coefficient, the direct measure has a negative and significant coefficient. This finding is robust to different estimation techniques.

We also performed a simple decomposition of the proxy-based measure. We find that the proxy measure fails to accurately capture the cross-sectoral variation in offshoring intensity because—as a result of the proportionality assumption—it is heavily influenced by the cross-sectoral variation in domestic input demand. More precisely, the cross-sectoral variation of the proxy measure is only determined by the input-induced variation, and the input-induced variation is to a large extent determined by domestically purchased inputs.

The implications of our findings go beyond the case of Germany. Researchers must be cautious about drawing policy conclusions from estimates using the proxy-based measure of offshoring when we know, at least in the case of Germany for 1995–2004, that using a direct measure sometimes gives the opposite result. Whereas the proxy measure would support the view that workers should have no “fear of offshoring,” the direct measure indicates that offshoring has a negative effect on labor demand. The two results would support very different policy prescriptions. Researchers relying (because of a lack of data) on the proxy measure should be very cautious when interpreting the results of their analysis.

Given our results, we would urge that industrialized countries seek to improve data on imported intermediates along the lines suggested by Sturgeon (2006). This would be especially important for the United States, the United Kingdom, and Japan, where offshoring levels and their labor market effects are known to be significant and the subject of considerable policy debate.

Appendices

Appendix A: Sectoral Classification

	Manufacturing Sectors (36 Sectors)
1	Food products
2	Beverages
3	Tobacco products
4	Textiles
5	Wearing apparel, dressing and dying of fur
6	Leather, leather products and footwear
7	Wood and products of wood and cork
8	Pulp and paper
9	Paper products
10	Publishing
11	Printing
12	Coke, refined petroleum products and nuclear fuel
13	Pharmaceuticals
14	Chemicals exluding pharmaceuticals
15	Rubber products
16	Plastic products
17	Glass and glass products
18	Ceramic goods and other non-metallic mineral products
19	Iron and steel
20	Non-ferrous metals
21	Metal castings
22	Fabricated metal products, except machinery and equipment
23	Machinery and equipment, n.e.c.
24	Office, accounting and computing machinery
25	Electrical machinery and apparatus, n.e.c.
26	Radio, television and communication equipment
27	Medical, precision and optical instruments
28	Motor vehicles, trailers and semi-trailers
29	Other transport equipment
30	Manufacturing n.e.c.
31	Recycling
32	Electricity, steam and hot water supply
33	Gas and gas supply
34	Collection, purification and distribution of water
35	Construction site and civil engineering
36	Construction installation and other construction
	Service Sectors (7 Sectors)
37	Post and telecommunications
38	Financial intermediation except insurance and pension funding
39	Activities related to financial intermediation
40	Renting of machinery and equipment
41	Computer and related activities
42	Research and development
43	Other business activities

Appendix B: Materials Offshoring Intensities per Input Category in Germany

Material input *m*	***DOMm* 1995** (weighted average)	**Mean**	**Std Dev**	***DOMm* 2004** (weighted average)	**Mean**	**Std Dev**	***POMm* 1995** (weighted average)	**Mean**	**Std Dev**	***POMm* 2004** (weighted average)	**Mean**	**Std Dev**
Food products	0.51%	0.35%	1.75%	0.68%	0.60%	2.73%	0.42%	0.30%	1.52%	0.63%	0.43%	2.17%
Beverages	0.02%	0.04%	0.24%	0.03%	0.04%	0.22%	0.02%	0.06%	0.36%	0.04%	0.09%	0.57%
Tobacco products	0.01%	0.14%	0.93%	0.00%	0.05%	0.32%	0.00%	0.06%	0.36%	0.00%	0.05%	0.34%
Textiles	0.46%	1.14%	4.18%	0.44%	1.11%	3.69%	0.68%	1.92%	7.36%	0.70%	2.05%	7.44%
Wearing apparel, dressing, and dying of fur	0.17%	0.58%	3.78%	0.17%	0.58%	3.76%	0.14%	0.54%	3.53%	0.16%	0.68%	4.43%
Leather, leather products, and footwear	0.10%	0.86%	5.46%	0.10%	0.73%	4.52%	0.12%	0.91%	5.61%	0.15%	1.12%	6.80%
Wood and products of wood and cork	0.37%	0.46%	1.60%	0.38%	0.48%	1.55%	0.38%	0.52%	2.03%	0.37%	0.53%	1.96%
Pulp and paper	0.67%	1.41%	4.94%	0.83%	1.90%	6.83%	0.76%	1.67%	5.72%	0.91%	1.99%	6.72%
Paper products	0.08%	0.14%	0.29%	0.16%	0.26%	0.43%	0.12%	0.25%	0.66%	0.30%	0.54%	1.35%
Publishing	0.03%	0.06%	0.28%	0.11%	0.16%	0.75%	0.02%	0.02%	0.05%	0.11%	0.11%	0.34%
Printing	0.04%	0.04%	0.10%	0.06%	0.06%	0.12%	0.08%	0.13%	0.38%	0.07%	0.12%	0.34%
Coke, refined petroleum products, and nuclear fuel	0.38%	0.60%	2.19%	0.78%	1.17%	3.94%	0.31%	0.60%	2.47%	0.75%	1.41%	6.26%
Pharmaceuticals	0.11%	0.21%	1.29%	0.18%	0.35%	2.25%	0.11%	0.13%	0.77%	0.52%	0.88%	5.75%
Chemicals exluding pharmaceuticals	1.93%	1.76%	3.60%	3.39%	3.58%	6.63%	2.22%	2.03%	3.18%	3.88%	3.27%	5.46%
Rubber products	0.21%	0.15%	0.48%	0.40%	0.32%	1.16%	0.21%	0.17%	0.49%	0.50%	0.39%	1.31%
Plastic products	0.44%	0.36%	0.46%	0.77%	0.67%	0.91%	0.56%	0.45%	0.80%	0.94%	0.74%	1.31%
Glass and glass products	0.15%	0.36%	1.75%	0.23%	0.50%	2.55%	0.16%	0.33%	1.31%	0.25%	0.50%	2.04%
Ceramic goods & other non-metallic mineral products	0.35%	0.27%	0.75%	0.34%	0.31%	0.73%	0.47%	0.41%	1.52%	0.38%	0.36%	1.27%
Iron and steel	1.02%	0.57%	1.48%	1.68%	1.27%	4.32%	1.17%	0.73%	3.03%	1.83%	1.12%	4.52%
Non-ferrous metals	1.10%	1.19%	4.98%	1.69%	2.63%	9.80%	1.11%	1.37%	5.02%	1.78%	2.64%	9.88%
Metal castings	0.07%	0.03%	0.12%	0.26%	0.23%	1.25%	0.10%	0.05%	0.11%	0.29%	0.13%	0.34%
Fabricated metal products, excl. machinery & equip.	0.52%	0.38%	0.51%	1.00%	0.71%	0.99%	0.67%	0.44%	0.76%	1.24%	0.78%	1.41%
Machinery and equipment, n.e.c.	0.78%	0.46%	1.08%	1.84%	1.05%	2.47%	0.96%	0.62%	1.15%	1.93%	1.20%	2.39%
Office, accounting, and computing machinery	0.30%	0.52%	2.56%	0.59%	1.05%	4.16%	0.39%	0.71%	2.85%	1.06%	1.94%	7.60%
Electrical machinery and apparaturs, n.e.c.	0.70%	0.37%	1.04%	1.52%	0.80%	2.48%	1.02%	0.57%	1.63%	2.14%	1.20%	3.65%
Radio, television, and communication equipment	0.61%	0.59%	2.46%	1.67%	1.53%	5.98%	0.60%	0.61%	2.14%	2.20%	2.36%	8.93%
Medical, precision, and optical instruments	0.14%	0.20%	0.65%	0.33%	0.48%	1.59%	0.16%	0.27%	0.75%	0.37%	0.64%	2.12%
Motor vehicles, trailers, and semi-trailers	1.52%	0.26%	1.57%	2.83%	0.56%	2.98%	1.12%	0.19%	1.08%	3.86%	0.64%	3.45%
Other transport equipment	0.11%	0.15%	1.01%	0.41%	0.55%	3.60%	0.11%	0.14%	0.90%	0.70%	0.95%	6.21%
Manufacturing n.e.c.	0.09%	0.12%	0.63%	0.30%	0.40%	2.52%	0.07%	0.09%	0.49%	0.24%	0.26%	1.49%
Recycling	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Electricity, steam, and hot water supply	0.03%	0.06%	0.15%	0.48%	0.91%	5.31%	0.03%	0.06%	0.08%	0.24%	0.42%	0.83%
Gas and gas supply	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Collection, purification, and distribution of water	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Construction site and civil engineering	0.01%	0.01%	0.01%	0.00%	0.01%	0.02%	0.01%	0.01%	0.03%	0.00%	0.00%	0.01%
Construction installation & other construction	0.14%	0.08%	0.32%	0.21%	0.12%	0.55%	0.01%	0.01%	0.02%	0.02%	0.02%	0.04%
Total Materials Offshoring Intensity in *t*	**13.17%**	**13.91%**	**10.86%**	**23.84%**	**25.19%**	**16.90%**	**14.31%**	**16.36%**	**12.69%**	**28.57%**	**29.57%**	**19.68%**

Source: Source: Own illustration. Data: FSO, revised input-output tables (1995 and 2004).

Appendix C: Sectoral *DOS* vs. *POS* Measures

	DOSit											***POSit***										
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	Std. Dev. over *t*	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	Std. Dev. over *t*
Food products	0.0011	0.0008	0.0009	0.0009	0.0010	0.0020	0.0025	0.0029	0.0031	0.0032	0.0010	0.0059	0.0062	0.0070	0.0077	0.0085	0.0100	0.0118	0.0113	0.0101	0.0103	0.0021
Beverages	0.0023	0.0038	0.0041	0.0045	0.0042	0.0051	0.0070	0.0070	0.0052	0.0050	0.0014	0.0134	0.0146	0.0154	0.0164	0.0180	0.0206	0.0216	0.0202	0.0172	0.0165	0.0027
Tobacco products	0.0081	0.0134	0.0150	0.0172	0.0193	0.0226	0.0331	0.0351	0.0376	0.0391	0.0112	0.0170	0.0072	0.0197	0.0220	0.0126	0.0303	0.0323	0.0293	0.0246	0.0269	0.0081
Textiles	0.0002	0.0005	0.0003	0.0002	0.0002	0.0013	0.0016	0.0024	0.0014	0.0015	0.0008	0.0030	0.0030	0.0033	0.0037	0.0038	0.0043	0.0047	0.0050	0.0039	0.0041	0.0007
Wearing apparel, dressing, and dying of fur	0.0000	0.0003	0.0003	0.0008	0.0008	0.0011	0.0014	0.0015	0.0009	0.0009	0.0005	0.0027	0.0028	0.0031	0.0031	0.0033	0.0034	0.0039	0.0040	0.0029	0.0032	0.0004
Leather, leather products, and footwear	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0017	0.0021	0.0020	0.0020	0.0023	0.0029	0.0027	0.0020	0.0021	0.0004
Wood and products of wood and cork	0.0006	0.0051	0.0051	0.0049	0.0054	0.0015	0.0020	0.0019	0.0013	0.0013	0.0019	0.0034	0.0034	0.0036	0.0040	0.0049	0.0053	0.0052	0.0047	0.0037	0.0039	0.0008
Pulp and paper	0.0020	0.0014	0.0011	0.0011	0.0011	0.0039	0.0045	0.0047	0.0043	0.0043	0.0016	0.0024	0.0023	0.0027	0.0031	0.0036	0.0048	0.0047	0.0047	0.0040	0.0042	0.0010
Paper products	0.0040	0.0013	0.0012	0.0012	0.0012	0.0066	0.0060	0.0061	0.0078	0.0077	0.0029	0.0025	0.0024	0.0028	0.0031	0.0034	0.0044	0.0046	0.0046	0.0040	0.0044	0.0009
Publishing	0.0064	0.0105	0.0124	0.0119	0.0118	0.0229	0.0283	0.0271	0.0287	0.0302	0.0092	0.0165	0.0187	0.0211	0.0250	0.0277	0.0302	0.0322	0.0312	0.0278	0.0294	0.0055
Printing	0.0025	0.0026	0.0027	0.0032	0.0033	0.0050	0.0058	0.0066	0.0053	0.0055	0.0015	0.0029	0.0031	0.0034	0.0042	0.0048	0.0053	0.0059	0.0062	0.0050	0.0054	0.0012
Coke, refined petroleum products, and nuclear fuel	0.0035	0.0024	0.0024	0.0020	0.0030	0.0037	0.0050	0.0062	0.0068	0.0068	0.0019	0.0147	0.0151	0.0159	0.0126	0.0148	0.0100	0.0097	0.0118	0.0136	0.0140	0.0021
Pharmaceuticals	0.0691	0.0714	0.0916	0.0704	0.0923	0.1477	0.1499	0.1666	0.2091	0.1965	0.0540	0.0146	0.0182	0.0232	0.0318	0.0357	0.0450	0.0526	0.0576	0.0613	0.0577	0.0175
Chemicals exluding pharmaceuticals	0.0037	0.0030	0.0038	0.0041	0.0046	0.0093	0.0120	0.0126	0.0158	0.0164	0.0053	0.0047	0.0051	0.0058	0.0065	0.0074	0.0093	0.0095	0.0095	0.0081	0.0088	0.0018
Rubber products	0.0027	0.0041	0.0043	0.0063	0.0065	0.0078	0.0089	0.0091	0.0068	0.0070	0.0021	0.0046	0.0049	0.0058	0.0072	0.0077	0.0097	0.0097	0.0085	0.0075	0.0080	0.0018
Plastic products	0.0095	0.0054	0.0060	0.0062	0.0066	0.0153	0.0167	0.0183	0.0122	0.0129	0.0048	0.0053	0.0059	0.0070	0.0079	0.0095	0.0116	0.0126	0.0129	0.0096	0.0105	0.0027
Glass and glass products	0.0016	0.0040	0.0049	0.0052	0.0059	0.0052	0.0056	0.0068	0.0053	0.0060	0.0014	0.0088	0.0088	0.0101	0.0108	0.0120	0.0143	0.0149	0.0142	0.0125	0.0131	0.0023
Ceramic goods & other non-metallic mineral products	0.0087	0.0063	0.0062	0.0062	0.0063	0.0102	0.0126	0.0128	0.0099	0.0096	0.0026	0.0102	0.0103	0.0111	0.0119	0.0138	0.0150	0.0148	0.0141	0.0119	0.0122	0.0018
Iron and steel	0.0012	0.0007	0.0007	0.0008	0.0007	0.0027	0.0032	0.0028	0.0063	0.0068	0.0023	0.0015	0.0016	0.0019	0.0022	0.0022	0.0028	0.0032	0.0028	0.0027	0.0031	0.0006
Non-ferrous metals	0.0014	0.0004	0.0007	0.0008	0.0008	0.0068	0.0080	0.0082	0.0070	0.0070	0.0035	0.0014	0.0015	0.0018	0.0022	0.0025	0.0036	0.0038	0.0036	0.0030	0.0033	0.0009
Metal castings	0.0002	0.0016	0.0015	0.0030	0.0028	0.0026	0.0034	0.0039	0.0057	0.0063	0.0019	0.0026	0.0026	0.0033	0.0042	0.0046	0.0055	0.0056	0.0060	0.0060	0.0070	0.0015
Fabricated metal products, excl. machinery & equip.	0.0014	0.0024	0.0027	0.0026	0.0028	0.0036	0.0048	0.0052	0.0043	0.0044	0.0012	0.0037	0.0041	0.0045	0.0054	0.0061	0.0069	0.0076	0.0073	0.0068	0.0071	0.0014
Machinery and equipment, n.e.c.	0.0032	0.0027	0.0031	0.0030	0.0031	0.0054	0.0062	0.0066	0.0057	0.0059	0.0016	0.0044	0.0051	0.0056	0.0066	0.0073	0.0087	0.0101	0.0099	0.0094	0.0098	0.0022
Office, accounting, and computing machinery	0.0044	0.0196	0.0289	0.0363	0.0303	0.0270	0.0367	0.0362	0.0263	0.0224	0.0098	0.0064	0.0072	0.0096	0.0117	0.0112	0.0174	0.0202	0.0183	0.0155	0.0136	0.0047
Electrical machinery and apparaturs, n.e.c.	0.0052	0.0049	0.0054	0.0059	0.0053	0.0085	0.0091	0.0112	0.0091	0.0098	0.0023	0.0050	0.0057	0.0064	0.0078	0.0084	0.0085	0.0116	0.0123	0.0110	0.0119	0.0027
Radio, television, and communication equipment	0.0060	0.0025	0.0027	0.0025	0.0037	0.0128	0.0162	0.0174	0.0120	0.0112	0.0059	0.0056	0.0063	0.0071	0.0072	0.0097	0.0136	0.0161	0.0159	0.0139	0.0133	0.0041
Medical, precision, and optical instruments	0.0043	0.0044	0.0050	0.0052	0.0050	0.0079	0.0090	0.0094	0.0079	0.0076	0.0020	0.0055	0.0061	0.0070	0.0087	0.0097	0.0121	0.0133	0.0133	0.0121	0.0117	0.0030
Motor vehicles, trailers, and semi-trailers	0.0027	0.0008	0.0009	0.0011	0.0013	0.0061	0.0067	0.0065	0.0061	0.0065	0.0027	0.0019	0.0025	0.0027	0.0037	0.0047	0.0062	0.0066	0.0061	0.0045	0.0049	0.0017
Other transport equipment	0.0013	0.0026	0.0032	0.0038	0.0036	0.0036	0.0040	0.0043	0.0039	0.0038	0.0009	0.0038	0.0055	0.0059	0.0069	0.0075	0.0098	0.0124	0.0123	0.0101	0.0098	0.0029
Manufacturing n.e.c.	0.0001	0.0003	0.0003	0.0003	0.0003	0.0017	0.0022	0.0025	0.0018	0.0018	0.0009	0.0047	0.0049	0.0055	0.0063	0.0069	0.0082	0.0087	0.0080	0.0068	0.0072	0.0014
Recycling	0.0000	0.0049	0.0061	0.0067	0.0049	0.0012	0.0014	0.0011	0.0013	0.0019	0.0024	0.0029	0.0033	0.0049	0.0054	0.0050	0.0092	0.0107	0.0098	0.0088	0.0110	0.0031
Electricity, steam, and hot water supply	0.0037	0.0059	0.0068	0.0075	0.0068	0.0069	0.0076	0.0064	0.0092	0.0100	0.0017	0.0080	0.0090	0.0101	0.0122	0.0134	0.0133	0.0154	0.0121	0.0099	0.0105	0.0023
Gas and gas supply	0.0015	0.0077	0.0092	0.0098	0.0127	0.0071	0.0090	0.0098	0.0093	0.0105	0.0029	0.0073	0.0071	0.0093	0.0110	0.0166	0.0222	0.0240	0.0221	0.0200	0.0224	0.0068
Collection, purification, and distribution of water	0.0000	0.0070	0.0081	0.0086	0.0092	0.0054	0.0061	0.0059	0.0043	0.0049	0.0026	0.0066	0.0074	0.0080	0.0102	0.0118	0.0116	0.0115	0.0111	0.0091	0.0104	0.0019
Construction site and civil engineering	0.0015	0.0031	0.0032	0.0027	0.0026	0.0017	0.0021	0.0024	0.0018	0.0018	0.0006	0.0052	0.0059	0.0065	0.0067	0.0075	0.0082	0.0077	0.0070	0.0064	0.0063	0.0009
Construction installation & other construction	0.0009	0.0011	0.0011	0.0010	0.0010	0.0014	0.0018	0.0022	0.0017	0.0017	0.0004	0.0033	0.0038	0.0039	0.0046	0.0047	0.0052	0.0055	0.0058	0.0046	0.0049	0.0008
Cross-sectoral Std. Dev.	0.0113	0.0119	0.0155	0.0127	0.0157	0.0243	0.0251	0.0277	0.0345	0.0324		0.0043	0.0044	0.0055	0.0065	0.0070	0.0089	0.0100	0.0103	0.0105	0.0101	

Source: Own illustration. Data: FSO, revised input-output tables (1995–2004).

Appendix D: Sectoral *DOM* vs. *POM* Measures

	DOMit										Std. Dev.	***POMit***										Std. Dev.
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	over *t*	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	over *t*
Food products	0.1416	0.1221	0.1442	0.1181	0.1169	0.1479	0.1711	0.1660	0.2191	0.2392	0.0418	0.1317	0.1425	0.1771	0.1428	0.1383	0.1615	0.1725	0.1728	0.1912	0.2016	0.0238
Beverages	0.0931	0.1165	0.1184	0.1329	0.1308	0.1058	0.1114	0.1101	0.1115	0.1058	0.0118	0.1103	0.1087	0.1187	0.1099	0.1114	0.1334	0.1340	0.1326	0.1486	0.1461	0.0154
Tobacco products	0.1208	0.0873	0.0843	0.0720	0.1112	0.0838	0.1087	0.1058	0.0807	0.0872	0.0161	0.0945	0.0755	0.0738	0.0686	0.1343	0.0903	0.1029	0.1042	0.0950	0.1085	0.0195
Textiles	0.3591	0.2665	0.2810	0.3012	0.2924	0.3860	0.4141	0.3915	0.3689	0.3600	0.0521	0.4638	0.4446	0.4863	0.4673	0.4657	0.4923	0.4863	0.4859	0.4875	0.4798	0.0150
Wearing apparel, dressing, and dying of fur	0.4549	0.4785	0.5779	0.6177	0.4514	0.4739	0.5755	0.5617	0.4205	0.4599	0.0686	0.6082	0.5570	0.6823	0.7069	0.5990	0.6789	0.6677	0.6891	0.6452	0.7027	0.0501
Leather, leather products, and footwear	0.4309	0.4911	0.6266	0.4866	0.4541	0.4920	0.5604	0.5667	0.4780	0.4387	0.0628	0.4402	0.4560	0.5621	0.4956	0.5049	0.5624	0.6191	0.6319	0.5410	0.5640	0.0636
Wood and products of wood and cork	0.1178	0.1350	0.1488	0.1612	0.1679	0.1334	0.1298	0.1253	0.1464	0.1614	0.0170	0.2016	0.1824	0.2165	0.2199	0.2340	0.2378	0.2288	0.2192	0.2207	0.2413	0.0177
Pulp and paper	0.2994	0.2363	0.2289	0.3278	0.3155	0.4193	0.4165	0.4075	0.4286	0.4495	0.0819	0.3317	0.2832	0.3423	0.3239	0.3707	0.4537	0.4110	0.3900	0.4139	0.4215	0.0531
Paper products	0.1813	0.1620	0.1713	0.1776	0.1891	0.2285	0.2324	0.2442	0.3228	0.2979	0.0552	0.2822	0.2456	0.2904	0.2659	0.2857	0.3697	0.3753	0.3871	0.3897	0.3848	0.0582
Publishing	0.0365	0.0591	0.0528	0.0461	0.0375	0.0518	0.0562	0.0571	0.0619	0.0676	0.0101	0.0338	0.0347	0.0413	0.0383	0.0443	0.0555	0.0539	0.0580	0.0590	0.0552	0.0100
Printing	0.1611	0.1586	0.1690	0.1880	0.2033	0.2177	0.2309	0.2131	0.1916	0.1955	0.0244	0.1934	0.1612	0.1622	0.1850	0.1971	0.2539	0.2639	0.2671	0.2459	0.2459	0.0419
Coke, refined petroleum products, and nuclear fuel	0.1878	0.2481	0.3742	0.2558	0.1912	0.2551	0.2402	0.2239	0.2747	0.2786	0.0526	0.2159	0.2113	0.2617	0.1753	0.2211	0.3726	0.2986	0.2718	0.3786	0.4497	0.0887
Pharmaceuticals	0.1353	0.1833	0.1971	0.1874	0.1864	0.1405	0.1476	0.1815	0.2454	0.2216	0.0349	0.1213	0.1343	0.1887	0.1485	0.1437	0.2216	0.3297	0.3145	0.2850	0.4839	0.1159
Chemicals exluding pharmaceuticals	0.1446	0.0981	0.1313	0.1541	0.1799	0.2451	0.2572	0.2300	0.3556	0.3788	0.0943	0.1692	0.1953	0.2518	0.2356	0.2526	0.2948	0.3160	0.2914	0.3017	0.3314	0.0529
Rubber products	0.1716	0.1831	0.2046	0.2291	0.2240	0.2531	0.2895	0.2944	0.4186	0.4409	0.0930	0.2013	0.1826	0.2123	0.2521	0.2560	0.3237	0.3280	0.3246	0.3742	0.4085	0.0766
Plastic products	0.2024	0.2081	0.2247	0.2396	0.2458	0.2862	0.3306	0.2943	0.3015	0.3319	0.0485	0.1766	0.1466	0.1610	0.1982	0.2103	0.2591	0.2735	0.2583	0.2700	0.3103	0.0552
Glass and glass products	0.1588	0.1201	0.1302	0.1291	0.1319	0.1815	0.2265	0.2134	0.2490	0.2839	0.0579	0.1441	0.1355	0.1631	0.1540	0.1574	0.2055	0.2161	0.2186	0.2083	0.2303	0.0356
Ceramic goods & other non-metallic mineral products	0.0767	0.0879	0.0934	0.0932	0.0907	0.0821	0.0973	0.0932	0.0780	0.0859	0.0070	0.1272	0.1193	0.1272	0.1287	0.1356	0.1503	0.1464	0.1441	0.1351	0.1509	0.0110
Iron and steel	0.0905	0.0789	0.0895	0.0947	0.0780	0.1095	0.1113	0.0956	0.2686	0.4123	0.1100	0.2293	0.2157	0.2650	0.2396	0.1937	0.2594	0.2506	0.2340	0.2467	0.3438	0.0397
Non-ferrous metals	0.3340	0.2914	0.3691	0.3702	0.3207	0.4417	0.4485	0.4817	0.4359	0.5321	0.0773	0.3213	0.2950	0.3981	0.3732	0.3942	0.5408	0.5102	0.5160	0.5013	0.6145	0.1044
Metal castings	0.1121	0.0707	0.1029	0.1297	0.1166	0.2646	0.2947	0.3069	0.5027	0.6695	0.1972	0.2099	0.2225	0.3216	0.2941	0.2921	0.4006	0.4019	0.3969	0.4253	0.5193	0.0971
Fabricated metal products, excl. machinery & equip.	0.1594	0.1351	0.1477	0.1629	0.1478	0.1995	0.2136	0.2127	0.2087	0.2414	0.0364	0.1763	0.1534	0.1631	0.1965	0.1981	0.2415	0.2373	0.2381	0.2537	0.2977	0.0456
Machinery and equipment, n.e.c.	0.1572	0.1532	0.2139	0.2053	0.2096	0.2580	0.2736	0.2763	0.2877	0.3127	0.0550	0.1644	0.1724	0.1914	0.2113	0.2208	0.2695	0.2812	0.2923	0.3037	0.3430	0.0611
Office, accounting, and computing machinery	0.2247	0.1578	0.2749	0.1553	0.0799	0.4370	0.4849	0.5032	0.4655	0.4069	0.1582	0.2471	0.2131	0.3430	0.3913	0.3738	0.6818	0.6511	0.7143	0.6963	0.6791	0.2030
Electrical machinery and apparaturs, n.e.c.	0.1242	0.1204	0.1500	0.1906	0.2065	0.2065	0.2187	0.2343	0.2511	0.2814	0.0532	0.1527	0.1515	0.1847	0.2183	0.2293	0.2696	0.3044	0.3167	0.3168	0.3706	0.0758
Radio, television, and communication equipment	0.1897	0.2011	0.2403	0.0807	0.1240	0.4120	0.4917	0.5007	0.4276	0.4407	0.1595	0.1672	0.1610	0.2101	0.1834	0.3187	0.5032	0.5141	0.5591	0.5842	0.6480	0.1952
Medical, precision, and optical instruments	0.1305	0.1382	0.1561	0.1936	0.1989	0.2672	0.3039	0.2955	0.2772	0.3101	0.0713	0.1628	0.1622	0.2112	0.2198	0.2591	0.3389	0.3644	0.3761	0.3895	0.4382	0.1010
Motor vehicles, trailers, and semi-trailers	0.1553	0.1380	0.1512	0.1590	0.1919	0.2274	0.2322	0.2272	0.3083	0.3387	0.0681	0.1183	0.1407	0.1736	0.1921	0.2305	0.2776	0.2943	0.3030	0.3211	0.3546	0.0813
Other transport equipment	0.1463	0.2040	0.1799	0.1648	0.3691	0.3902	0.3821	0.3576	0.3744	0.4032	0.1078	0.1420	0.1996	0.2379	0.2786	0.3765	0.4962	0.5784	0.5920	0.5635	0.5824	0.1783
Manufacturing n.e.c.	0.1829	0.2027	0.2427	0.2956	0.2936	0.3116	0.3778	0.3846	0.3446	0.3636	0.0714	0.1916	0.1883	0.2237	0.2510	0.2663	0.3002	0.2893	0.3031	0.3012	0.3224	0.0484
Recycling	0.0104	0.0146	0.0348	0.0445	0.0415	0.0329	0.0419	0.0442	0.0510	0.0713	0.0174	0.0275	0.0258	0.0400	0.0373	0.0374	0.0686	0.0772	0.0722	0.0721	0.0897	0.0234
Electricity, steam, and hot water supply	0.0955	0.0674	0.0677	0.0734	0.0780	0.1004	0.1890	0.2420	0.4128	0.4571	0.1473	0.0715	0.0708	0.0832	0.0931	0.0953	0.1134	0.1283	0.1260	0.1421	0.1607	0.0306
Gas and gas supply	0.0136	0.0216	0.0231	0.0314	0.0448	0.0433	0.0526	0.0498	0.0531	0.0564	0.0153	0.0266	0.0216	0.0303	0.0341	0.0496	0.0804	0.0915	0.0950	0.0997	0.1285	0.0377
Collection, purification, and distribution of water	0.0540	0.0648	0.0685	0.0971	0.1025	0.0971	0.1139	0.1097	0.1028	0.1147	0.0219	0.0724	0.0742	0.0828	0.1081	0.1157	0.1261	0.1269	0.1314	0.1288	0.1532	0.0272
Construction site and civil engineering	0.0881	0.0704	0.0745	0.0750	0.0890	0.1105	0.1149	0.1042	0.0969	0.0978	0.0155	0.1405	0.1357	0.1476	0.1345	0.1455	0.1441	0.1217	0.1205	0.1278	0.1258	0.0100
Construction installation & other construction	0.1420	0.1501	0.1676	0.1898	0.1773	0.2026	0.2312	0.2211	0.2016	0.1991	0.0290	0.1877	0.1899	0.2070	0.2281	0.2260	0.2494	0.2404	0.2449	0.2503	0.2523	0.0247
Cross-sectoral Std. Dev.	0.1019	0.1036	0.1316	0.1221	0.1055	0.1315	0.1448	0.1460	0.1358	0.1508		0.1211	0.1131	0.1402	0.1366	0.1280	0.1669	0.1667	0.1754	0.1672	0.1791	

Source: Own illustration. Data: FSO, revised input-output tables (1995–2004).

Appendix E: Correlation per Sector

Sector	ln*POS* with ln*HPS*	ln*POM* with ln*HPM*
1	0.9316	0.6367
2	0.7974	0.1888
3	0.9743	0.4938
4	0.8660	-0.6270
5	0.3774	-0.2668
6	0.7975	0.5548
7	0.8414	-0.3938
8	0.9555	-0.3943
9	0.9109	0.0625
10	0.8534	0.4093
11	0.9142	0.4707
12	0.9732	0.8299
13	0.8915	0.7139
14	0.8856	0.1969
15	0.8932	0.8416
16	0.9300	0.5367
17	0.8412	-0.2155
18	-0.0699	-0.6444
19	0.8826	0.4941
20	0.9802	0.7943
21	0.9711	-0.1708
22	0.9172	0.9690
23	0.9472	0.7441
24	0.9176	0.6081
25	0.9533	0.9161
26	0.9825	0.6371
27	0.9674	0.9607
28	0.9834	0.9814
29	0.9736	0.7621
30	0.9536	-0.4605
31	0.9789	0.9954
32	0.9203	0.7762
33	0.9869	0.9488
34	0.8916	-0.4489
35	0.5789	0.7683
36	0.8838	-0.9230
overall	0.8933	-0.0145

Appendix F: Sectoral *HPS* and *HPM* Measures

	HPSit										Std. Dev. over *t*	*HPMit*										Std. Dev. over *t*
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**		**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	
Food products	0.1453	0.1506	0.1523	0.1608	0.1755	0.1800	0.2023	0.2124	0.2154	0.2165	0.0286	0.4683	0.5322	0.6354	0.4693	0.4377	0.4680	0.5012	0.4993	0.5431	0.5475	0.0570
Beverages	0.3512	0.3712	0.3478	0.3584	0.3900	0.3878	0.3844	0.3947	0.3791	0.3580	0.0173	0.4940	0.4578	0.4708	0.3669	0.3491	0.4217	0.4255	0.4160	0.4576	0.4359	0.0449
Tobacco products	0.4017	0.1554	0.3882	0.4228	0.2349	0.4992	0.4992	0.4984	0.4550	0.4926	0.1195	0.3789	0.3136	0.2710	0.2101	0.4424	0.2411	0.2628	0.2667	0.2249	0.2450	0.0732
Textiles	0.0728	0.0705	0.0702	0.0769	0.0779	0.0777	0.0810	0.0912	0.0819	0.0844	0.0065	0.6177	0.6605	0.6824	0.5484	0.5259	0.4503	0.4566	0.4591	0.4572	0.4424	0.0931
Wearing apparel, dressing, and dying of fur	0.0602	0.0616	0.0615	0.0568	0.0605	0.0546	0.0600	0.0665	0.0542	0.0595	0.0036	0.3897	0.2682	0.2782	0.2250	0.2698	0.3002	0.2890	0.2914	0.2648	0.2746	0.0421
Leather, leather products, and footwear	0.0398	0.0402	0.0461	0.0402	0.0402	0.0406	0.0477	0.0478	0.0401	0.0427	0.0033	0.2574	0.2141	0.1875	0.2198	0.2453	0.2672	0.3203	0.3175	0.2533	0.2900	0.0435
Wood and products of wood and cork	0.1051	0.0993	0.0979	0.1008	0.1175	0.1185	0.1127	0.1108	0.1072	0.1091	0.0072	0.7464	0.6791	0.7560	0.6328	0.6648	0.6588	0.6526	0.6595	0.6011	0.6434	0.0480
Pulp and paper	0.0640	0.0600	0.0647	0.0715	0.0803	0.0922	0.0863	0.0917	0.0918	0.0944	0.0135	0.5230	0.5820	0.7762	0.3977	0.4825	0.4558	0.4526	0.4464	0.4714	0.4816	0.1065
Paper products	0.0788	0.0771	0.0802	0.0826	0.0880	0.0930	0.0954	0.1014	0.1032	0.1083	0.0111	0.6216	0.6300	0.7964	0.5352	0.5625	0.6278	0.6423	0.6220	0.6007	0.6190	0.0686
Publishing	0.3922	0.4220	0.4042	0.4666	0.4900	0.4659	0.4635	0.4783	0.4920	0.5153	0.0402	0.3499	0.3516	0.4092	0.3673	0.4383	0.4579	0.4324	0.4181	0.3616	0.3460	0.0423
Printing	0.1271	0.1328	0.1272	0.1413	0.1521	0.1484	0.1566	0.1735	0.1649	0.1691	0.0170	0.5407	0.5009	0.5105	0.4573	0.4992	0.5304	0.5547	0.5520	0.4906	0.5010	0.0306
Coke, refined petroleum products, and nuclear fuel	0.3892	0.3877	0.3622	0.2839	0.3296	0.1969	0.1814	0.2345	0.3102	0.3128	0.0745	0.6908	0.5966	0.5236	0.2464	0.4505	0.7236	0.5670	0.5273	0.8808	1.1540	0.2485
Pharmaceuticals	0.1299	0.1378	0.1458	0.1993	0.2023	0.2021	0.1864	0.1950	0.2697	0.2597	0.0470	0.2981	0.3124	0.4616	0.2221	0.1995	0.3894	0.5055	0.4458	0.2944	0.4941	0.1119
Chemicals exluding pharmaceuticals	0.0993	0.1014	0.1017	0.1081	0.1216	0.1254	0.1212	0.1276	0.1321	0.1423	0.0147	0.4393	0.7112	0.9651	0.5409	0.5297	0.5610	0.5729	0.5928	0.6066	0.6332	0.1418
Rubber products	0.1131	0.1129	0.1209	0.1387	0.1462	0.1595	0.1518	0.1439	0.1605	0.1668	0.0198	0.4133	0.3802	0.4317	0.4080	0.3989	0.4965	0.4898	0.4905	0.4715	0.4783	0.0440
Plastic products	0.1169	0.1241	0.1325	0.1430	0.1612	0.1614	0.1600	0.1682	0.1631	0.1752	0.0200	0.4795	0.4425	0.4995	0.4337	0.4277	0.4937	0.4720	0.4955	0.4918	0.5478	0.0363
Glass and glass products	0.2049	0.1953	0.1974	0.2037	0.2227	0.2320	0.2295	0.2341	0.2416	0.2490	0.0193	0.4367	0.4471	0.5062	0.4184	0.4083	0.4582	0.4446	0.4487	0.3915	0.3982	0.0338
Ceramic goods & other non-metallic mineral products	0.2616	0.2581	0.2484	0.2515	0.2796	0.2588	0.2390	0.2454	0.2415	0.2430	0.0122	0.6800	0.6343	0.6075	0.5442	0.5586	0.5660	0.5266	0.5258	0.4892	0.5180	0.0589
Iron and steel	0.0377	0.0386	0.0404	0.0460	0.0435	0.0461	0.0484	0.0460	0.0517	0.0585	0.0063	0.8068	1.0116	1.3028	0.8240	0.6289	0.7738	0.7859	0.8045	0.7937	0.9882	0.1862
Non-ferrous metals	0.0399	0.0415	0.0449	0.0532	0.0576	0.0667	0.0660	0.0681	0.0658	0.0707	0.0118	0.2854	0.3552	0.4604	0.3181	0.3834	0.4616	0.4500	0.4131	0.4234	0.4778	0.0656
Metal castings	0.0688	0.0664	0.0748	0.0901	0.0941	0.0997	0.0962	0.1037	0.1138	0.1309	0.0202	0.4456	0.6811	1.0178	0.5712	0.5485	0.5419	0.5344	0.4961	0.4807	0.5158	0.1652
Fabricated metal products, excl. machinery & equip.	0.0923	0.0984	0.0931	0.1065	0.1156	0.1153	0.1188	0.1225	0.1301	0.1326	0.0145	0.5358	0.5285	0.5230	0.5531	0.5529	0.5771	0.5824	0.5802	0.6006	0.6474	0.0378
Machinery and equipment, n.e.c.	0.1036	0.1166	0.1130	0.1304	0.1403	0.1444	0.1576	0.1668	0.1804	0.1856	0.0285	0.4697	0.4922	0.4534	0.4712	0.4646	0.4789	0.5035	0.4927	0.5249	0.5589	0.0317
Office, accounting, and computing machinery	0.1398	0.1300	0.1366	0.1580	0.1417	0.2074	0.2075	0.1927	0.1832	0.1588	0.0298	0.0883	0.1125	0.1228	0.2828	0.3262	0.2798	0.2343	0.2323	0.1937	0.1726	0.0803
Electrical machinery and apparaturs, n.e.c.	0.1016	0.1116	0.1119	0.1316	0.1391	0.1254	0.1630	0.1800	0.1876	0.1973	0.0346	0.4264	0.4279	0.4695	0.4987	0.5117	0.5030	0.5677	0.5301	0.5005	0.5631	0.0485
Radio, television, and communication equipment	0.1201	0.1298	0.1330	0.1328	0.1770	0.2119	0.2318	0.2390	0.2456	0.2317	0.0521	0.1384	0.1141	0.1287	0.2295	0.3654	0.2809	0.2238	0.2059	0.2389	0.2550	0.0767
Medical, precision, and optical instruments	0.1296	0.1398	0.1447	0.1737	0.1893	0.2048	0.2125	0.2295	0.2416	0.2285	0.0407	0.3116	0.2954	0.3513	0.3110	0.3557	0.3999	0.4133	0.4036	0.4501	0.4484	0.0571
Motor vehicles, trailers, and semi-trailers	0.0447	0.0585	0.0566	0.0734	0.0915	0.1003	0.0989	0.0969	0.0857	0.0920	0.0202	0.2604	0.3612	0.4347	0.4511	0.5183	0.6017	0.6409	0.6484	0.6323	0.6898	0.1429
Other transport equipment	0.0869	0.1118	0.1054	0.1179	0.1231	0.1361	0.1557	0.1581	0.1574	0.1521	0.0252	0.2692	0.3414	0.3733	0.3919	0.2857	0.3711	0.4346	0.4544	0.4914	0.4626	0.0746
Manufacturing n.e.c.	0.1143	0.1177	0.1158	0.1276	0.1385	0.1410	0.1424	0.1411	0.1355	0.1406	0.0115	0.4112	0.3664	0.3858	0.3660	0.3914	0.3976	0.3779	0.3681	0.3214	0.3428	0.0264
Recycling	0.0901	0.0913	0.1205	0.1276	0.1118	0.1867	0.2048	0.2136	0.2131	0.2558	0.0597	0.2083	0.2048	0.3271	0.3049	0.2718	0.5963	0.6238	0.6322	0.5702	0.7330	0.2016
Electricity, steam, and hot water supply	0.2250	0.2436	0.2415	0.2837	0.3021	0.2676	0.2939	0.2630	0.2446	0.2522	0.0251	0.3275	0.3462	0.3580	0.4931	0.4994	0.4286	0.4448	0.4375	0.4628	0.5655	0.0751
Gas and gas supply	0.1866	0.1702	0.1973	0.2259	0.3303	0.3976	0.4083	0.4022	0.4153	0.4566	0.1118	0.3311	0.2990	0.3711	0.3186	0.3610	0.4411	0.4313	0.4388	0.4275	0.4793	0.0616
Collection, purification, and distribution of water	0.1923	0.2011	0.1911	0.2403	0.2679	0.2427	0.2286	0.2287	0.2197	0.2444	0.0250	0.7198	0.7532	0.7351	0.8189	0.8288	0.6846	0.6137	0.6166	0.6127	0.6889	0.0796
Construction site and civil engineering	0.2232	0.2369	0.2373	0.2362	0.2656	0.2643	0.2278	0.2222	0.2271	0.2152	0.0170	0.9358	0.9159	0.8871	0.7365	0.8037	0.6912	0.6036	0.6163	0.6167	0.5801	0.1383
Construction installation & other construction	0.0994	0.1119	0.1070	0.1216	0.1248	0.1254	0.1243	0.1327	0.1305	0.1338	0.0114	0.6372	0.6313	0.6252	0.6097	0.6009	0.5698	0.5539	0.5511	0.5493	0.5416	0.0377
Cross-sectoral Std. Dev.	0.1012	0.0943	0.0973	0.1017	0.1030	0.1112	0.1103	0.1101	0.1109	0.1156		0.1900	0.2073	0.2525	0.1615	0.1409	0.1318	0.1246	0.1276	0.1503	0.1908	

Source: Own illustration. Data: FSO, revised input-output tables (1995–2004).

Appendix G: Correlation Matrix (without Outliers)

	lnY_t	lnY_{t-1}	lnw_t	lnw_t	lnDOS_t	lnDOS_{t-1}	lnPOS_t	lnPOS_{t-1}	$lnDOM_t$	lnDOM_{t-1}	lnPOM_t	lnPOM_{t-1}	lnHPS_t	lnHPS_{t-1}	lnHPM_t	lnHPM_{t-1}
lnY_t	1.0000															
lnY_{t-1}	0.9954	1.0000														
lnw_t	0.1384	0.1273	1.0000													
lnw_{t-1}	0.1376	0.1266	0.9730	1.0000												
lnDOS_t	-0.1061	-0.1076	0.3451	0.3467	1.0000											
lnDOS_{t-1}	-0.0989	-0.0931	0.3468	0.3487	0.9022	1.0000										
lnPOS_t	-0.1290	-0.1248	0.1880	0.1873	0.7107	0.6914	1.0000									
lnPOS_{t-1}	-0.1218	-0.1091	0.1917	0.1885	0.7012	0.7008	0.9681	1.0000								
lnDOM_t	0.1528	0.1444	0.1527	0.1477	-0.1105	-0.1195	-0.3175	-0.2813	1.0000							
lnDOM_{t-1}	0.1321	0.1389	0.1391	0.1312	-0.1526	-0.1286	-0.3393	-0.2856	0.9356	1.0000						
lnPOM_t	0.0944	0.0805	0.1146	0.1046	-0.2068	-0.2092	-0.4373	-0.4053	0.8895	0.8670	1.0000					
lnPOM_{t-1}	0.0953	0.0929	0.0968	0.0788	-0.2270	-0.2196	-0.4556	-0.4062	0.8752	0.8935	0.9752	1.0000				
lnHPS_t	-0.1277	-0.1171	0.0596	0.0624	0.5926	0.5976	0.9335	0.9107	-0.4540	-0.4623	-0.5918	-0.5959	1.0000			
lnHPS_{t-1}	-0.1245	-0.1087	0.0618	0.0634	0.5851	0.5858	0.9061	0.9316	-0.4344	-0.4308	-0.5717	-0.5678	0.9742	1.0000		
lnHPM_t	0.3065	0.3011	-0.1663	-0.1350	-0.2953	-0.2704	-0.3135	-0.2959	-0.1674	-0.1926	-0.0441	-0.0597	-0.1964	-0.1887	1.0000	
lnHPM_{t-1}	0.2916	0.2988	-0.1913	-0.1773	-0.2854	-0.2607	-0.2806	-0.2542	-0.1237	-0.1705	-0.0561	-0.0083	-0.1599	-0.1499	0.8754	1.0000

Appendix H: Summary Statistics

Variable	Obs	Mean	Std Dev	Min	Max
lnL_t	360	4.95857	1.193256	2.079442	7.375882
lnY_t	360	10.09768	1.057592	7.352441	12.43005
lnY_{t-1}	324	10.08927	1.05493	7.352441	12.37422
lnw_t	360	3.684319	0.3741977	2.885917	4.724108
lnw_{t-1}	324	3.677526	0.3706786	2.919391	4.724108
lnDOS_t	347	-5.451265	1.188521	-9.113486	-1.56484
lnDOS_{t-1}	312	-5.495673	1.196417	-9.113486	-1.56484
lnDOM_t	360	-1.739417	0.7123115	-4.569239	-0.401197
lnDOM_{t-1}	324	-1.777272	0.708497	-4.569239	-0.4675112
lnPOS_t	360	-4.923661	0.7191872	-6.545177	-2.792723
lnPOS_{t-1}	324	-4.942728	0.7196687	-6.545177	-2.792723
lnPOM_t	360	-1.545565	0.6845935	-3.832979	-0.3364642
lnPOM_{t-1}	324	-1.580076	0.6828826	-3.832979	-.3364642
ln$(IM/Y)_t$	330	-1.291672	1.220144	-4.816542	0.9946187
ln$(IM/Y)_{t-1}$	297	-1.307515	1.223805	-4.814771	0.9946187

Appendix I: Data

The empirical analysis covers 10 observations over time for 36 manufacturing industries, which leads to a total number of 360 observations per variable. Input-output data at current prices are used to calculate *offshoring intensities DOS*, *DOM*, *POS* and *POM*, as well as domestic outsourcing intensities *HPS* and *HPM*. German input-output tables are disaggregated to 71 sectors following the three-digit and, for some sectors, the four-digit NACE Rev. 1.1 classification (German Federal Statistical Office: revised input-output tables 1995 to 2004 in current prices; Fachserie 18 Reihe 2). *Gross output data Y* is retrieved from the input-output tables. We calculated real output using sectoral producer price indices from the German Federal Statistical Office.[209] *Labor demand* is mapped using sectoral employment data from the input-output tables. The number of employees is preferred to the number of total employment. The latter considers all persons that are engaged in domestic production of a country, whereas the former excludes self-employed an unpaid family workers and better reflects the workforce of companies that is exposed to layoffs due to offshoring.

Sector-specific labor compensation of employees is used as a measure for disaggregated *wages w* and is retrieved from the OECD STAN Industrial Database based on Federal Statistical Office data. Labor compensation consists of annual wages and salaries of employees at a sectoral level paid by producers as well as supplements such as contributions to social security, private pensions, health insurance, life insurance and similar schemes. Labor compensation instead of gross wages and salaries is chosen, since labor demand is rather driven by a firm's entire labor costs. Some sectors only have wage data available at a more aggregated level. Therefore, disaggregation is acquired weighting the wage data by its sectoral output share.[210] The data is divided by the respective sectoral employment to calculate average annual labor compensation per employee. As labor demand depends on *real wages*, an appropriate price index is needed. Therefore, sectoral producer price indices from the Federal Statistical Office are used, since producer prices rather than consumer prices matter.

[209] Producer price indices are available at several aggregation levels (28, 107, and 225 sectors). Since some producer prices at the required input-output aggregation level were not available, we used producer prices of more disaggregated sectors (within the same industry) as a proxy, because similar price trends can be expected there. This procedure was also done in cases where years were missing.

[210] Wage data, for example, are only available for the aggregated sector Food products and beverages. The wages of the aggregated sector are weighted with the respective output shares of the single sectors Food products and Beverages in order to achieve more disaggregated sectoral wages. This procedure was done eight times in the following sectors: 1–2; 8–9; 10–11; 15–16; 17–18; 19–21; 32–33, and 35–36.

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