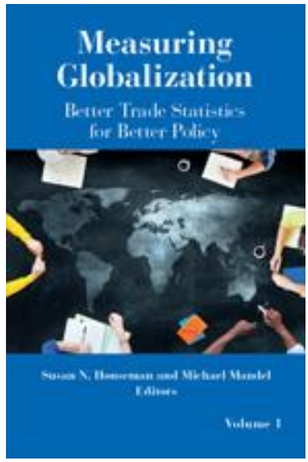
Upjohn Institute Press

Sourcing Substitution and Related Price Index Biases



Alice O. Nakamura
University of Alberta

W. Erwin Diewert
University of British Columbia

John S. Greenlees
Formerly of the Bureau of Labor Statistics

Leonard I. Nakamura
Federal Reserve Bank of Philadelphia

Marshall B. Reinsdorf
International Monetary Fund

Chapter 2 (pp. 21-88) in:
Measuring Globalization: Better Trade Statistics for Better Policy, Volume 1, Biases to Price, Output, and Productivity Statistics from Trade
Susan N. Houseman and Michael Mandel, eds.
Kalamazoo, MI: W.E. Upjohn Institute for Employment Research, 2015
DOI: 10.17848/9780880994903.vol1ch2

2
Sourcing Substitution and Related Price Index Biases

Alice O. Nakamura
University of Alberta

W. Erwin Diewert
University of British Columbia and University of New South Wales

John S. Greenlees
formerly of the Bureau of Labor Statistics

Leonard I. Nakamura
Federal Reserve Bank of Philadelphia

Marshall B. Reinsdorf
International Monetary Fund

Price indexes are fundamentally important for understanding what is happening to national economies. Unfortunately, for reasons we will explain, price-index bias problems seem likely to have grown with the evolution of information technologies and accompanying changes in business price setting and product-variant development practices, as well as with the growth in the amount and timeliness of price information available to potential buyers. We argue, however, that specific changes to statistical agency practices and data-handling capabilities can greatly reduce the bias problems we focus on.

We recommend hybrid alternatives to the conventional price indexes. Our hybrid indexes use unit values to combine price information for transactions that take place at different prices for homogenous product items. The hybrid indexes reduce to the conventional price indexes when there is truly just one price per product each time period. This recommendation is in line with the advice provided in several international price index manuals such as ILO et al. (2004a,b, 2009). For example, in the manual for the Producer Price Index (PPI) it is stated that "having specified the [product] to be priced . . . , data should be collected on both the value of the total sales in a particular month and the total quantities sold in order to derive a unit value to be used as the price . . ." (ILO et al. 2004a, p. 22).

Some of the prices used in a typical U.S. Bureau of Labor Statistics PPI are calculated now in this way. Yet, as a rule, the conventional statistics agency practice does not measure prices as unit values.[1] The conventional practice of national statistics agencies is to collect the price of a precisely defined product at a particular establishment and designated point in time, with this collection process being designed to yield a unique price each period for the given product-establishment combination. (See, for example, BLS [2007a,b,c,d].)

Throughout the chapter, a short list of terms is used in distinct ways that are important to bear in mind: product unit (or "product" for short), product unit item (or "product item," or simply "item"), product content, index basket product unit (or simply "index basket product"), the unit value (or, equivalently, the "unit value price," or "unit price"), and the product content unit value. Our usage of, and need for, these terms are most easily conveyed in a specific context. We will use the example of Campbell's tomato soup, which is most often sold in a 10.75-ounce can, but it is also available in a variety of other can sizes, including a 15.2-ounce can.

We define a product by the brand and the company that owns the brand, or at any rate that is responsible for the product (if, say, it is not marketed under a brand name), and by the precise nature of the product content as well as by the specific sort and size of packaging the product is sold in. A commercial product is assigned a Universal Product Code (UPC) by the company responsible for the product. The rules for how UPCs are to be assigned are maintained by (and conformity with them is monitored by) an international governing body (as we explain subsequently), to which a company must belong in order to be able to assign UPCs to the company's products.

Products of different companies have different UPCs. The rules for assigning UPCs also dictate that if either the content or the nature or size of the packaging format differs for products produced by a company, then separate UPCs must be assigned. The way in which we use the term "product unit" or "product" is consistent with how commercial products are defined for UPC assignment. Hence a 10.75-ounce can of Campbell's tomato soup, which is the most common can size, is a separate product from a 15.2-ounce can of Campbell's tomato soup.

Each can of the 10.75-ounce size for Campbell's tomato soup is referred to as a "product item" or simply an "item." No matter how short the time period, different items of a product may sometimes be sold by different merchants or even the same merchant at different prices. For example, the same grocery outlet on the same day could sell 10.75-ounce cans of Campbell's soup at different prices because a promotional sale began partway through the day, or because some cans had stickers on them for a lower price owing to an earlier promotional sale, or because of arrangements such as discounts for customers who have coupons. The average of the prices for which items of a product are transacted in a stated time period and market area is the unit value (or unit price).

The product content is what is inside a can of Campbell's tomato soup, and that content is the same whether it is a 10.75-ounce can or a 15.2-ounce can. In many jurisdictions in the United States, a grocer is required by law to display for each product not only the per-item price for the product, but also the price being charged for a stated unit of quantity of the product content, such as a fluid ounce. The latter sort of standardized prices are sometimes referred to as "unit value prices," but they do not result from any sort of averaging of the realized prices in different transactions, and this is not what we mean (nor what is meant in the index number literature) by the term "unit price" or "unit value."

Price indexes are defined for baskets of products. The basket for, say, the U.S. Consumer Price Index (CPI) consists of product categories. At each retail outlet selected for price collection for the CPI program, when price collection is initiated there, the price collector chooses, based on outlet information about product sales at that outlet, a specific product unit for each CPI product category for which prices are to be collected there. Each selected product then becomes an index basket product for which a price collector attempts to collect a price each pricing period.

Suppose now that a 10.75-ounce can of Campbell's tomato soup has been selected as an index basket product to be priced, period after period, at a specific establishment. And suppose that the establishment subsequently ceases to sell the 10.75-ounce cans and switches to instead selling the 15.2-ounce can format for Campbell's tomato soup. In this situation, the decision could be made to "quality-adjust" the price for the 15.2-ounce can so that the observed price for that product item could be used as a proxy for the missing price for the 10.75-ounce Campbell's tomato soup index basket product. The simplest such adjustment would be to compute the per-ounce price for the soup sold in the 15.2-ounce can and then to multiply that times 10.75, with the resulting value being used as a proxy price for Campbell's tomato soup in a 10.75-ounce can.[2]

The chapter's second section, titled "Background Material," introduces the issues. Section Three, "Basic, Hybrid, and Conventional Versions of Laspeyres, Paasche, and Fisher Price Indexes," provides notation and definitions used in the rest of the chapter. The Laspeyres, Paasche, and Fisher price index formulas are introduced in the basic forms in which these are usually presented in textbooks and in the economics, accounting, and price-index scholarly literatures. Next we develop hybrid price-index formulas that explicitly allow for possible price differences in a given time period for homogeneous units of each product. We proceed to develop grouped transaction variants of the conventional and hybrid price index formulas that allow us to conveniently represent various bias problems for the conventional indexes.

In the fourth section, "Different Sorts of Price Index Selection Bias," we use our bias formula for a Laspeyres-type price index to characterize certain ways in which bias can arise. The biases discussed include the recognized problem of Consumer Price Index (CPI) outlet substitution bias,[3] the CPI promotions bias defined in this chapter, and what Diewert and Nakamura (2010) define as "sourcing substitution bias" in the PPI and Import Price Index (MPI).[4] We deal briefly as well with sourcing substitution bias in the proposed new Input Price Index (IPI).

The U.S. Bureau of Labor Statistics (BLS) produces the price indexes we focus on in this chapter. The BLS largely abandoned the use of unit values in price index compilation because of advice from experts, including the 1961 report of the Stigler Committee (Price Statistics Review Committee 1961), and research by its own staff (exemplified by Alterman [1991]).[5] In the fifth section, "Five Sorts of Barriers to Adoption of Unit Values for Official Statistics Purposes," we examine the problems with unit values that are highlighted in the Stigler

Committee report and also by Alterman (1991). We explain why the main basis of condemnation in those historical reports does not pertain to our present unit-value recommendation.

Nevertheless, there are formidable practical challenges to implementing unit values as we recommend. Producers give their products identifying names and Universal Product Codes (UPCs). UPCs have come to play ubiquitous roles in business information systems for managing all aspects of the handling of products and their associated cost and sales financial flows. Once a 10.75-ounce can of Campbell's tomato soup is shipped out from the production facility carrying the UPC that Campbell's has assigned to that product, then that UPC stays with that soup can wherever it goes.

However, along the way from the original producer to the final purchaser, a unit of a product can take on auxiliary attributes that may matter to the final purchaser, or to the final user, or both, and that may be associated with price differences. For example, some of the cans of tomato soup may be shipped by the producer to convenience stores, and some may be shipped to superstores.[6]

Separate UPCs are sometimes defined for products that most users might regard as differing only in ways that make no difference to them. This issue can arise, for example, with products that differ in ways that are necessary for avoidance of a patent infringement ruling but that are intentionally the same in terms of all attributes of concern to most users. Or a producer might bring out a slightly reformulated product with a different UPC and with a price that yields a higher profit margin.[7] When a producer brings out a new product and discontinues an older one, if the product change is trivial, a statistics agency may decide that the reformulated version of the product should be treated as a continuation of the original version so that the price increase can be captured. We discuss operational issues that arise in situations like these in the subsections below that deal with what we refer to as "Impediment 3" and "Impediment 4" (see also Reinsdorf [1999]).

How, then, can we best measure price change over time when units of precisely defined and interchangeable product items are sold at different prices in the same time period and market area? And when is it best to treat highly similar but commercially distinguishable products as separate products for inflation measurement purposes? Consideration of these questions requires an understanding of the role of measures of inflation in the compilation of other key economic performance measures for nations: the topic of Section Six, titled "Inflation Measurement Effects on Other Economic Performance Measures." Finally, in the seventh section, "Possible Price Measurement Practice Reforms," we suggest possible changes to conventional price-index-making practices.

Two brief appendices provide additional materials that some readers may find helpful. In Appendix 2A, we show with a numerical example that the featured bias problem in the example cannot be fixed simply by adopting a superlative price index formula like the Fisher.[8] Appendix 2B demonstrates why, ideally, the same product definitions should be used both for price quote collection and for the collection of the data needed to compute value-share weights.

This chapter is written with three different groups of readers in mind. One group consists of those who view the averaging of observable prices for different items of the same product to form unit values as an inferior practice. We hope to persuade these readers that for a wide class of price index uses, including the deflation of gross domestic product (GDP) components, it is important that the price quotes utilized be representative of the prices for the transactions that make up the associated value aggregates.

A second group we hope will benefit from this chapter are those who were already convinced by what early contributors to the price index literature—Walsh (1901, p. 96; 1921, p. 88), Davies (1924, p. 183; 1932, p. 59), and Fisher (1922, p. 318) in particular—wrote long ago on the use of unit values in price indexes. These are experts who hold the view that there is no need to elaborate on the issues we deal with in this chapter. We hope to persuade these readers that there is considerable value in having a more explicit exposition of these issues. We hope too that these readers will turn their research efforts toward helping to develop feasible implementation strategies for the sort of approach that we recommend.

A third group of readers that we hope to engage with this chapter are those not previously acquainted with some of the price index bias problems that we focus on, including the sourcing substitution bias problems defined by Diewert and Nakamura (2010) and for which Houseman et al. (2011) provide the first empirical results. We hope to provide these readers with a readily understandable exposition of these biases. We feel it is crucial for economists at large to understand how these inflation measurement distortions arise and why they have likely become more serious in recent years.

BACKGROUND MATERIAL

In this chapter, we focus mostly on three main price indexes produced by the BLS: the Consumer Price Index (CPI), the Producer Price Index (PPI), and the Import Price Index (MPI). We focus on one aspect of conventional official statistics price-index-making and abstract from many other important issues in the process. It should also be noted that although our discussion will focus on the handling of prices for physical products with associated UPC codes, the major price indexes include services as well as goods categories.

Knowing some specifics of how price indexes are produced is helpful for considering price index bias problems. The official price indexes used to measure inflation first aggregate price relatives into elementary indexes for narrow categories of products, such as men's suits or crude petroleum. They then aggregate the elementary indexes, in most cases employing a Laspeyres or similar formula.[9] Price relatives are ratios of current to previous period prices for specific products sold by specific establishments. The aggregation formula for an elementary price index typically includes weights for the price relatives that reflect shares of the total value of the transactions (and may also take sample selection probabilities into account). Similarly, weights that reflect shares of total expenditure for the products covered by each of the elementary indexes are used to aggregate the elementary indexes in order to arrive at higher-level and overall inflation measures like the "All Items CPI" or the "PPI for Final Demand."

The CPI is intended to measure the inflation experience of households, so the value share weights used for the CPI are based on household survey information. However, the product units included in the CPI basket are priced at selected retail outlets because it is operationally easier to collect prices from businesses.

The PPI primarily measures changes in prices received by domestic businesses in selling their products to other domestic or foreign businesses. Selected products are regularly priced at selected establishments of domestic producers. The PPI value-share weights are based on what domestic businesses report as their sales revenues by product.

The BLS produces the MPI as part of its International Price Program. The MPI is intended to be a measure of the inflation experience of domestic purchasers of imported products. Products are priced at selected U.S. importer establishments, and the value-share weights are based on U.S. survey and customs data for all imports.

We find it useful to differentiate what we call primary product and auxiliary product attributes. We define "primary product attributes" (or simply "primary attributes") as characteristics of an item of the product when first sold by the original producer that continue to be characteristics of the product item regardless of where and how it may be resold on its way to the final purchaser. We define "product item attributes" as "auxiliary attributes" if an item acquires these attributes as a consequence of how it is cared for on its way to the merchant that makes the final sale or because of where or how it is sold. For example, being sold during a promotional sale is a potentially relevant auxiliary attribute of a product item in studies of price evolution and consumer behavior. As Hausman and Leibtag (2007, 2009) note, markets typically offer consumers product items that are sold by different merchants and have differing amenities, with those amenities being one sort of auxiliary product item attribute. For the issues we focus on in this chapter, it is useful to differentiate auxiliary product item attributes from primary product attributes that all items of a product have and that stay with those product items wherever and however they are sold.[10]

BASIC, HYBRID, AND CONVENTIONAL VERSIONS OF LASPEYRES, PAASCHE, AND FISHER PRICE INDEXES

We begin in this section with basic formulas for the Laspeyres, Paasche, and Fisher price indexes. These are the usual definitions given in economics and accounting textbooks and in the relevant scholarly literatures, although it is important to note that the U.S. CPI now relies on a weighted geometric mean formula to compute elementary indexes for physical commodities. We next take up the case of multiple transactions per product. The hybrid price indexes we develop for the multiple transactions case are what we recommend be used: that is, these are what we subsequently specify to be the target indexes.

We next show how our hybrid indexes that can accommodate the multiple transactions case can be rewritten to allow for grouping the transactions in each period. We then use the grouped-transaction representations of our hybrid price index formulas to relate what we label as conventional formulas (which embody a key feature of current statistical agency practice) to our target hybrid indexes. Once we can explicitly relate the conventional formulas to our target indexes, we show that formulas for various biases of the conventional indexes are easily derived.

Basic versus Hybrid Price Indexes

We denote by $n = 1,\ldots, N$ the products in the index basket for a price index. The time period is denoted by t. All the price indexes considered involve two time periods (e.g., two months for a monthly index), denoted as $t = 0$ and $t = 1$. Each of the J_n^t transactions for product n in period t ($j = 1,\ldots, J_n^t$) involves a seller k and a purchaser k'. Hence, for transaction j in time period t for product n, $q_{n,k,k'}^{t,j}$ is the quantity of the product bought by purchaser k' from seller k. This quantity is given in terms of the same units of measure used in reporting the price per unit of the product, and that price is denoted by $p_{n,k,k'}^{t,j}$.

In each segment of the chapter, we simplify the superscript and subscript notation by showing just the superscripts and subscripts needed there. Hence, in the rest of this section, just the superscript t and the subscript n are used. The total nominal revenue received or remittance paid for product n in period t ($t = 0,1$) is thus denoted here by R_n^t, and the total received or paid for all N products is

$$(2.1) \quad R^t = \sum_{n=1}^{N} R_n^t = \sum_{n=1}^{N} p_n^t q_n^t .$$

The basic Laspeyres price index (P_L) is given by[11]

$$(2.2) \quad P_L^{0,1} = \frac{\sum_{n=1}^{N} p_n^1 q_n^0}{\sum_{n=1}^{N} p_n^0 q_n^0} = \frac{\sum_{n=1}^{N} \left(\frac{p_n^1}{p_n^0}\right) p_n^0 q_n^0}{\sum_{n=1}^{N} p_n^0 q_n^0} = \sum_{n=1}^{N} s_n^0 \left(\frac{p_n^1}{p_n^0}\right);$$

the basic Paasche index (P_P) is given equivalently by

$$(2.3) \quad P_P^{0,1} = \frac{\sum_{n=1}^{N} p_n^1 q_n^1}{\sum_{n=1}^{N} p_n^0 q_n^1} = \left[\sum_{n=1}^{N} S_n^1 \left(\frac{p_n^1}{p_n^0} \right)^{-1} \right]^{-1};$$

and the basic Fisher price index (P_F) is

$$(2.4) \quad P_F^{0,1} = (P_L^{0,1} P_P^{0,1})^{1/2},$$

where S_n^t in Equations (2.2) and (2.3) denotes the value share of R^t for product n in period t given by

$$(2.5) \quad S_n^t = \frac{p_n^t q_n^t}{\sum_{n=1}^{N} p_n^t q_n^t} = \frac{R_n^t}{R^t}.$$

From the final expression in Equation (2.2) and also in Equation (2.3), and from Equation (2.4), we see that the basic Laspeyres, Paasche, and Fisher price indexes are all summary metrics for price relatives for product n ($n = 1, \ldots, N$), where a price relative is given by

$$(2.6) \quad p_n^1 / p_n^0.$$

A price index is always evaluated for a given pair of time periods (i.e., the given current and comparison periods) and a given market area. To evaluate a basic price index formula like the Laspeyres given by Equation (2.2), each specified product covered by the index can only have one price in each time period. Historically, competitive forces have been appealed to (i.e., the "law of one price") as a justification for this one-price-per-product approximation to reality for a given time period and market area. Yet many businesses no longer set their prices on a product-by-product basis (if, indeed, they ever did that). Rather, they use pricing strategies aimed at maximizing their overall rate of return on their product sales. Hence product items typically end up being offered for sale at differing prices within a given market area, sometimes even by a single supplier.[12] Kaplan and Menzio (2014) use a large data set of prices for retail store transactions and show that the coefficient of variation of the average UPC price is 19 percent. The rapid rise of online retail seems likely to give rise to even greater opportunities for complex pricing strategies (Tran 2014).

Allowing for Multiple Transactions per Product at Multiple Prices

Suppose that there are multiple transactions per product (i.e., multiple product items are sold) each period and product items can sell for different prices in these transactions. Suppose, too, that we have the price and quantity details for the item-level product transactions. For these data to be used for price index evaluation, either we need a way of choosing one representative price for each product (the conventional approach), or the raw transactions-level data *must* be represented using some sort of price and quantity summary statistics. We use the word "must" because, in general, even if the number of products is the same, the number of product items sold usually will not be the same from one time period to the next. If we have an acceptable way of choosing a single transaction each period for an index basket product item, then it is those transaction prices that can be compared using a price index. Or, alternatively, some summary metric must be used for the transactions data, and then the values of that summary metric can be compared using a price index. Generating price observations that can be used to form price relatives, and in this manner can be compared over time, is a necessary step in constructing price indexes using raw transactions data, including scanner data.

The existence of multiple prices for a product in a time period can cause two kinds of bias in a conventional price index. The "formula bias" problem arises if a single price is selected to represent the multiple prices that exist in a given time period, and if the formula for the elementary price index is an arithmetic average of price relatives calculated as the ratio of the selected price for Period 1 to the selected price for Period 0. When multiple prices are present in the population and a single price is selected to represent the population in the price index, the price that is used in the price index becomes a random variable. Assuming that the two random variables are not perfectly correlated, the expected value of a ratio of random variables is an increasing function of the variance of the denominator, so the greater the variance of the price observations, the greater the upward bias in the average of price relatives. In the CPI of the United States and many other countries, formula bias is avoided by using geometric means to form the elementary indexes. The geometric mean of a set of price relatives is the same as the ratio of geometric means of the prices, so a geometric mean elementary index is, in effect, a ratio of average prices. The variance of the denominator will be so small that formula bias is not a problem if many price observations are averaged and the index is calculated as a ratio of the average prices.

The second kind of bias that can occur if a single price is used to represent the multiple prices that are present in a time period is that the behavior of the selected price may be unrepresentative of what is going on with the distribution of prices that are available to buyers. It is this problem that the rest of this chapter will focus on. Nevertheless, it should be noted here that the unit-value approach that we will recommend for reasons of maintaining sample representativeness also has benefits for eliminating formula bias and improving the statistical properties of the index. (For additional background on formula bias, see McClelland and Reinsdorf [1999], Reinsdorf [1998], and Reinsdorf and Triplett [2009].)

We denote the yet-to-be-specified price and quantity summary statistics for each product n in each period t by $p_n^{t,S}$ and $q_n^{t,S}$. The nominal value of the jth transaction is $R_n^{t,j} = p_n^{t,j} q_n^{t,j}$. Thus the nominal value of all transactions for product n in period t is

$$(2.7) \qquad R_n^t = \sum_{j=1}^{J_n^t} R_n^{t,j} = \sum_{j=1}^{J_n^t} p_n^{t,j} q_n^{t,j} .$$

If any important auxiliary product unit attributes do not vary systematically across transactions, the following is a desirable condition for the price and quantity summary statistics to satisfy for each of the N products covered by the price index:

$$(2.8) \qquad \frac{R_n^1}{R_n^0} = \left(\frac{p_n^{1,S}}{p_n^{0,S}} \right) \left(\frac{q_n^{1,S}}{q_n^{0,S}} \right).$$

This condition says that the growth in the per-period value of all transactions for product n from Period 0 to 1 can be expressed as the product of a pure price-change ratio times a pure quantity-change ratio. We call this condition the *product-level product rule*.[13]

The product-level product rule will always hold if, for each period ($t = 0,1$), the product of the price and quantity summary statistics equals the nominal value figure:

(2.9) $$R_n^t = p_n^{t,S} q_n^{t,S}.$$

Moreover, it is readily apparent that the condition in Equation (2.9) will always hold if the quantity and price summary statistics are defined for each period ($t = 0,1$) as

(2.10) $$q_n^{t,S} = \sum_{j=1}^{J_n^t} q_n^{t,j} = q_n^t$$

and

(2.11) $$p_n^{t,S} = R_n^t / q_n^t = \overline{p_n^{t,\bullet}},$$

where the dot ($\bullet$) replaces the index over which the summation is taken to compute the per-unit price average.[14] The price summary statistic given in Equation (2.11) is the period t *unit value* for product n. The quantity summary statistic given in Equation (2.10) is the total quantity transacted of product n in the given period t.

Substituting the period t unit value, $\overline{p_n^{t,\bullet}}$, for the price variable p_n^t in the basic specifications for the Laspeyres and Paasche indexes given in Equations (2.2) and (2.3), and redefining the quantity variable as the summation over all transactions in the given period, we obtain, respectively, the following expressions for what we call the *hybrid Laspeyres index* (the *HLaspeyres index* for short)[15]

(2.12)
$$P_{HL}^{0,1} = \frac{\sum_{n=1}^{N} \overline{p_n^{1,\bullet}} q_n^0}{\sum_{n=1}^{N} \overline{p_n^{0,\bullet}} \; q_n^0} = \frac{\sum_{n=1}^{N} \left(\dfrac{\overline{p_n^{1,\bullet}}}{\overline{p_n^{0,\bullet}}} \right) \overline{p_n^{0,\bullet}} q_n^0}{\sum_{n=1}^{N} \overline{p_n^{0,\bullet}} \; q_n^0} = \sum_{n=1}^{N} s_n^0 \left(\frac{\overline{p_n^{1,\bullet}}}{\overline{p_n^{0,\bullet}}} \right)$$

and for the *hybrid Paasche index* (the *HPaasche index*)

$$(2.13) \quad P_{HP}^{0,1} = \frac{\sum_{n=1}^{N} \overline{p_n^{1,\bullet}} q_n^1}{\sum_{n=1}^{N} \overline{p_n^{0,\bullet}} q_n^1} = \left[\sum_{n=1}^{N} S_n^1 \left(\frac{\overline{p_n^{1,\bullet}}}{\overline{p_n^{0,\bullet}}} \right)^{-1} \right]^{-1}.$$

Thus, the *hybrid Fisher index* (the *HFisher*) is given by

$$(2.14) \quad P_{HF}^{0,1} = (P_{AL}^{0,1} P_{AP}^{0,1})^{1/2}.$$

The value-share weights in Equations (2.12) and (2.13), S_n^0 and S_n^1, are given for all *n* by

$$(2.15) \quad S_n^t = R_n^t / R^t,$$

where R_n^t is now given by Equation (2.7) and where $R^t = \sum_{n=1}^{N} R_n^t$.

The HLaspeyres, HPaasche, and HFisher indexes use unit values for the first stage of aggregation, so these indexes can explicitly accommodate a product being transacted at multiple prices within a unit time period. They reduce to the basic formulas in situations in which there truly is just one price per period for each product. From Equations (2.12) to (2.14), we see too that the HLaspeyres, HPaasche, and HFisher indexes are summary metrics for relatives of average prices (i.e., what we will refer to as *unit-value price relatives*), defined as

$$(2.16) \quad (\overline{p_n^{1,\bullet}} / \overline{p_n^{0,\bullet}}).$$

These unit-value price relatives reduce to the usual price relatives given in Equation (2.6) when there is just one price per period for each product. Thus the HLaspeyres, HPaasche, and HFisher formulas are generalizations of the basic formulas.

Analysts who have estimated price indexes using raw scanner or other transactions-level data[16] from merchants or from financial markets are, in fact, already accustomed to evaluating price indexes based on unit-value price relatives,[17] but they have not always made this practice explicit by spelling out the data-processing specifics. By calling attention to how the formulas in Equations (2.12) through (2.16) depart from the corresponding basic formulas, and by providing terminology for these practices, we hope to facilitate efforts aimed at finding practical solutions to the problems statistical agencies face in dealing with the reality of multiple prices per index basket product per period.

An Important Historical Clarification

We chose to label as “hybrid” indexes the Laspeyres, Paasche, and Fisher formulas given in Equations (2.12) to (2.14) above. But, in fact, these are the “true” Laspeyres, Paasche, and Fisher indexes as introduced by the original authors. Only one of the multiple authors of this chapter (namely, Erwin Diewert) had the language skills needed to go back to the original German articles by Laspeyres (1871) and Paasche (1874). However, Walsh (1901, 1921) and Fisher (1922) wrote in English and are quite explicit that unit-value prices and total quantities transacted in a given time period and market place are the “right” p’s and q’s that should be used in a bilateral index-number formula at the first stage of aggregation over transactions that take place at different prices within the period.

Of course, when authors put their creations into the public domain, they cannot control how others alter what they originally proposed. It is clear that large numbers of authors have defined and used the indexes as in Equations (2.2) through (2.4) above, which correspond to what we have labeled as the “basic” indexes. And official statistics agencies have typically defined and used the indexes in the form we give subsequently (in Equations [2.31] through [2.33]), and which we refer to as the “conventional” indexes. It is in this context, and in the context of uses we make of the indexes subsequently in this chapter, that we refer to the formulas in Equations (2.12) through (2.14) as “hybrid” indexes.

Working with Grouped Transactions Data

Suppose we want to divide up the transactions for the N products covered by a price index according to one or more auxiliary attributes. For transaction j for product n in period t, the price and quantity are denoted here by $p_n^{t,j}$ and $q_n^{t,j}$. We can designate a total of C exhaustive and mutually exclusive groups for the transactions: $G1,\ldots,GC$. For each group of transactions, the total quantity and the average price (i.e., the group quantity and the group unit value) are given, respectively, by

$$(2.17)\qquad q_n^{t,Gc} = \sum_{j\in Gc} q_n^{t,j} \quad \text{and} \quad p_n^{t,Gc} = (\sum_{j\in Gc} p_n^{t,j} q_n^{t,j}) / q_n^{t,Gc} .$$

Hence, for each product *n*, the overall quantity transacted in period *t* can be represented as

$$(2.18)\qquad q_n^t = q_n^{t,G1} + \ldots + q_n^{t,GC} = \sum\nolimits_{Gc=G1}^{GC} \left(\sum_{j\in Gc} q_n^{t,j} \right).$$

The overall unit price for product *n* in period *t* can now be given as

$$(2.19)\qquad \overline{p_n^{t,\bullet}} = (\sum\nolimits_{Gc=G1}^{GC} \sum_{j\in GC} p_n^{t,j} q_n^{t,j}) / q_n^t$$

$$= (\sum\nolimits_{Gc=G1}^{GC} p_n^{t,Gc} q_n^{t,Gc}) / q_n^t$$

$$= \sum\nolimits_{Gc=G1}^{GC} p_n^{t,Gc} s_n^{t,Gc},$$

where for group $Gc = Gc,\ldots, GC$, the following conditions hold for the quantity shares: $s_n^{t,Gc}$, for groups $Gc = 1,\ldots, GC$:

$$(2.20)\qquad s_n^{t,Gc} = q_n^{t,Gc} / q_n^t \quad \text{and} \quad s_n^{t,G1} + \ldots + s_n^{t,GC} = 1 .$$

Note that the quantity shares defined in Equation (2.20) can only be meaningfully computed when the product units being added are *homogeneous* with respect to their primary attributes. With this proviso, when the total quantity transacted in period *t* is computed as in Equation (2.18) and the period *t* unit value for each product *n* is computed as in Equation (2.19), then the HLaspeyres, HPaasche, and HFisher formulas given in Equations (2.12) through (2.14) can be evaluated. In other words, the only adjustment needed in this grouped-transactions case is to use Equations (2.18) and (2.19), rather than (2.10) and (2.11), to compute the quantity and price summary statistics.

A Formula for the Bias in Conventional Laspeyres, Paasche, and Fisher Indexes

As noted, with some exceptions, the conventional statistics agency practice is to collect just *one* price per index basket product at a selected establishment in a time period. Without loss of generality, we denote the one transaction used in the conventional index as Transaction 1 (i.e., as $j = 1$). The full set of transactions in a given period t for each product n can then be divided into two mutually exclusive and exhaustive groups, $G1$ and $G2$, with $G1$ containing the single transaction used in compiling a conventional price index and $G2$ containing the rest of the transactions, which are transactions ignored in the conventional way of compiling the index. Hence, for $G1$, the quantity and price summary statistics can be denoted, respectively, as

$$(2.21) \quad q_n^{t,G1} = q_n^{t,1} \text{ and } p_n^{t,G1} = p_n^{t,1},$$

and, from Equation (2.17), we see that for group $G2$ we have

$$(2.22) \quad q_n^{t,G2} = \sum_{j=2}^{J_n^t} q_n^{t,j} = \sum_{j \in G2} q_n^{t,G2} \text{ and } p_n^{t,G2}$$

$$= (\sum_{j=2}^{J_n^t} p_n^{t,j} q_n^{t,j}) / q_n^{t,G2} = (\sum_{j \in G2} p_n^{t,j} q_n^{t,j}) / q_n^{t,G2},$$

where $q_n^{t,G2}$ is the quantity total and $p_n^{t,G2}$ is the unit value for the $G2$ transactions.

The total quantity transacted for each product n in period t is the sum of the transaction quantities for the $G1$ and the $G2$ groups, so we have

$$(2.23) \quad q_n^t = \sum_{j=1}^{J_n^t} q_n^{t,j} = \sum_{j \in G1} q_n^{t,j} + \sum_{j \in G2} q_n^{t,j} = q_n^{t,G1} + q_n^{t,G2}.$$

And, from the last expression in Equation (2.19), the overall unit price for product n in period t is

$$(2.24) \quad \overline{p_n^{t,\bullet}} = p_n^{t,G1} s_n^{t,G1} + p_n^{t,G2} s_n^{t,G2},$$

where now for the quantity share statistics we have

(2.25) $s_n^{t,G1} = q_n^{t,G1} / q_n^t$ and $s_n^{t,G2} = q_n^{t,G2} / q_n^t$ with $s_n^{t,G1} + s_n^{t,G2} = 1$.

For our price index bias analyses in the next section, it will prove useful to define a factor relating the average of the $G2$ transaction prices to the single $G1$ price. The *product-specific discount factor*, d_n^t, is defined so that 1 minus this discount factor is the factor of proportionality relating the average for the ignored $G2$ prices to the $G1$ price:

(2.26) $p_n^{t,G2} = (1 - d_n^t) p_n^{t,G1}$.

When the average price for the $G2$ transactions for product n in period t is less than the corresponding $G1$ price, then d_n^t will be strictly between 0 and 1. When the average for the $G2$ prices is greater than the $G1$ price, then d_n^t will be negative, making $(1 - d_n^t)$ greater than 1. The overall average price can now be represented as follows for product n in period t:

(2.27)

$$\begin{aligned}
\overline{p_n^{t,\bullet}} &= (p_n^{t,G1} s_n^{t,G1} + p_n^{t,G2} s_n^{t,G2}) && \text{using (2.24)} \\
&= p_n^{t,G1} s_n^{t,G1} + (1 - d_n^t) p_n^{t,G1} s_n^{t,G2} && \text{using (2.26)} \\
&= p_n^{t,G1} s_n^{t,G1} + p_n^{t,G1} s_n^{t,G2} - d_n^t p_n^{t,G1} s_n^{t,G2} && \\
&= p_n^{t,G1} (s_n^{t,G1} + s_n^{t,G2}) - d_n^t p_n^{t,G1} s_n^{t,G2} && \text{where } s_n^{t,G1} + s_n^{t,G2} = 1 \\
&= (1 - d_n^t s_n^{t,G2}) p_n^{t,G1} && \text{after factoring out } p_n^{t,G1}.
\end{aligned}$$

We see from the last line of Equation (2.27) that what we label as the *price quote representativeness term*, given by $(1 - d_n^t s_n^{t,G2})$, relates the unit value for *all* the period t transactions for product n to the one price quote used when following conventional index-making practice.

Now we define a product-specific *price index representativeness factor* $\gamma_n^{0,1}$ as the ratio of the price quote representativeness terms for Period 1 versus Period 0:

(2.28) $$\gamma_n^{0,1} = \frac{1 - d_n^1 s_n^{1,G2}}{1 - d_n^0 s_n^{0,G2}}.$$

This price index representativeness factor equals 1 when the representativeness term has the same value in both Period 0 and Period 1. As long as this factor is approximately equal to 1, then the overall average price for product n is related in the same manner in both Periods 0 and 1 to the one price quote conventionally utilized each period. In contrast, values of $\gamma_n^{0,1}$ that are appreciably different from 1 indicate that there is a difference between Periods 0 and 1 in how the overall average price relates to the price quote utilized. (Note that $\gamma_n^{0,1}$ exists and is positive if there are at least two transactions per period; $s_n^{t,G2}$ must be strictly less than 1 because $G1$ must contain a transaction for some positive quantity in both time periods, and d_n^t must be strictly less than 1 since the average $G2$ price is positive in either time period.)

The last expression for the HLaspeyres price index given in Equation (2.12) can now be restated to incorporate the relative price index representativeness factor $\gamma_n^{0,1}$:

(2.29)

$$P_{HL}^{0,1} = \sum_{n=1}^{N} S_n^0 \left(\frac{\overline{p_n^{1,\bullet}}}{\overline{p_n^{0,\bullet}}} \right) = \sum_{n=1}^{N} S_n^0 \left[\frac{(1 - d_n^1 s_n^{1,G2}) p_n^{1,G1}}{(1 - d_n^0 s_n^{0,G2}) p_n^{0,G1}} \right] \quad \text{using (2.27)}$$

$$= \sum_{n=1}^{N} S_n^0 \left[\frac{\left(\frac{1 - d_n^1 s_n^{1,G2}}{1 - d_n^0 s_n^{0,G2}} \right) p_n^{1,G1}}{p_n^{0,G1}} \right]$$

$$= \sum_{n=1}^{N} S_n^0 \left(\gamma_n^{0,1} \times \frac{p_n^{1,G1}}{p_n^{0,G1}} \right) \quad \text{using (2.28).}$$

Similarly, the HPaasche price index given in Equation (2.13) can be restated as

$$(2.30)\quad P_{HP}^{0,1}=\left[\sum_{n=1}^{N} s_n^1\left(\gamma_n^{0,1}\times\frac{p_n^{1,G1}}{p_n^{0,G1}}\right)^{-1}\right]^{-1}.$$

The HFisher counterpart of Equations (2.29) and (2.30) is still given by Equation (2.14), but with the HLaspeyres and HPaasche components now given by Equations (2.29) and (2.30).

We are now ready to define the price index formulas we will refer to as conventional.[18] To obtain the *conventional Laspeyres price index* ($P_{CL}^{0,1}$), we substitute the single price relative, given by ($p_n^{1,G1}/p_n^{0,G1}$), for the price relative of the *average* prices, given by ($\overline{p_n^{1,\bullet}}/\overline{p_n^{0,\bullet}}$), in the first expression for $P_{HL}^{0,1}$ in Equation (2.29). This yields what we refer to as the conventional Laspeyres index, based on the conventional practice of only using one price observation per product in each time period:

$$(2.31)\quad P_{CL}^{0,1}=\sum_{n=1}^{N} s_n^0\left(\frac{p_n^{1,G1}}{p_n^{0,G1}}\right).$$

Similarly, to obtain the *conventional Paasche price index* ($P_{CP}^{0,1}$), we substitute ($p_n^{1,G1}/p_n^{0,G1}$) for ($\overline{p_n^{1,\bullet}}/\overline{p_n^{0,\bullet}}$) in the expression for $P_{HP}^{0,1}$ given in Equation (2.30). This substitution yields what we refer to as the conventional Paasche index, based also on the conventional practice of only using one price observation per product in each time period:

$$(2.32)\quad P_{CP}^{0,1}=\left[\sum_{n=1}^{N} s_n^1\left(\frac{p_n^{1,G1}}{p_n^{0,G1}}\right)^{-1}\right]^{-1}.$$

The *conventional Fisher price index* ($P_{CF}^{0,1}$) is given by

$$(2.33)\quad P_{CF}^{0,1}=(P_{CL}^{0,1}P_{CP}^{0,1})^{1/2}.$$

In the index-number literature, the term "bias" refers to a systematic difference between the result that would be obtained for some index in use or considered for use versus a specified target index. To this point, we have only demonstrated the price index representativeness factor as an outcome of sampling error: basing an index on one product item will generally yield a different answer from using the entire population of product prices. In the next section, however, we present reasons why the price of the selected item could have a systematically different expectation from the population unit value. If we use P_{HL}, given in Equation (2.29) as the target index, then the bias of the conventional Laspeyres index given in Equation (2.31) is

$$(2.34)\quad B_{CL}^{0,1} = P_{CL} - P_{HL}$$
$$= \sum_{n=1}^{N} s_n^0 \left(\frac{p_n^{1,G1}}{p_n^{0,G1}} \right) - \sum_{n=1}^{N} s_n^0 \left[\gamma_n^{0,1} \frac{p_n^{1,G1}}{p_n^{0,G1}} \right]$$
$$= \sum_{n=1}^{N} (1-\gamma_n^{0,1}) s_n^0 \left(\frac{p_n^{1,G1}}{p_n^{0,G1}} \right)$$
$$= \sum_{n=1}^{N} \left(\frac{d_n^1 s_n^{1,G2} - d_n^0 s_n^{0,G2}}{1 - d_n^0 s_n^{0,G2}} \right) s_n^0 \left(\frac{p_n^{1,G1}}{p_n^{0,G1}} \right) \text{ using (2.28).}$$

Similarly, using Equations (2.30) and (2.32), the bias for the conventional Paasche index is

$$(2.35)\quad B_{CP}^{0,1} = P_{CP} - P_{HP}$$
$$= \sum_{n=1}^{N} \left[s_n^1 \left(\frac{p_n^{1,G1}}{p_n^{0,G1}} \right)^{-1} \right]^{-1} - \sum_{n=1}^{N} \left[s_n^1 \left(\gamma_n^{0,1} \frac{p_n^{1,G1}}{p_n^{0,G1}} \right)^{-1} \right]^{-1}.$$

It is cumbersome to develop a bias formula for the conventional Fisher index given in Equation (2.33). However, as Diewert and Nakamura (2010, appendix) explain, it is straightforward to develop formulas for the differences between the arithmetic averages of the Laspeyres and Paasche components for the conventional and for the target Laspeyres and Paasche components, respectively, of the conventional and the target Fisher indexes.[19] Thus, the bias of the conventional

Fisher index can be approximated by

$$(2.36)\quad B_{CF}^{0,1} = P_{CF}^{0,1} - P_{HF}^{0,1} \cong [(P_{CL}^{0,1} + P_{CP}^{0,1})/2] - [(P_{HL}^{0,1} + P_{HP}^{0,1})/2].$$

DIFFERENT SORTS OF PRICE INDEX SELECTION BIAS

In this section, we show how the expression in Equation (2.34) can be used to represent and provide a framework of analysis for price index bias stemming from various sorts of causes. We focus here on the Laspeyres bias formula because the BLS (and other statistical agencies) mostly use the Laspeyres index in their inflation measurement programs. However, comparable results for the Paasche and Fisher formulas can be derived starting instead from Equation (2.35) or (2.36).

Outlet Substitution Bias in the CPI

For the CPI, the BLS collects prices from selected retail outlets. In an effort to control for possible price-determining factors that can differ even for the same commercial product (i.e., to control for what we call auxiliary product item attributes), the BLS only forms price relatives for product items sold at the same retail outlet (see Greenlees and McClelland [2011]). Suppose, however, that households mostly care about what they must pay for products characterized by their primary attributes (including the brand and producer) and hence shift their expenditures among retail outlets in response to advertising about pricing policies and temporary promotional sales. The benefits of this sort of price-informed shopping in terms of the prices actually paid for the products used by any one consumer will be missed by a practice of only pairing prices for product items purchased at the same retail outlet in forming price relatives. If the ratio of the average price paid to the price used in the index is falling because opportunities for paying lower prices are increasingly being taken up by consumers using new forms of Internet- and cell phone–based advertising, then the conventional index will be upwardly biased.

The potential for outlet-specific evaluation to cause CPI price index bias was noted decades ago. In a 1962 report, Edward Denison raised the concern that, in his words, "revolutionary changes in establishment type that have taken place in retail trade" may have caused "a substantial upward bias" in the CPI (Denison 1962, p. 162).[20]

Marshall Reinsdorf empirically investigated Denison's CPI bias hypothesis. The BLS produces average price (AP) series for selected food groups. These are unit-value series for certain food categories, though not for strictly homogenous products, as we advocate. Reinsdorf (1993) compared selected AP series for food and gasoline with the corresponding CPI component series. He discovered that from 1980 to 1990, the CPI and AP series for comparable products diverged by roughly 2 percentage points a year, with the CPI series rising *faster* than the AP series, as would be expected if the CPI systematically fails to capture the benefits to consumers of price-motivated retail outlet switching. These empirical results captured the attention of Erwin Diewert, inspiring him to derive a formula for what he called the outlet substitution bias problem (Diewert 1998).

Reinsdorf (1998) later found that formula bias in the CPI caused part of the divergences between CPIs and corresponding AP series, so the outlet substitution effects turned out to be less than what was reported in his 1993 paper. However, a still substantial bias of 0.25 percentage points per year was found for both food and gasoline. The combined efforts of Reinsdorf and Diewert then galvanized other economists and price statisticians to take the outlet substitution bias problem seriously.[21]

If a significant number of consumers regularly switch where they shop among multiple retail outlets depending on the product prices each is currently offering, then we would expect d_n^t, defined in Equation (2.26), to be strictly between 0 and 1 in value for both Periods 0 and 1. This alone, however, will not cause a bias problem. We see from Equation (2.34) that the key question is whether the term $d_n^t s_n^{t,G2}$ has been *changing* in value over time. If the value of this term happened to stabilize, there would then be no outlet substitution bias. We believe, however, that the *G*2 quantity share ($s_n^{t,G2}$) has been growing over time for two sorts of complementary reasons. The first is that there have been steady improvements in the access that consumers have to current information about retail prices at different outlets in consumers' market areas, including now even "smart phone" geotargeted advertising. The second is that modern information technologies have made it cheaper and easier for retailers to implement strategically designed temporary promotional sales, which tend to generate high demand given the expanded abilities of advertisers to inform consumers of promotional sales. Hence, we expect the Laspeyres index bias given by Equation (2.34) to be positive.

CPI Promotional Sale Bias

Outlet substitution bias, discussed above, can result from a failure to capture a growing trend for consumers to take advantage of temporary sale and other price differences among retail outlets. However, even at the *same* retail outlet, units of a product are often sold at both regular and promotional sale prices within a month, which is the unit time period for the CPI. The frequency of temporary sales is believed to be increasing in the United States. The information available to consumers about sale pricing has been steadily expanding, too, presumably allowing consumers to take progressively greater advantage of temporary promotional sale prices.[22]

The BLS collects and uses for the CPI whatever prices are in effect at the time the price quotes are collected from each selected retail outlet, regardless of whether the prices are identified as “sale” or “regular” prices.[23] Temporary sales are believed to be in effect for any one product at any one outlet for less than half of the days or hours of business. Hence, the value of d_n^t is expected to be predominantly between 0 and 1. Nevertheless, because the capture of regular or sale prices is random, the value of d_n^t can be either positive or negative.

The volumes sold at promotional sale prices tend to be large and, as already stated, the frequency of temporary sales is believed to be rising, in the United States at least. As is evident from Equation (2.28), the sign of the change in the term $d_n^t s_n^{t,G2}$ determines the sign of the promotions bias.[24] Because the U.S. CPI includes sales prices in proportion to the percentage of time in which they are offered, increased frequency of sales could result in either a rise or a fall in this term. A fall would occur if the increased frequency of sale-price offerings increased the relative frequency of sale prices being selected for the CPI by more than it increased the relative frequency of sale prices being paid by consumers. On the other hand, if consumers’ costs of acquiring information fell, the term would likely rise, implying a positive promotions bias.

Information costs have, indeed, fallen, so promotions bias is expected to be positive on average.[25]

Sourcing Substitution Biases in the PPI and MPI

Finding cheaper input sources and then making sourcing substitutions is a prevalent strategy for lowering business costs. Empirical evidence suggests that this sort of supplier switching behavior plays an economically important role in the survival and growth of new firms (e.g., Bergin, Feenstra, and Hanson 2009; Foster, Haltiwanger, and Syverson 2008).[26] If both the old and the new suppliers are domestic, it is the uses of the Producer Price Index (PPI) as a deflator for inputs that can be affected. If both the old and the new suppliers are foreign, it is the Import Price Index (MPI) that can be affected.

For both the PPI and MPI cases, we would expect the values of d_n^t in Equation (2.26) to be strictly between 0 and 1. Moreover, we would expect the *G*2 quantity share ($s_n^{t,G2}$) to have been growing over time because of expanding information availability about suppliers and their prices, enabling purchasers to take greater advantage of lower-priced offers. Hence, we would expect positive biases in the relevant price indexes from sourcing substitutions.[27]

We next provide a simple example illustrating the sourcing substitution bias problem for the MPI. We then go on to take up two other possible sorts of producer sourcing changes that may cause bias problems.

An Example of MPI Sourcing Substitution Bias Due to Import Sourcing Switches

Here we distinguish a supplier (k) from a buyer (k'). For our example, Businesses 1 and 2 are foreign suppliers (hence, $k = 1,2$), and Businesses 3 and 4 are domestic buyers (hence, $k' = 3,4$) for a single product. The quantities and prices are denoted by $q_{k,k'}^t$ and $p_{k,k'}^t$. With only one product, a Laspeyres (or Paasche or Fisher) price index reduces to a ratio of a single price or average price for the one product in each of the two time periods for the price index

The value flows summarized in Table 2.1 reflect the following specifics:

Table 2.1 Value Flows for the Four Businesses

Output flows		Input flows	
Business 1	Business 2	Business 3	Business 4
Period 0 value flows			
$p^0_{1,3}q^0_{1,3}$	$p^0_{2,4}q^0_{2,4}$	$-p^0_{1,3}q^0_{1,3}$	$-p^0_{2,4}q^0_{2,4}$
Period 1 value flows			
$p^1_{1,3}q^1_{1,3}$	$p^1_{2,3}q^1_{2,3} + p^1_{2,4}q^1_{2,4}$	$-p^1_{1,3}q^1_{1,3} - p^1_{2,3}q^1_{2,3}$	$-p^1_{2,4}q^1_{2,4}$

- Business 1 is a developed-country supplier to Business 3, with this supply arrangement having been in place already for more than two periods as of the start of Period 0 for this example.
- Business 2 is a cheaper, developing-country supplier that has a supply arrangement with Business 4 that was in place already for more than two periods as of the start of Period 0.
- Business 3 purchases from Business 1 in both Periods 0 and 1. In Period 1, Business 3 also enters into a new purchasing relationship with the low-cost supplier Business 2. Houseman et al. (2011) note the potential importance of the entry of lower-cost suppliers in the domestic economy (as well as competition from foreign producers, which is the case to which they devote more attention). What a new supplier charges has no effect on the "conventional" price index.
- Business 4 has had an ongoing purchasing relationship with Business 2 and continues to buy exclusively from Business 2 in Periods 0 and 1.
- The following inequalities hold:

$$p^0_{1,3} > p^0_{2,4} > 0,\ p^1_{1,3} > p^1_{2,4} > 0,\ p^1_{1,3} > p^1_{2,3} > 0.$$

The price indexes for domestic businesses 3 and 4 can be regarded as the MPI index series.

The conventional price index for Business 4, $P^{(4)}_{CL}$ is the same as our hybrid Laspeyres target price index for that business, $P^{(4)}_{HL}$, because

Business 4 uses just one supplier each period. That is, for this case, the conventional price index equals the target price index:

$$(2.37) \quad P_{CL}^{(4)} = p_{2,4}^{1} / p_{2,4}^{0} = P_{HL}^{(4)}.$$

Thus there is no bias problem for $P_{CL}^{(4)}$.

In contrast, we can show that the conventional price index for Business 3 is biased, and we can show what the bias depends on. For Business 3, the conventional price index is

$$(2.38) \quad P_{CL}^{(3)} = p_{1,3}^{1} / p_{1,3}^{0} = 1 + i,$$

where (1 + *i*) is the measured inflation rate using this conventional price index. This conventional price index takes no account of the fact that in Period 1, Business 3 not only bought from Business 1 but also used a new supplier, Business 2. In contrast, and under our assumption that Business 3 views the products from the two suppliers as equivalent, the specified target index for Business 3 uses the information for all the transactions in Period 1. This price information is summarized in Period 1 by the unit value

$\overline{p_{\bullet,3}^{1}}$; i.e., we have

$$(2.39) \quad \overline{p_{\bullet,3}^{1}} = \frac{p_{1,3}^{1} q_{1,3}^{1} + p_{2,3}^{1} q_{2,3}^{1}}{q_{1,3}^{1} + q_{2,3}^{1}} = p_{1,3}^{1} s_{1,3}^{1} + p_{2,3}^{1} s_{2,3}^{1},$$

where

$$(2.40) \quad s_{1,3}^{1} = \frac{q_{1,3}^{1}}{(q_{1,3}^{1} + q_{2,3}^{1})}, \ s_{2,3}^{1} = \frac{q_{2,3}^{1}}{(q_{1,3}^{1} + q_{2,3}^{1})}, \text{ and } s_{1,3}^{1} + s_{2,3}^{1} = 1.$$

Hence, the target output price index for Business 3 is given by

$$(2.41) \quad P_{HL}^{(3)} = u_{3}^{1} / p_{1,3}^{0} = (p_{1,3}^{1} / p_{1,3}^{0}) s_{1,3}^{1} + (p_{2,3}^{1} / p_{1,3}^{0}) s_{2,3}^{1}.$$

It is the price charged by the lower-priced supplier, Business 2, that is ignored by the conventional price index for Business 3. The price charged by Business 2 is what constitutes the *G*2 group price for this example, whereas $p_{1,3}^{1}$ is the $G1$ price. Using Equation (2.26), we have

$$(2.42) \quad p_{1,3}^{1} = (1 - d^{1})\, p_{2,3}^{1} ,$$

where $0 < d^1 < 1$. In Period 0, there is only the one supplier for Business 3. Hence, applying Equation (2.34) yields the following:[28]

$$(2.43) \quad B_{CL}^{0,1} = P_{CL}^{(3)} - P_{HL}^{(3)}$$

$$= d^{1} s_{2,3}^{1} \left(\frac{p_{1,3}^{1}}{p_{1,3}^{0}} \right)$$

$$= d^{1} s_{2,3}^{1} (1 + i) > 0 \qquad \text{using Equation (2.38).}$$

The last two lines of Equation (2.43) are convenient alternative expressions for the sourcing substitution bias of $P_{CL}^{(3)}$.

We note that the last expression in Equation (2.43) is the same as Equation (2.12) in Diewert and Nakamura (2010).[29] This bias is seen to depend on

- the rate of price inflation as measured by the conventional index,
- the proportional cost advantage of any ignored supply source(s), and
- the quantity share for any ignored supply source(s).

If estimates can be made for the above factors, then a rough approximation to the bias given in Equation (2.43) can be made using this formula, which is a special case of our general bias formula found in Equation (2.34).

Domestic to Foreign Supplier Switches and a Proposed True Input Price Index (IPI)

We next consider the case of a business that switches from using a domestic supplier to a foreign one, thereby benefiting from an input cost decrease.[30] Neither the PPI nor the MPI can capture the cost savings from this sort of a sourcing substitution. The PPI's domain of definition does not include imports, and the MPI measures price changes beginning in the second month in which a newly selected imported product is observed. The resulting price index coverage gap is worrisome, since most of the increase in the relative importance of trade in the U.S. economy is accounted for by the expansion of imports of intermediate products.[31]

The pricing gap between the PPI and the MPI programs could be closed by creating a true Input Price Index (IPI) program that is defined to measure the inflation experience of producers in buying their inputs from all sources: foreign as well as domestic. In this case, the price evolutions measured should include those associated with shifts in purchase shares from more to less expensive domestic producers, and from more to less expensive foreign producers, as well as from domestic to cheaper foreign producers.

The BLS has put forward a plan for a true IPI (Alterman 2008, 2009; Chapter 10, this volume). With an IPI, a newly imported product that matches the primary attributes of a domestically supplied product could be brought into the IPI as a directly comparable substitute. Also, in principle, the purchaser of the inputs would be able to report the price per unit irrespective of the sources for inputs they treat as homogeneous in terms of what is done with the product purchases.

However, current BLS practice is not to average over prices for items of different products, even when they were explicitly designed to meet the same product specifications and differ only in terms of the producer of the product items. If this practice is retained for the IPI program too, then the new IPI could also be subject to sourcing substitution bias.[32] This potential IPI bias can be represented using Equation (2.34) in the same manner as for the PPI and MPI cases, except that purchases for domestic as well as imported inputs must now be covered. For the same sorts of reasons as discussed above for the PPI and MPI, we would expect this potential bias problem to be positive.[33]

Inflation Measurement Problems Due to the Initial Switch to Outsourcing

When a business switches from in-house production to procurement of an intermediate input, this is usually done in hopes of realizing cost savings. The fact that this sort of cost savings will not be picked up by the PPI or MPI programs is sometimes treated as an aspect of the new-goods price index bias problem, even if there is nothing new in terms of the input product in question. We note, however, that there will usually be no way for a business to make this sort of a change without alterations to the operating processes of the business. Perhaps, therefore, this sort of sourcing change should be viewed as a business technology change that should be counted as a contribution to productivity growth. Nevertheless, regardless of which of these perspectives is adopted, this sort of change is outside the scope of this chapter.

FIVE SORTS OF BARRIERS TO ADOPTION OF UNIT VALUES FOR OFFICIAL STATISTICS PURPOSES

The target indexes we recommend incorporate unit values. As we have noted, there are impediments to the adoption of indexes like this by statistics agencies in their official published series. Here we deal with what we see as the main impediments, grouped under five subheadings.

Impediment 1: Bad Reputation Due to Historical Misuse of Unit-Value Indexes

More than a half-century ago, the Price Statistics Review Committee chaired by George Stigler, also known as the Stigler Committee, considered the relative merits of unit value versus what is referred to as specification pricing. It recommended the latter. Under the heading of "Specification vs. Unit Pricing," the Stigler Committee report states the following:

> In 1934, the Bureau of Labor Statistics adopted "specification" pricing, and since then has sought to price narrowly defined commodities and services to obtain price relatives for price indexes…. The Committee believes that in principle the specification method of pricing is the appropriate method for price indexes. The changing unit values of a *broad* class of goods (say shirts or automobiles) reflect both the changes in prices of comparable items and the shifting composition of lower and higher quality items. (Price Statistics Review Committee 1961, p. 32, italics added)

Note, however, that the Stigler Committee's opposition to unit values did not arise in the context of price collection for carefully and very narrowly specified products, as we are recommending; rather, it arose in the context of prices collected for what nowadays would be viewed as very broadly specified products.

The Stigler Committee report recommended that the BLS move to probability sampling methods for narrowly specified products rather than using the customs administrative data, which were for unacceptably broad product groups. For example, with the BLS practices based on customs data, the price of new cars was based on the average of what were referred to as the "low-priced three" makes of automobile (Chevrolet, Ford, and Plymouth), with no adjustment for quality as the models evolved over time. The committee report particularly was concerned that "in the case of the Farm Indexes the classes over which unit values are computed are still often too wide" (p. 33). An accompanying study by Rees (1961) argued that the Farm Index measure of rugs, which did not specify the fiber content, failed to capture a substantial rise in the price of wool rugs as reflected in the BLS data (and in Sears and Ward catalogs) because it increasingly captured the pricing of wool-rayon blend rugs (pp. 150–153).[34] Similarly, the old U.S. Census Bureau unit-value indexes for imports and exports were based on customs administrative data for very broad product categories. As a result, the Census Bureau unit-value average prices were clearly subject to mix shifts.

As part of its response to the Stigler Report, in 1973 the BLS began producing rudimentary versions of an Import Price Index (MPI) and an Export Price Index (XPI) using price quotes and value-share weights produced by methods similar to those used for the PPI program. Full coverage of import and export goods categories was achieved by 1982 for the MPI and XPI (Silver 2010). Nevertheless, the Census Bureau unit-value indexes were not discontinued until July 1989. Alterman (1991) takes advantage of data from the overlap years to conduct a comparative empirical study of the Census Bureau unit-value indexes versus the MPI and XPI produced by the BLS. That study notes that if unit values are computed for what, in fact, are different products, then those price indexes will reflect not only the underlying price changes but also any changes in product mix as well. By way of example, he goes on to state that if there were a market shift, say, "from cheap economy cars to expensive luxury cars, the unit value of the commodity (autos) will increase, even if all prices for individual products remain constant." This clarifying remark makes it clear that Alterman, in his 1991 paper, is referring to the commodity categories the Census Bureau used in constructing its unit-value indexes rather than to precisely and very narrowly defined products. Alterman's remark was true for the customs data that the Census Bureau used in constructing its unit-value indexes but does not pertain to our proposals, as seen in the following quotation:

> In comparing price trends of imported products, the BLS series, surprisingly, registered a consistently higher rate of increase between 1985 and 1989. Between March 1985 and June 1989 the BLS index rose 20.8 percent, while the equivalent unit-value index increased just 13.7 percent. . . .With the exception of motor vehicles, the major import components—foods, feeds, and beverages, industrial supplies and materials, capital goods, and consumer goods—*all* show larger increases in the BLS series than in the unit-value series. *The most dramatic difference between the two series is found in the comparison for imported consumer goods. Between March 1985 and June 1989 the BLS series recorded a 30.7 percent increase, while the comparable unit-value series rose just 10.3 percent.* (Alterman 1991, p. 116, italics added)

In the above quotation, Alterman (1991) also reports an interesting anomaly along with his other findings. As Alterman explains, his discovery that the Census Bureau unit-value series shows *smaller* price increases for imports than the MPI contradicts a common presumption about the nature of unit-value indexes. This is the presumption that quality levels tend to rise over time, so that the failure to adjust for product mix changes within the product categories for which prices are being averaged will typically cause unit-value indexes based on broad product categories to overstate the true price increases.[35]

We, however, now suspect that what Alterman identified as an "anomalous" result is a manifestation of sourcing substitution bias in the MPI: a problem that would not have affected the Census Bureau unit-value series in the same way. In particular, the MPI produced by the BLS could not capture direct cost savings that buyers achieved by switching to lower-cost suppliers. In contrast, the old Census Bureau unit-value series probably did capture at least some of those price-motivated buying switches among products sharing the same, or almost the same, primary attributes.[36]

Impediment 2: Questions Regarding the Proper Treatment of Auxiliary Attributes

Producers of mass-marketed products try to ensure the homogeneity of items of what they label as being the same commercial product. Producers usually want it to be the case that items of what they label as "a product" can be advertised and sold interchangeably. For example, a 10.75-ounce can of Campbell's tomato soup, as this is defined by the company that owns the brand, is intended by Campbell's to be the same product no matter when, where, or how a can of the soup is purchased. Nevertheless, as has been noted, product items that all have the same primary attributes can acquire different auxiliary attributes such as having been sold at regular price or during a temporary promotional sale, or at a neighborhood convenience store versus a superstore.

We argue that in terms of the final uses made of products, it is usually just the primary attributes that matter. For example, when it comes to using cans of soup in a kitchen cupboard that may have been purchased from different outlets to take advantage of price promotions, typically no account is taken of the forgone effort or time of the family member who did the shopping. This is in line with current practices for compiling the gross domestic product (GDP). That aggregate is compiled for the United States by the Bureau of Economic Analysis (BEA) following the guidelines of the System of National Accounts (SNA). It is explicit in the SNA that no account is taken of unpaid time expenditures of household members, whether for picking up groceries at a superstore as opposed to a nearby convenience store, or for any other activity (United Nations Statistics Division 2014). Moreover, the nominal value of the consumption aggregate includes *all* sales of consumer products at the prices for which they were, in fact, purchased. One main purpose of the CPI program is to provide components to be used for constructing deflators for the consumption aggregate of the GDP.

We can, nevertheless, see reasons for wanting to hold a variety of auxiliary attributes constant in estimating the price relatives that are used in compiling a price index. After all, customers are willing to pay more per unit for the soup cans sold in a convenience store, and, in that sense, those cans of soup are definitely of "higher quality" than lower-priced units of the product sold at a discount superstore. An important secondary consideration from our perspective is that whatever product differentiation and index basket definitions are adopted for price-quote collection purposes, it is important that those same index basket product definitions are used as well in collecting the data for and in producing the product-specific value-share weights for the price index. The question of if and when auxiliary product unit attributes should be used in forming index basket product definitions is deep, and largely beyond the scope of this chapter.

Impediment 3: Producer Goods with Different UPCs but the Same Primary Attributes

The mechanics of price measurement for producer goods are greatly simplified when the products can be specified as individual product UPCs or predefined groups of these. It is the primary product characteristics that usually matter for how product units are utilized in a production process, and differences in primary attributes are always reflected in different UPCs.

Nevertheless, UPCs for product units sometimes differ even though the product units are, for all practical purposes, identical. For example, as previously noted, many large manufacturers issue precise specifications for needed intermediate products, and then purposely select multiple suppliers from among the businesses that bid on the supply contract opportunity. If intermediate product units are produced according to specifications that are identically the same but they nevertheless come from different producers, then the product units from each producer will have a different producer-specific UPC. For price index compilation purposes, we recommend that items of products that are believed to be the same and are utilized in the same manner by the final user should usually be treated as the same product for price index evaluation purposes even when their UPCs may differ. In addition, if a producer indicates that the product items from different suppliers are used or sold in the same way except for some allowance for a quality difference (e.g., through purchase order adjustments to allow for supplier-specific defect rates), then the producer could also be asked to report and evaluate the quality difference, and that information could be used in implementing quality adjustments so that the items from the different suppliers can all be treated as quality-adjusted items of the same index basket product.

However, defining meaningful classification systems of UPCs can be expected to be a laborious process.

Impediment 4: Consumer Products Sharing Primary Attributes but Not UPCs

Concerns have also been raised regarding the inflation measurement implications of a growing proliferation of retail products with different UPCs even when the producer is the same and the primary product-attribute differences are trivial. One reason for this proliferation may be that producers supplying retail products fear that their customers may switch to buying the products of competitors if they raise their prices. Hence, they instead may bring out new versions of a product that are minor variants: variants that are advertised as being improved and that are offered at increased prices that yield higher profit margins. The corresponding old versions can then continue to be sold too, only to be discontinued if and when a new version has become a sales success (see Nakamura and Steinsson [2008, 2012]).

Another reason for the introduction by a producer of a new product that intentionally has primary attributes that are highly similar to the attributes of an existing product may be a desire to take market share from competitors with successful products. In these cases, the producer wants the new product to differ enough from the old one marketed by the competitor to avoid successful trademark or patent infringement lawsuits but hopes that potential users will judge the new product to meet all the needs and uses of the old one they were purchasing. We view this as the spirit, for example, in which large grocery store chains often introduce their own "private label" variants of popular established brand-name products. Similarly, clothing makers often try to bring out styles like those of popular designers. And pharmaceutical companies often try to find ways of producing drugs as effective as the successful drugs produced by competitors. These products have different UPCs but are deliberately similar to existing products in terms of the primary attributes.

Conversely, but equivalently for measurement purposes, a producer may have the goal of maintaining a constant price by replacing a product with another that is less costly to produce.

Although statistical agencies like the BLS do not average over changing sets of multiple-price quotes for individual products, for price change to be measured correctly, unit values are sometimes defined in BLS price index programs to encompass multiple UPCs that represent the same index basket product. Adoption of our recommendations implies an extension of these practices. However, the task of determining when consumer products with different UPCs should be treated as the same index basket product for inflation measurement purposes may be harder than the corresponding problem discussed above for producer products. There are three reasons for this:

1) Consumers are far more numerous than producers, and they generally each buy much smaller amounts than producers purchasing intermediate products. Hence the product-use views and experiences of much larger user groups would need to be considered to follow an approach for consumers like what we suggest above for producers.
2) Producers inevitably keep and analyze data about the performance of units of an intermediate product that are obtained from different suppliers. Consumers, on the other hand, are not usually in a position to systematically note primary attribute quality differences for similar product items from different producers.
3) Producer products that are similar enough that it might make sense to consider them as being the same index basket product were often *requested* by the purchaser. Thus, the product item sameness is an openly declared objective to satisfy specifications issued by the purchaser. In contrast, sameness in the consumer case that results from an effort to expand or enter a market by competing with the product of a competitor is usually illegal if the duplication is exact. Hence, for consumer products, design work is needed to produce a similar product that is nonetheless sufficiently different so that allegations of patent or trademark infringement can be defended against. Foreign suppliers trying to gain market share from domestic producers of consumer products often invest heavily in that sort of product design work. A great deal of effort can go into legally producing a product that is almost identical to one that already is being sold by some other producer.

Even when a very similar new product is developed by a producer as an alternative for one of the producer's own established products—perhaps in the hopes of being able to use the new product as a means of making a de facto price adjustment—design work is usually required. This is so no matter how small the differences may seem. From some perspectives, product development should be treated as part of productivity growth rather than as a price change mechanism. Hence, maybe these products truly should be treated as new products rather than as quality-adjusted old products. Kaplan and Menzio (2014) offer data on the distribution of prices across similar products as well as within UPCs; their analysis sheds some light on the relative importance of alternative product specification methods. We do not attempt to provide answers here to these difficult questions.

Nevertheless, the issue must be faced of when and how to average prices over units of consumer products with very similar primary attributes, as is now sometimes done on the consumer side using hedonic and other quality-adjustment methods. This is so whether or not our recommendation to use unit-value price indexes is adopted. The BLS is already engaged on an ongoing basis in deciding when different commercial products are similar enough to be treated as the same index basket product, but those efforts, however important, are outside the scope of this chapter and are not covered here.

Impediment 5: A Need to Change Current Data Collection Arrangements

The most straightforward impediment to conquer might be the most serious. The information requirements for a unit-value price approach based on narrowly defined index basket products are much larger than for the approaches used for conventional price indexes. Nevertheless, private businesses have paved the way. Businesses formerly carried out their decision making and forecasting using sample and other sorts of incomplete information for their own transactions. In contrast, modern big businesses strive to operate with full, real-time transactional visibility.

Thus the nature of the needed changes at the BLS and other national statistics agencies can be seen from the way in which large private-sector businesses have remade their data systems over the recent decades and have then also remade their business processes to utilize their improved information capabilities. The needed hardware and software have been developed. Nevertheless, moving a national statistics agency into a position of roughly equivalent data storage and handling capabilities with what big companies now have will require budget allocations and investments in training and hiring people with the needed capabilities. Private-sector data system experts do not have official statistics expertise, and those already with the statistics agencies have had no opportunity to master data capture, warehousing, and utilization methods of the sort that have become common for big businesses, or the intricacies of the UPCs.[37]

It is instructive to briefly examine the steps that the private sector had to take to attain its modern data-handling capabilities. The 1961 Stigler Report was written before the business world had UPCs. Indeed, for most of the twentieth century, as stores got bigger and varieties multiplied, the only way for a grocer or other retailer to find out what was in stock was by physically counting all the cans, boxes, bags, and cartons. The achievement of widespread use of UPCs was the result of sustained business-world efforts of many sorts. A machine-readable product-code design had to be devised and agreed on. Equipment for cost-effectively reading the product codes and for storing and processing the product-code data had to be invented, produced, purchased, and put to use by businesses. A product-code numbering system had to be invented and widely accepted. And an organization had to be developed to oversee the assignment and use of product codes over time. Also, business processes had to be redesigned to make use of the product-code data.

More than a decade before the Stigler Report was written, Bernard Silver and Norman Joseph Woodland developed (and in 1952 were granted a patent for) a bar-code design consisting of concentric circles that could be scanned from any direction. However, without a cheap, fast, and convenient way to read and record bar-code data, their invention could not be put to use. The development of cheap lasers and integrated circuits in the 1960s made bar-code scanners and bar-code data handling potentially affordable for retailers. However, the original Silver-Woodland "bull's-eye" bar-code design performed poorly in an important field test. Also, there was the challenge still to be met of getting all needed participants to more forward together.

In the early 1970s, IBM researcher George J. Laurer devised a new bar-code design for which the field test results were acceptable. He then succeeded as well in getting the U.S. Supermarket Ad Hoc Committee interested in what was named the IBM Universal Product Code (UPC) system.[38] On April 3, 1973, the Ad Hoc Committee voted to accept the symbol proposed by IBM.

Standardization made it worth the expense for manufacturers to put bar codes on their packages and for printers to develop the needed new ink types, plates, and other necessities for reproducing the code with the accuracy required for the UPC scanners, and the Ad Hoc Committee succeeded in bringing the grocery industry and other needed participants together to implement UPC scanning at the point of sale (POS). This included agreement on a standardized system for assigning and retiring bar-code product numbers. To facilitate this, the nonprofit Uniform Code Council (UCC) was established. Businesses applied for registration with the UCC, which eventually changed its name to Global Standards One, or GS1.[39] Each business that was accepted as a registered member began paying an annual fee and was then issued a manufacturer identification number and given training on how to register its products and on how to assign and retire UPCs as needed.

Use of scanners grew slowly at first. In 1978, less than 1 percent of grocery stores nationwide had scanners. By mid-1981, the figure was 10 percent. Three years later it was 33 percent. And by 1999, it was already over 60 percent.[40]

GS1 today manages what is collectively referred to as the Global Trade Item Number (GTIN) System, which includes the UPCs (GS1 .org 2014). The official GS1 member organization for the United States is now called GS1 US. The modern logistics, inventory management, pricing, advertising, and supply chain coordination operations of businesses of many sorts, especially including grocers and general merchandise retailers, would be inconceivable without the information derived from tracking items of product units identified by UPCs.

In 1999, the Supermarket Ad Hoc Committee commissioned PricewaterhouseCoopers to make a report examining the extent to which the aims of the original Ad Hoc Committee business plan had materialized (Jones, Garg, and Sheedy 1999). The resulting report finds that the direct savings from bar-code adoption (i.e., savings at the checkout counter) proved greater than originally projected. The report also finds, however, that it was the general merchandise companies, rather than the supermarkets, that managed to most fully realize the projected *indirect* savings from bar-code scanning, and it argues that the supermarkets have been losing market share to superstores because of this reality.

(The indirect savings envisioned by the original Ad Hoc Committee pertain to business functions such as inventory management.) We see Walmart as a notable example of this last point.

From 1973 on, as grocery and other retail chain stores grew, the chains almost all established semiautonomous regional data centers that collected and processed bar-code scanner data. The reason for the regional data centers that most chains created and many still have is that the volume of the bar-code data seemed too large for processing in a single data warehouse for even a midsized chain store. Nevertheless, in 1979 Walmart built an initial *company-wide* data warehouse (Metters and Walton 2007). Walmart was also the first large retailer to give its suppliers access to Walmart's point-of-sale and inventory data for the products of each of those suppliers, thereby helping the suppliers reduce costs due to under- or overproducing. Walmart recognized that by sharing this information with its supply-chain partners, the company and its suppliers could all gain from improved coordination.

To improve the reliability of access to its data warehouse, Walmart in 1987 also built the world's largest private-sector satellite communications system. Then, in 1991, the company reportedly spent $4 billion more to create its new Retail Link company-wide data warehouse. Nowadays, Walmart suppliers are able to monitor in almost real time how their products are selling on Walmart store shelves everywhere that Walmart carries their products. The POS data is credited with enabling Walmart suppliers to reduce their inventories, shorten their lead times, and increase their profitability. Also, with product items being electronically identified at the checkout counters and with financial as well as physical inventory records being updated on an ongoing, almost real-time basis, store managers in Walmart outlets everywhere as well as those in the company headquarters can plan better.

Investments that bring the data capabilities of official statistics agencies more into line with what big companies have could pay big dividends.[41] This and our other reform suggestions are presented in the final section. However, before proceeding to those suggestions, we briefly note how price indexes affect some other key economic performance metrics.

INFLATION MEASUREMENT EFFECTS ON OTHER ECONOMIC PERFORMANCE MEASURES

Price indexes are used to measure inflation for nations and to transform nominal into real values. Real values of national output are then used to measure economic growth, and for creating measures of productivity growth and growth in material well-being over time.

Previously we defined R^t in Equation (2.1) as the sum of *either* the nominal period t revenue for all products sold by some economic entity or the nominal period t remittance paid (i.e., the cost) for all products bought by a given economic entity. However, outputs need to be distinguished from inputs for productivity and economic well-being measurement purposes. Productivity is a measure of the efficiency of an economic entity in turning inputs into desired outputs (see, e.g., Diewert [2007] and Diewert and Nakamura [2007]), and economic well-being is usually gauged by restating in per-capita terms a measure of the total output for a nation (such as GDP).

For some given economic entity, here we redefine R^t, p_n^t, q_n^t, and the index limits N and J as pertaining just to *output* products (rather than including inputs too, as in our previous definitions). Thus the total nominal revenue in period t for a specified economic entity is now given by

$$(2.44)\quad R^t = \sum_{n=1}^{N} R_n^t = \sum_{n=1}^{N} \sum_{j=1}^{J_n^t} p_n^{t,j} q_n^{t,j} .$$

Here, we redefine $P^{0,1}$ as an index measure of *output* price change from $t = 0$ to $t = 1$.

The most commonly used productivity performance metric for nations is labor productivity growth. Suppose L^t is defined as a pure quantity measure of labor services input such as aggregate hours of work. Labor productivity growth from Period 0 to 1, denoted here by $LP^{0,1}$, can be measured as the ratio of real revenue growth to a growth ratio for aggregate hours of work:

$$(2.45)\quad LP^{0,1} = \frac{(R^1 / R^0) / P^{0,1}}{L^1 / L^0} .$$

The interpretation people want to make of labor productivity values is that values greater than 1 (less than 1) mean that real GDP has grown faster (slower) over time than the quantity of labor required to produce the real output.

We now consider how the price-index bias problems discussed in previous sections of this chapter could distort measures of real GDP growth. Nominal GDP for period t is defined as

$$(2.46) \quad \text{GDP} = C + I + G = (X - M),$$

where C denotes aggregate consumption, I is investment, G is government expenditure, X is exports, and M is imports. If inflation is overestimated (underestimated) for the C component of GDP, this will cause the growth of real GDP to be underestimated (overestimated), since C enters with a positive sign into GDP. If inflation is overestimated (underestimated) for the M component of GDP, this will cause the growth of real GDP to also be overestimated (underestimated), since M enters with a negative sign into GDP.

The outlet substitution bias problem explained in the subsection titled "Outlet Substitution Bias in the CPI" is believed to have contributed to the overestimation of inflation for C, and hence to the underestimation of real GDP growth. The MPI sourcing substitution problem explained in the subsection "Sourcing Substitution Biases in the PPI and MPI" is also believed to have contributed to an overestimation of inflation—for imports in this case—which would contribute to an overestimate, rather than an underestimate, for GDP growth because M enters the expression for GDP with a negative sign.[42]

The extent to which these bias effects on real GDP cancel each other out is an empirical question. Although for the United States the C component of nominal GDP is much larger than the M portion, there are fairly narrow limits on the proportion by which it makes sense for a retailer selling in any given market area to undercut the prices of competitors. This places bounds on the likely size of the CPI outlet substitution bias problem. In contrast, intermediate product-supply contracts can be very large, and suppliers sometimes have labor, raw-materials access, patent, government subsidy, or other cost advantages that make it possible for them to profitably sell their products, if they wish, at prices far below what competitors are charging. Hence, it is plausible that positive MPI bias problems have outweighed positive CPI bias problems, resulting in the systematic overestimation of real GDP growth. There is an urgent need for empirical research on this point.

Haskel et al. (2012) paint a vivid picture of real income declines for the large majority of Americans over the previous decade. They classify U.S. workers into five groups by their levels of education—five groups that *all* enjoyed substantial increases in average real income in the second half of the 1900s. However, since 2000, these same groups of workers have suffered real average-income declines. This is perplexing, Haskel et al. note, since the U.S. economy enjoyed superior measured labor-productivity growth.[43] They point out that the last 10 to 15 years have also brought dramatic changes in economic globalization, but that connections between globalization and the observed economic trends are unclear based on available research. Our own results, considered along with other findings cited in our chapter, raise the possibility in our minds that price-index bias problems that have been indirectly worsened by the growth of electronic information processing and communications and associated business process changes (changes that enabled globalization) may, in part at least, be responsible for the perplexing picture of how the U.S. economy has been doing, as reported by Haskel et al.

We conclude with suggested changes in official statistics price measurement that we feel could improve our ability to understand the evolving economy.

POSSIBLE PRICE MEASUREMENT PRACTICE REFORMS

We have shown that the bias formulas derived in this chapter can be used to represent the sourcing substitution bias problem in the Import Price Index (MPI) and the Producer Price Index (PPI), and the potential sourcing substitution bias problem in the proposed Input Price Index (IPI) (see Alterman 2008, 2009, and Chapter 10 of this volume), as well as the outlet substitution and promotions biases in the Consumer Price Index (CPI). Our recommendations in this final section are aimed at reducing the noted bias problems.

Our main recommendation is that when items of the same commercial product unit are sold at multiple prices even by the same merchants during a time period such as a month, then the conventional practice of using a *single* price observation per period for the product from each establishment where the product is priced during the time period (with this single price then being used to represent the price *distribution* at each establishment) should be replaced by the use of establishment-specific unit-value prices. Hence, we argue for greater adoption of unit-value-based price indexes to handle cases of multiple prices for the same product in the same period. This first recommendation implies a need for modifications of both data collection operations and compilation procedures. In the text, the need for these modifications is part of what we allude to as the fifth and most serious of the impediments to the adoption of unit-value-based price indexes. We propose a way here in which the BLS might proceed incrementally toward a capability for unit-value-based price-index compilation.

At present, the BLS price-quote-collection operation for each of the agency's main price index programs (e.g., the CPI, the PPI, and the International Price Program) starts with selecting establishments on a probabilistic basis from comprehensive lists of various sorts. Next comes the selection of products on a probabilistic basis at each selected establishment. Then, the BLS collects a *single* price quote in each pricing period (typically a month) for each selected product at each of the selected establishments.[44] The way products are selected for pricing at different establishments does not usually result in the same product being chosen for price collection at more than one establishment in a given geographic market area. Moreover, even when the BLS price collection approach does yield multiple price observations for the same product version, the BLS does not average over changing sets of the price observations.[45] In addition, for producer products, an effort is made to only make price comparisons over time for the same buyer-seller pairs. These are the main reasons why the BLS price-collection operations could not, at present, support a switch to compiling unit-value-based price indexes.

Yet most businesses in a developed country like the United States have their full transactions data for at least the current month readily available in electronic form. Hence, with equal ease, a business *could* give the BLS information on the quantity of the selected product that was bought or sold along with the price per unit that the BLS presently collects. Moreover, most modern businesses could provide their transaction value and quantity as well as price data for all transactions over some recent time period, such as a month, for a list of UPC-identified products. Feenstra and Shiells (1997) made a similar recommendation almost 20 years ago. The respondent burden would barely vary depending on the length of the product list. Hence, the same basic probabilistic selection approach for products at each selected establishment could be retained if desired, but the products selected at each establishment could be added to a common product list for all establishments, and then a month's worth of transactions data could be obtained from *all* selected establishments for *all* products on the common list.[46] The BLS would then have the option of producing various sorts of unit-value price indexes.

If averaging of prices for UPC-identified products is done over time, month by month, for each establishment, it should be possible to produce unit-value-based price indexes that are largely free of promotions bias problems. However, the outlet substitution bias would remain as long as there is no averaging over establishments. Alternatively, if unit values are produced by averaging of prices for UPC-identified products over the establishments in each designated market area, then it should be possible to produce unit-value-based price indexes that are largely free of outlet substitution as well as promotions bias problems.

Unfortunately, though, even averaging over establishments and time will not help with MPI and PPI sourcing substitution bias problems. The reason is that items of intermediate products that are the same from the perspective of how the purchasing firm plans to use the items are often bought from multiple suppliers, and product items from different producers have different UPCs even when all their attributes are identical. Thus the sourcing substitution bias problem would remain. Nor would this averaging of prices help with the product replacement bias phenomenon identified by Nakamura and Steinsson—another important case in which the UPCs differ for product items that have essentially the same attributes and that should perhaps be treated as the same index basket product.

At least for producer intermediate products, however, the user of the intermediate product units is in a position to specify the UPCs that are, from that user's perspective, for the same product. Hence, we recommend asking all producers from whom price quotes are collected whether they regard some of the UPC-identified products they purchase as identical, in that they use the product items interchangeably and in identically the same manner. Moreover, if a producer indicates that the product items from different suppliers are used or sold in the same way except for some allowance for a quality difference (e.g., purchase order adjustments to allow for supplier-specific defect rates), then the producer could also be asked to report and evaluate the quality difference, and that information could be used in implementing quality adjustments so that the product items from the different suppliers could be treated as items of the same constant-quality product.

As we have noted, there are also four other sorts of impediments to the adoption of unit-value-based price indexes by an official statistics agency like the BLS. One is an established and somewhat indiscriminate prejudice against unit values. We have argued that the reasons that led to this prejudice do not apply when the unit values are for UPC-identified or similarly very narrowly defined products, which is what we recommend.[47]

We differentiate what we call primary product and auxiliary product attributes. We define *primary product attributes* as characteristics that a product item has when first sold by the original producer and that normally continue to be characteristics of the product item regardless of where and how it may be resold. We define *auxiliary product item attributes* as attributes that a product item acquires as a consequence of where and how it is sold. A second impediment we then identify is that some of what a producer ships out as items of the same product can acquire additional auxiliary price-determining attributes, depending on where and how the product items are sold. We note that there are difficult conceptual and operational questions that arise regarding the treatment of auxiliary product attributes.

We can, as already acknowledged, see reasons for wanting to hold a variety of auxiliary attributes constant in estimating the price relatives that are used in compiling a price index. However, if an auxiliary attribute is used in product differentiation for price-quote collection purposes, then it is important for that same auxiliary-product attribute to be taken into account too in collecting the data for and in producing the product-specific value-share weights for a price index.

A third impediment is that there are unresolved issues regarding the price measurement appropriateness and the operational difficulty of recognizing the sameness of units of producer intermediate inputs from different suppliers that are viewed as identical (or almost so) by the businesses using these inputs. Related issues arise as well for consumer products, and we label those issues as the fourth impediment. So both Impediments 3 and 4 relate to situations where the UPC product definitions may be narrower than ideal for inflation measurement purposes. We view the task of determining when units of consumer products with different UPCs are, in fact, the same—or sufficiently similar that they should be treated as the same for inflation measurement purposes—as intrinsically harder than the corresponding problem discussed above for producer products.

Clearly, we do not provide full solutions to all the problems noted,[48] and some of our proposed solutions may prove to be suboptimal. We offer these suggestions in the spirit of a search for better ways, which we believe are possible now, given product code and other modern information-technology developments.

The incremental new transactions data collection approach outlined above would allow estimates to be made of the importance of the identified price-index bias problems, since this recommended approach nests the current BLS price-quote collection processes. The BLS could also draw on the growing experiences of other national statistics agencies that are now producing unit-value-based price indexes using electronic data from businesses (though, as we understand, without designating them as different from the conventional price indexes or explaining the relationship).[49]

We note too that the suggested incremental new data-collection approach would vastly enrich the BLS research databases, in addition to contributing to the price-index improvement agenda. Price indexes are ubiquitously used as measures of inflation and as deflators. In addition, however, the BLS research databases have been enabling a true empirical examination of the origins and transmissions of price signals in the U.S. economy.[50] If the BLS is given the resources needed to harness the power of the new information technologies, including making fuller use of the product codes now ubiquitously used by businesses, and if our recommendations (or appropriate modifications of these) are accepted, we believe the eventual result will be far superior price indexes.[51] We also believe this will result in great improvements in the accuracy of a host of other economic measures that embed price indexes as component parts, as well as an even greater flowering of insights into price signals, which are fundamental to the functioning of a free-market economy.

Notes

The corresponding author is Alice Nakamura with the University of Alberta; she can be reached at alice.nakamura@ualberta.ca. Other than for the corresponding author, the authors' names appear in alphabetical order. Erwin Diewert is with the University of British Columbia and the University of New South Wales and can be reached at diewert@econ.ubc.ca. John Greenlees is recently retired and was formerly with the Bureau of Labor Statistics (BLS). He can be reached now at jsgreenlees@verizon.net. Leonard Nakamura is a vice president and economist with the Philadelphia Federal Reserve Bank and can be reached at leonard.nakamura@phil.frb.org. Marshall Reinsdorf was with the Bureau of Economic Analysis (BEA) when the chapter was written and accepted. He is now with the International Monetary Fund (IMF) and can be reached at mreinsdorf@imf.org. The views expressed in this chapter are those of the authors and should not be attributed to the IMF, its management, or its executive directors. Nor does the chapter reflect the views of the Federal Reserve Bank of Philadelphia or of the Federal Reserve System or the BEA, or any other organization. Our research draws on papers presented and discussions with participants at two Washington, D.C., conferences: "Measurement Issues Arising from the Growth of Globalization," held November 6–7, 2009, and "Measuring the Effects of Globalization," held February 28th and March 1st, 2013. Partial support from the Social Sciences and Humanities Research Council of Canada (SSHRC) is gratefully acknowledged. Brent Moulton, Emi Nakamura, and Jón Steinsson made especially valuable contributions. The term "hybrid," which we give to the generalized price index formulas we develop and recommend, was suggested to Marshall Reinsdorf by Harlan Lopez of the Central Bank of Nicaragua. Thanks are also due to Bill Alterman, Michael Horrigan, and Ben Jones for helpful comments. Any remaining errors or misinterpretations and all opinions are the responsibility of the authors.

1. Statistical agencies with practices more in line with our recommendation are noted in the seventh section, titled "Possible Price Measurement Practice Reforms." In addition to those agencies, many countries rely on monthly unit values for some of the prices used to compile their PPIs.
2. If that is how the proxy price is arrived at, an implicit assumption is being made that consumers are indifferent between the 10.75-ounce and the 15.2-ounce formats for the Campbell's tomato soup content. Other, more elaborate methods of quality adjustment might be utilized if that assumption were believed to be inappropriate.

3. Reinsdorf (1993) and Diewert (1995, 1998) defined and brought attention to this price-index bias problem. For related materials, see Greenlees and McClelland (2011), Moulton (1993, 1996a,b), Reinsdorf (1994a,b,c, 1998, 1999), and Reinsdorf and Moulton (1997), as well as Hausman (2003), Nakamura (1999), and White (2000).
4. Diewert and Nakamura (2010) define this bias problem and provide a measurement formula for it, having been inspired to work on this problem by the arguments and empirical evidence of Houseman (2007, 2009, 2011), Mandel (2007, 2009), and Mandel and Houseman (2011). See also Fukao and Arai (Chapter 7, this volume), Houseman et al. (2011), and Inklaar (2012).
5. Reinsdorf and Triplett (2009) review the context and content of the Stigler Committee's recommendations.
6. The person who purchases a can of soup may have preferences regarding shopping at a convenience store or a superstore for various sorts of products, but others who end up eating the soup at home will likely not care where a particular can of the soup happened to have been purchased and often will not even be aware of that detail.
7. See Nakamura and Steinsson (2008, 2012) for more on this sort of "price flexibility" and its significance for understanding and for the management of inflationary pressures in the macro economy.
8. Superlative indexes, defined by Diewert (1976, 1992), have many desirable properties when it comes to taking account of buyer substitution behavior, but they cannot properly account for the effects on the prices paid by buyers when that behavior changes because buyers progressively learn about cheaper sources of products rather than because of suppliers lowering their prices. See also Diewert (1987, 2013a,b); Diewert and Nakamura (1993, 2007); Nakamura (2013); and Reinsdorf, Diewert, and Ehemann (2002) regarding aspects of the Fisher index of relevance for the use of price indexes in the making of productivity indexes for nations.
9. The Laspeyres formula is defined below. It can be calculated in multiple stages of aggregation or in a single step. The Paasche index, also defined below, shares this convenient property.
10. Note that attributes of the product content will always be primary attributes of a product item.
11. See, for example, United Nations Economic Commission for Europe et al. (2009), Chapter 10, p. 147, expression 10.1. There, the quantity weights are for a base period other than the base period for the price observations because of the additional time often needed to obtain the data for estimating the index weights. We ignore this additional complication in this chapter.
12. There are many documented examples of narrowly defined products for both households and businesses being available from different producers for different prices. See, for example, Byrne, Kovak, and Michaels (2009); Foster, Haltiwanger, and Syverson (2008); and Klier and Rubenstein (2009).
13. While not defining the product-level product rule as we do here, von der Lippe and Diewert (2010) do make a similar sort of argument. They note that economic agents often purchase and sell the same commodity at different prices over a single

accounting period. They assert that a bilateral index-number formula requires that these multiple transactions in a single commodity be summarized in terms of a single price and quantity for the period. They explain, moreover, that if the quantity is taken to be the total number of units purchased or sold during the period and it is desired to have the product of the price summary statistic and the total quantity transacted be equal to the value of the transactions during the period, then the single price must be the average value. They note that this point was also made by Walsh (1901, p. 96; 1921, p. 88) and Davies (1924, 1932) and more recently by Diewert (1995). See Diewert (1987) and Diewert and Nakamura (2007) on the conventional product test.

14. Note that if there truly is just one price for each unit time period as each product *n* is defined, then each individual price observation equals $p_n^{t,\bullet}$ for the given *n*,*t* combination. Hence, the condition in Equation (2.11) will be satisfied when the conventional statistical agency practice of utilizing a single price observation for each product in each time period is followed.
15. The term "hybrid" was suggested to Marshall Reinsdorf by Harlan Lopez of the Central Bank of Nicaragua.
16. By "raw" we mean transactions data not already aggregated over time. Providers of what is labeled "transactions data" often, in fact, deliver data sets consisting of the total quantities transacted and the unit values for some unit time period such as a week. See, for instance, Nakamura, Nakamura, and Nakamura (2011) for a study done using transactions data of this sort.
17. See, for example, Ivancic, Diewert, and Fox (2011) and Nakamura, Nakamura, and Nakamura (2011).
18. In defining these formulas, we ignore the important aspect of conventional practice that is the focus of the Lowe index literature: namely, that the data used in estimating the value shares is collected separately from the price information used in index making, and is not usually even for the same time periods. See Balk (2008, Chapter 1) and Diewert (1993) for more on this issue.
19. For a formal proof of this result, see Diewert and Nakamura (2010, appendix), where this result was first presented.
20. For more on the practical aspects of these "revolutionary changes" that Denison (1962) noted and foresaw, see Brown (1997); Freeman et al. (2011); Hausman and Leibtag (2007, 2009); Jones, Garg, and Sheedy (1999); and Senker (1990).
21. Important papers on this topic include Greenlees and McClelland (2011), Hausman (2003), Hausman and Leibtag (2007, 2009), and Moulton (1993, 1996a,b). Also, White (2000) presents related evidence for Canada.
22. For more on the importance of temporary sales for explaining retail price dynamics, see Nakamura and Steinsson (2008, 2012), Pashigian (1988), and Pesendorfer (2002).
23. The same is true for Statistics Canada (1996, p. 5): "Since the Consumer Price Index is designed to measure price changes experienced by Canadian consumers, the prices used in the CPI are those that any consumer would have to pay on the day of the survey. This means that if an item is on sale, the sale price is collected."

The BLS does, however, have other special procedures for handling sale prices of apparel at the end of the selling season.

24. The statistical agencies for some U.S. trading partners exclude temporary sale prices in compiling their Consumer Price Index (CPI). For example, price collectors are instructed by the Statistics Bureau of Japan not to collect sale prices. More specifically, price collectors are instructed that "the following prices are excluded: Extra-low prices due to the bargain sales, clearance sales, discount sales, etc., which are held for less than seven days" (Statistics Bureau of Japan 2012, p. 3, item 10). (See also Imai, Shimizu, and Watanabe [2012].) This methodology difference could definitely affect inter-nation comparisons of inflation, economic growth, and well-being, and the formula in Equation (2.34) can be useful for understanding these effects.
25. We thank Brent Moulton for comments that greatly improved this section of the chapter.
26. Supply chain models like what Oberfield (2013) specifies assume that much of what typically is measured as technical progress in fact reflects the cost savings from supplier switches.
27. Houseman et al. (2011) provide a variety of relevant empirical evidence for the MPI case.
28. Note that the terms in Equation (2.34) involving d_n^0 drop out of the final expression in this case, and also that here we have $S^0 = 1$ because, in period 0, there is only the one supplier for Business 3, charging a single price.
29. Equation (2) in Reinsdorf and Yuskavage (2014) modifies this formula to use a value share weight instead of a quantity share by multiplying by a factor that is between 1 and $1/d^1$. Also, Houseman et al. (2010, p. 70) derive a formula for calculating quantity shares from value shares and the discount d^1. A related formula for outlet substitution bias is found in Diewert (1998, p. 51).
30. Houseman et al. (2011) also provide relevant empirical evidence for the IPI bias case, including pointing out evidence in studies of others about the cost savings possible to a business from switching from domestic to foreign suppliers for intermediate products. They note as well that "the foreign price deflator for intermediate materials rose somewhat *faster* than the domestic deflator" (p. 122). This result is the opposite of what, as they explain, would be the expected result and could be explained by price-index bias problems of the sort we consider here and in the previous section. They empirically implement a bias correction to an input price index under a range of alternative possible assumptions.
31. See Eldridge and Harper (2010); Kurz and Lengermann (2008); and Yuskavage, Strassner, and Medeiros (2008).
32. This point was independently noted both by Diewert and Nakamura (2010) and by Reinsdorf and Yuskavage (2014).
33. An additional conceptual test is international aggregation, as in Maddison (2001). The sum of world GDP should be a consistent measure of world investment and consumption; this implies that exports and imports (with shipping costs) equate across nations in real terms. Eliminating sourcing biases moves us toward an ability to meet this test.

34. From 1948 to 1959, the relevant BLS price index services and Sears and Montgomery Ward prices grew by 50 percent, whereas the Farm Index series grew by less than 10 percent.
35. Alterman (1991) proposes and checks out other possible explanations as well for the results he observed, but he reports that those other hypotheses were rejected by the data.
36. Written comments by Pinelopi Koujianou Goldberg on Nakamura and Steinsson (2012), shared with us by those authors, led us to see this point, and made us aware that similar issues may affect a variety of other studies and views on changes over time in price flexibility and related issues for the U.S. economy and for international comparisons.
37. There is an even larger knowledge gap opening up between the business world and the official statistics agencies as the business world now begins to move from UPCs and bar code scanners to Electronic Product Code (EPC) and Radio Frequency Identification (RFID) usage. See Roberti (2005) for more on the nature of and reasons for this continuing evolution.
38. The Ad Hoc Committee consisted primarily of presidents, vice presidents, and CEOs who were selected from manufacturers, distributors, and retailers so as to ensure that the interests of all parts of the grocery supply chain were represented. In addition to being corporate executives, the individuals selected for the committee had significant knowledge, respect, and influence within the entire industry.
39. See http://www.upccode.net/upc-guide/uniform-code-council.html.
40. On how bar codes can be obtained in each nation, see http://www.gs1.org/barcodes/need_a_bar_code. For more on this history, see http://en.wikipedia.org/wiki/Universal_Product_Code and also Kennedy (2013).
41. Walmart's superior information systems have even enabled the company to respond better to emergencies such as hurricanes than government agencies, as was widely reported during Hurricane Katrina (see, e.g., Barbaro and Gillis 2005).
42. We focus on just the bias problems for the CPI and MPI here because those bias problems affect the computation of real GDP. In contrast, whereas bias problems for the PPI or the proposed IPI are relevant for estimation of real input values for intermediate products, these problems do not affect in any direct way the computation of official real GDP estimates, hence they do not directly affect the labor productivity growth estimates of official statistics agencies like the BLS. Houseman (2007, 2009, 2011) and Mandel (2007, 2009) have explored and helped raise interest in these issues. See also Fukao and Arai (Chapter 7, this volume); Howells et al. (2013); Inklaar (2012); and Strassner, Yuskavage, and Lee (2009).
43. Haskel et al. (2012) refer to BLS data series #PRS85006092 at http://www.bls.gov.
44. So if an establishment, in fact, charged or paid multiple per-unit prices for a chosen product in a given month, there would be no evidence of this in the BLS price-quote data.
45. As noted above, the geometric mean indexes used in the CPI amount to averaging prices, but the sample of prices that are averaged is held constant between the two time periods being compared. In contrast, unit-value indexes allow the composition of the averages to change.

46. It is important for this sampling to include Internet and multichannel retailers (Metters and Walton 2007).
47. Indeed, the UPC-identified products may be too narrowly defined in some cases, so sometimes it may be judged to be better for inflation measurement purposes to treat a stated group of UPCs as being all for the same product.
48. For example, we have not even made a start on considering the problems of producing unit values for products such as computers that are currently handled using hedonic methods (see, for example, Baldwin et al. [1996], Berndt and Rappaport [2001], Pakes [2003], and Pakes and Erickson [2011]), or pharmaceuticals and medical services (Berndt and Newhouse 2012).
49. The Australian Bureau of Statistics and the New Zealand Bureau of Statistics have reportedly been exploring ways of obtaining supermarket scanner data directly from the main supermarket chains in those nations and then of using weekly unit-value prices for grocery products that are computed by the statistical agencies directly from grocery-store scanner data. Also, as Guðmundsdóttir, Guðnason, and Jónsdóttir (2008) explain, Statistics Iceland collects electronic data from the information systems of firms. Besides prices and quantities, the data Statistics Iceland harvests show customer identifiers and business terms for each customer at the time of the trade. Statistics Iceland reports that electronic data collection has resulted in lower collection costs and lighter response burdens for the participating firms. Statistics Iceland also reports that when the agency switched to electronic data collection from firms, it was also able to adopt a superlative approach for price-index compilation. Feenstra et al. (2013) analyze several sources of mismeasurement in the U.S. terms of trade and find that one important source of bias comes from the fact that the import and export price indexes published by the BLS are Laspeyres indexes, rather than being based on a superlative formula.
50. The CPI Research Database is a confidential data set that contains all the product-level nonshelter price and characteristics data that were used to construct the CPI from 1988 to the present. The goods and services included in the CPI Research Database represent about 70 percent of consumer expenditures, the excluded categories being rent and owners' equivalent rent. Nakamura and Steinsson (2008, 2012) created analogous data sets from the production files underlying the PPI and also the MPI and XPI. Those data sets have become the new research databases for the PPI and International Price Program. These BLS research databases are enabling far-reaching and fundamental advances in economic understanding.
51. It is possible that more than financial resources will be required. Participation in all BLS price surveys is voluntary, unlike the situation in many nations, and some businesses may consider the provision of electronic price and quantity data to be more burdensome than the current BLS data collection procedures.

Appendix 2A

Putting the Picture Together with a Final Example

The BLS collects and uses prices for the CPI regardless of whether they are "regular" or "sale" prices. In contrast, as noted in the text, some U.S. trading partners, such as Japan and the EU countries, exclude sale prices in compiling their CPI programs. A numerical example may help clarify why this choice matters. Consider the hypothetical data in Table 2A.1.

Table 2A.1 Regular and Temporary Sale Transaction Data for a Product

	Price ($)	Quantity	Transaction value ($)
		Period ($t = 0$)	
Regular price transactions for product *n*	2.00	2,000	4,000
Temporary sale discount price transactions	1.00	3,000	3,000
Total		5,000	7,000
		Period ($t = 1$)	
Regular price transactions for product *n*	2.20	1,000	2,200
Temporary sale discount price transactions	1.15	4,000	4,600
Total		5,000	6,800

Case 1. Suppose that only the regular price quotes are used for compiling a price index. As for the estimates of the value weights, following conventional practice, suppose these come from a household survey that does not distinguish between regular and sale transactions and will reflect all transactions for a product. With the hypothetical data in rows 1 and 4 of Table 2A.1 for regular price transactions, the resulting Laspeyres, Paasche, and Fisher price indexes[1] all equal 1.1.

Case 2. Next, suppose that both the regular and sale prices are used, treating the items of product *n* sold at regular price as a different product from the items sold during temporary sale periods. If we do that,[2] we get $P_L^{0,1} = 1.121$, $P_P^{0,1} = 1.333$, and $P_F^{0,1} = (P_L^{0,1} P_P^{0,1})^{1/2} = 1.127$.[3] Note that only the quantities of the product sold at the regular price are used now as weights for the observed regular-price quotes, and only the quantities of the product sold at a temporary sale price are used as weights for those price quotes, which is what one might expect to be the procedural implication of treating the two groups of units of the product as *different* products.

Case 3. Finally, suppose we treat each unit of a product as being the same regardless of whether it is sold at regular price or at a discount during a temporary sale period. In this case, we first compute the average price for the product *n* in each period:

$$\overline{p_n^{0,\bullet}} = \frac{\$4{,}000 + \$3{,}000}{2{,}000 + 3{,}000} = 1.4 \text{ and}$$

$$\overline{p_n^{1,\bullet}} = \frac{\$2{,}200 + \$4{,}600}{1{,}000 + 4{,}000} = 1.36.$$

Using the average prices for the price variable and the total transaction volumes for the quantity variable in each price index,[4] now we get

$$P_L^{0,1} = P_P^{0,1} = P_F^{0,1} = 0.9714.$$

In Period 0 and also in Period 1, the quantity of 5,000 units of product *n* was transacted. These transactions had a nominal value of $4,000 in Period 0 and $6,800 in Period 1. If we deflate the Period 1 nominal value by 0.9714, we get a *real value* of $7,000, so we find no change in the "real value" from Period 0 to 1: a result that is in agreement with the data on the physical quantities transacted. This result only pertains to the last of the above approaches for calculating a price index; the others do not yield this outcome.

Appendix Notes

1. $P_L^{0,1} = \frac{\$2.20\times(2{,}000+3{,}000 \text{ items})}{\$2.00\times(2{,}000+3{,}000 \text{ items})} = 1.1$, $P_P^{0,1} = \frac{\$2.20\times(1{,}000+4{,}000 \text{ items})}{\$2.00\times(1{,}000+4{,}000 \text{ items})} = 1.1$,

   and $P_F^{0,1} = (P_L^{0,1} P_P^{0,1})^{1/2}$.

2. We note again that the U.S. CPI actually would employ a geometric mean, rather than Laspeyres, formula.

3. $P_L^{0,1} = \frac{(\$2.20\times 2{,}000 \text{ items})+(\$1.15\times 3{,}000 \text{ items})}{(\$2.00\times 2{,}000 \text{ items})+(\$1.00\times 3{,}000 \text{ items})} = 1.1$ and

   $P_P^{0,1} = \frac{(\$2.20\times 1{,}000 \text{ items})+(\$1.15\times 4{,}000 \text{ items})}{(\$2.00\times 1{,}000 \text{ items})+(\$1.00\times 4{,}000 \text{ items})} = 1.3.$

   $P_L^{0,1} = \frac{\$1.36\times(2{,}000+3{,}000 \text{ items})}{\$1.40\times(2{,}000+3{,}000 \text{ items})} = 0.971$ and

   $P_L^{0,1} = \frac{\$1.36\times(1{,}000+4{,}000 \text{ items})}{\$1.40\times(1{,}000+4{,}000 \text{ items})} = 0.971.$

Appendix 2B

An Example Showing How Product Definitions Matter

The producer-side product substitution bias problems identified by Nakamura and Steinsson (2008, 2012) and the sourcing substitution bias problems identified by Diewert and Nakamura (2010) have in common the fact that the solutions to both necessarily involve some sort of averaging of per-unit prices for products with different UPCs. As already noted, these bias problems force a consideration of how products are defined.

UPCs have the desirable attributes of being documented and electronically recognizable. Also, business data systems are built to keep track of product purchases and sales using UPC information, making it easy for businesses to provide information to statistical agencies for products identified by UPCs.

Consider the case of an economy with just two commercially distinct output products, *A* and *B*. We will briefly examine the measurement consequences of treating the two products as distinct for both price and value-share data collection purposes versus grouping them together as a single product. We will assume we have full price and quantity data for all transactions for the two products in both periods $t = 0$ and $t = 1$, and that there truly is just one price per product in each time period.

In row 1 of Table 2B.1 we show the nominal output growth ratio. Below that on the left-hand side we show the Fisher price index, the real output growth ratio created by deflating the nominal revenue ratio by the Fisher price index (which equals the Fisher quantity index), and the Fisher labor productivity index. (The results if a Laspeyres price index is used instead can be seen by ignoring the second term in the left-hand column and not taking the indicated square root in both row 2 and row 3 and also in the numerator in row 4.)

The counterpart expressions that are obtained if we use the same full transactions data but treat products *A* and *B* as the same product for measurement purposes are shown on the right-hand side of the table. The nominal revenue ratio is shown in the middle of row 1 because it is unchanged by whether we treat products *A* and *B* as distinct or as the same product for measurement purposes.

The consequences of choices made about product definitions are clearest perhaps from the quantity growth ratios in row 3. When we distinguish the products, the quantity growth measure involves price-weighted aggregates, whereas when we treat the items of *A* and *B* as all being items of the same index basket product, then the numbers of items of each are simply added into the total for each period without the use of weights.

Table 2B.1 The Consequences of Treating Two Products as Distinct versus the Same Index Basket Product

Using a Fisher price index for deflation with A and B treated as distinct index basket products	Using a Fisher price index for deflation with A and B treated as the same index basket product
$\frac{R^1}{R^0}=\frac{p_A^1q_A^1+p_B^1q_B^1}{p_A^0q_A^0+p_B^0q_B^0}$	
$P_F^{0,1}=\left[\left(\frac{p_A^1q_A^0+p_B^1q_B^0}{p_A^0q_A^0+p_B^0q_B^0}\right)\left(\frac{p_A^1q_A^1+p_B^1q_B^1}{p_A^0q_A^1+p_B^0q_B^1}\right)\right]^{(1/2)}$	$P_F^{0,1}=\frac{(p_A^1q_A^1+p_B^1q_B^1)/(q_A^1+q_B^1)}{(p_A^0q_A^0+p_B^0q_B^0)/(q_A^0+q_B^0)}$ $=\left(\frac{R^1}{R^0}\right)\left(\frac{q_A^0+q_B^0}{q_A^1+q_B^1}\right)$
$\left(\frac{R^1}{R^0}\right)/P_F^{0,1}=\left[\left(\frac{p_A^0q_A^1+p_B^0q_B^1}{p_A^0q_A^0+p_B^0q_B^0}\right)\left(\frac{p_A^1q_A^1+p_B^1q_B^1}{p_A^1q_A^0+p_B^1q_B^0}\right)\right]^{(1/2)}$	$\left(\frac{R^1}{R^0}\right)/P_F^{0,1}=\frac{q_A^1+q_B^1}{q_A^0+q_B^0}$
$LP_F^{0,1}=\frac{\left[\left(\frac{p_A^0q_A^1+p_B^0q_B^1}{p_A^0q_A^0+p_B^0q_B^0}\right)\left(\frac{p_A^0q_A^1+p_B^0q_B^1}{p_A^0q_A^0+p_B^0q_B^0}\right)\right]^{(1/2)}}{\left(L_A^1+L_B^1\right)/\left(L_A^0+L_B^0\right)}$	$LP_F^{0,1}=\frac{\left(\frac{q_A^1+q_B^1}{q_A^0+q_B^0}\right)}{\left(L_A^1+L_B^1\right)/\left(L_A^0+L_B^0\right)}$

References

Alterman, William. 1991. “Price Trends in U.S. Trade: New Data, New Insights.” In *International Economic Transactions: Issues in Measurement and Empirical Research*, Peter Hooper and J. David Richardson, eds. NBER Studies in Income and Wealth 55. Chicago: University of Chicago Press, pp. 109–143.

———. 2008. “Globalization and Price Measurement Challenges and Options.” PowerPoint presentation at the “World Congress on National Accounts and Economic Performance Measures for Nations,” held in Washington, DC, May 13–17.

———. 2009. “Producing an Input Price Index.” Paper presented at the conference “Measurement Issues Arising from the Growth of Globalization,” held in Washington, DC, November 6–7.

Baldwin, Andrew, Pierre Després, Alice Nakamura, and Masao Nakamura. 1996. “New Goods from the Perspective of Price Index Making in Canada and Japan.” In *The Economics of New Goods*, Timothy F. Bresnahan and Robert J. Gordon, eds. Chicago: University of Chicago Press, pp. 437–476.

Balk, Bert M. 2008. *Price and Quantity Index Numbers: Models for Measuring Aggregate Change and Difference*. Cambridge: Cambridge University Press.

Barbaro, Michael, and Justin Gillis. 2005. “Wal-Mart at Forefront of Hurricane Relief.” *Washington Post*, September 6. http://www.washingtonpost.com/wp-dyn/content/article/2005/09/05/AR2005090501598.html (accessed March 31, 2014).

Bergin, Paul R., Robert C. Feenstra, and Gordon H. Hanson. 2009. “Offshoring and Volatility: Evidence from Mexico’s Maquiladora Industry.” *American Economic Review* 99(4): 1664–1671.

Berndt, Ernst R., and Joseph P. Newhouse. 2012. “Pricing and Reimbursement in U.S. Pharmaceutical Markets.” In *The Oxford Handbook of the Economics of the Biopharmaceutical Industry*, Patricia M. Danzon and Sean Nicholson, eds. New York: Oxford University Press, pp. 201–265.

Berndt, Ernst R., and Neal J. Rappaport. 2001. “Price and Quality of Desktop and Mobile Personal Computers: A Quarter-Century Historical Overview.” *American Economic Review* 91(2): 268–273.

Brown, Stephen A. 1997. *Revolution at the Checkout Counter: The Explosion of the Bar Code.* Cambridge, MA: Harvard University Press.

Bureau of Labor Statistics (BLS). 2007a. “Consumer Expenditures and Income.” In *The BLS Handbook of Methods*. Washington, DC: Bureau of Labor Statistics, pp. 1–9. http://www.bls.gov/opub/hom/pdf/homch16.pdf (accessed April 1, 2014).

———. 2007b. "The Consumer Price Index." In *The BLS Handbook of Methods*. Washington, DC: Bureau of Labor Statistics, pp. 1–108. http://www.bls.gov/opub/hom/pdf/homch17.pdf (accessed April 1, 2014).

———. 2007c. "International Price Indexes." In *The BLS Handbook of Methods*. Washington, DC: Bureau of Labor Statistics, pp. 154–159. http://www.bls.gov/opub/hom/pdf/homch15.pdf (accessed March 31, 2014).

———. 2007d. "Producer Prices." In *The BLS Handbook of Methods*. Washington, DC: Bureau of Labor Statistics, pp. 1–16. http://www.bls.gov/opub/hom/pdf/homch14.pdf (accessed March 31, 2014).

Byrne, David, Brian K. Kovak, and Ryan Michaels. 2009. "Offshoring and Price Measurement in the Semiconductor Industry." Paper presented at the conference "Measurement Issues Arising from the Growth of Globalization," held in Washington, DC, November 6–7.

Davies, George R. 1924. "The Problem of a Standard Index Number Formula." *Journal of the American Statistical Association* 19(146): 180–188.

———. 1932. "Index Numbers in Mathematical Economics." *Journal of the American Statistical Association* 27(177A): 58–64.

Denison, Edward F. 1962. *The Sources of Economic Growth in the United States and the Alternatives before Us*. New York: Committee for Economic Development.

Diewert, W. Erwin. 1976. "Exact and Superlative Index Numbers." *Journal of Econometrics* 4(2): 115–145. Reprinted in *Essays in Index Number Theory*, Vol. 1, W. Erwin Diewert and Alice O. Nakamura, eds., pp. 223–252. Contributions to Economic Analysis 217. Bingley, UK: Emerald Group Publishing, 1993.

———. 1987. "Index Numbers." In *The New Palgrave: A Dictionary of Economics*, Vol. 2, John Eatwell, Murray Malgate, and Peter Newman, eds. New York: Palgrave Macmillan, pp. 767–780.

———. 1992. "Fisher Ideal Output, Input, and Productivity Indexes Revisited." *Journal of Productivity Analysis* 3(3): 211–248. Reprinted in *Essays in Index Number Theory*, Vol. 1, W. Erwin Diewert and Alice O. Nakamura, eds., pp. 317–357. Contributions to Economic Analysis 217. Bingley, UK: Emerald Group Publishing, 1993.

———. 1993. "The Early History of Price Index Research." In *Essays in Index Number Theory*, Vol. 1, W. Erwin Diewert and Alice O. Nakamura, eds. Bingley, UK: Emerald Group Publishing, pp. 33–65.

———. 1995. "Axiomatic and Economic Approaches to Elementary Price Indexes." Discussion paper. Vancouver, BC: University of British Columbia, Department of Economics. Reprinted in *Price and Productivity Measurement*. Vol. 6, *Index Number Theory*, W. Erwin Diewert, Bert M. Balk, Dennis Fixler, Kevin J. Fox, and Alice O. Nakamura, eds., pp. 333–360. Bloomington, IN: Trafford Publishing, 2010.

———. 1998. “Index Number Issues in the Consumer Price Index.” *Journal of Economic Perspectives* 12(1): 47–58.

———. 2007. “Measuring Productivity in the System of National Accounts.” Discussion Paper No. 07-06. Vancouver, BC: University of British Columbia, Department of Economics. http://www.economics.ubc.ca/files/2013/06/pdf_paper_erwin-diewert-07-06-measuring-productivity.pdf (accessed April 1, 2014).

———. 2013a. “The Consumer Price Index: Recent Developments.” Discussion Paper No. 13-12. Vancouver, BC: University of British Columbia, Vancouver School of Economics. http://www.price.e.u-tokyo.ac.jp/img/news/0300Diewert.pdf (accessed April 1, 2014).

———. 2013b. “Irving Fisher and Index Number Theory.” *Journal of the History of Economic Thought* 35(2): 199–232.

Diewert, W. Erwin, and Alice O. Nakamura. 1993. *Essays in Index Number Theory*, Vol. 1. Contributions to Economic Analysis 217. Bingley, UK: Emerald Group Publishing.

———. 2007. “The Measurement of Productivity for Nations.” In *Handbook of Econometrics*, Vol. 6A, James J. Heckman and Edward E. Leamer, eds. Amsterdam: North-Holland, pp. 4501–4586.

———. 2010. “Bias Due to Input Source Substitutions: Can It Be Measured?” Discussion Paper 10-06. Vancouver, BC: University of British Columbia, Department of Economics.

Eldridge, Lucy P., and Michael J. Harper. 2010. “Effects of Imported Intermediate Inputs on Productivity.” *Monthly Labor Review* 133(6): 3–15.

Feenstra, Robert C., Benjamin R. Mandel, Marshall B. Reinsdorf, and Matthew J. Slaughter. 2013. “Effects of Terms of Trade Gains and Tariff Changes on the Measurement of U.S. Productivity Growth.” *American Economic Journal: Economic Policy* 5(1): 59–93.

Feenstra, Robert C., and Clinton R. Shiells. 1997. “Bias in U.S. Import Prices and Demand.” In *The Economics of New Goods*, Timothy F. Bresnahan and Robert J. Gordon, eds. NBER Studies in Income and Wealth 58. Chicago: University of Chicago Press, pp. 249–276.

Fisher, Irving. 1922. *The Making of Index Numbers: A Study of Their Varieties, Tests, and Reliability*. Boston: Houghton Mifflin.

Foster, Lucia, John Haltiwanger, and Chad Syverson. 2008. “Reallocation, Firm Turnover, and Efficiency: Selection on Productivity or Profitability?” *American Economic Review* 98(1): 394–425.

Freeman, Richard B., Alice O. Nakamura, Leonard I. Nakamura, Marc

Prud'homme, and Amanda Pyman. 2011. "Wal-Mart Innovation and Productivity: A Viewpoint." *Canadian Journal of Economics* 44(2): 486–508.

Greenlees, John S., and Robert McClelland. 2011. "New Evidence on Outlet Substitution Effects in Consumer Price Index Data." *Review of Economics and Statistics* 93(2): 632–646. http://www.mitpressjournals.org/doi/pdf/10.1162/REST_a_00107 (accessed April 1, 2014).

GS1.org. 2014. *GS1, the Global Language of Business: About*. Lawrenceville, NJ: GS1.org. http://www.gs1.org/epcglobal/about (accessed April 8, 2014).

Guðmundsdóttir, Heiðrún, Rósmundur Guðnason, and Guðrún R. Jónsdóttir. 2008. "Electronic Data Collection Methods: The Use of Transaction Data for PPI." Paper presented at the 2008 World Congress on National Accounts and Economic Performance Measures for Nations, held in Washington, DC, May 12–17.

Haskel, Jonathan, Robert Z. Lawrence, Edward E. Leamer, and Matthew J. Slaughter. 2012. "Globalization and U.S. Wages: Modifying Classic Theory to Explain Recent Facts." *Journal of Economic Perspectives* 26(2): 119–140.

Hausman, Jerry. 2003. "Sources of Bias and Solutions to Bias in the Consumer Price Index." *Journal of Economic Perspectives* 17(1): 23–44.

Hausman, Jerry, and Ephraim Leibtag. 2007. "Consumer Benefits from Increased Competition in Shopping Outlets: Measuring the Effect of Wal-Mart." *Journal of Applied Econometrics* 22(7): 1157–1177.

———. 2009. "CPI Bias from Supercenters: Does the BLS Know That Wal-Mart Exists?" In *Price Index Concepts and Measurement*, W. Erwin Diewert, John S. Greenlees, and Charles R. Hulten, eds. NBER Studies in Income and Wealth 70. Chicago: University of Chicago Press, pp. 203–231.

Houseman, Susan N. 2007. "Outsourcing, Offshoring, and Productivity Measurement in United States Manufacturing." *International Labour Review* 146(1–2): 61–80. http://research.upjohn.org/up_workingpapers/130/ (accessed April 1, 2014).

———. 2009. "Measuring Offshore Outsourcing and Offshoring: Problems for Economic Statistics." *Upjohn Institute Employment Research* 16(1): 1–3. http://research.upjohn.org/cgi/viewcontent.cgi?article=1031&context=empl_research (accessed April 1, 2014).

———. 2011. "Research Spotlight: Offshoring and Import Price Measurement: Selected Research from the Conference on 'Measurement Issues Arising from the Growth of Globalization'." *Survey of Current Business* 91(2): 7–11.

Houseman, Susan N., Christopher Kurz, Paul Lengermann, and Benjamin R. Mandel. 2010. "Offshoring Bias in U.S. Manufacturing: Implications for Productivity and Value Added." International Finance Discussion Paper No. 1007. Washington, DC: Board of Governors of the Federal Reserve

System. http://www.federalreserve.gov/pubs/ifdp/2010/1007/ifdp1007.pdf (accessed April 1, 2014).

———. 2011. "Offshoring Bias in U.S. Manufacturing." *Journal of Economic Perspectives* 25(2): 111–132.

Howells, Thomas F. III, Matthew Russell, Jon D. Samuels, and Erich H. Strassner. 2013. "Imports and Estimates of Industry Growth and Productivity." Paper presented at the conference "Measuring the Effects of Globalization," held in Washington, DC, February 28–March 1. http://www.upjohn.org/MEG/papers/Imports%20Industry%20GDP%20HRSS.pdf (accessed April 1, 2014).

Imai, Satoshi, Chihiro Shimizu, and Tsutomu Watanabe. 2012. "How Fast Are Prices in Japan Falling?" CARF Working Paper F-298. Tokyo: University of Tokyo, Center for Advanced Research in Finance. http://www.carf.e.u-tokyo.ac.jp/pdf/workingpaper/fseries/310.pdf (accessed April 2, 2014).

Inklaar, Robert. 2012. "Offshoring Bias in Manufacturing Growth across Advanced and Emerging Economies." Unpublished paper. Groningen, the Netherlands: University of Groningen. https://pwt.sas.upenn.edu/workshop2012/Offshoring%20bias%20in%20manufacturing%20growth.pdf (accessed April 2, 2014).

International Labour Organization, International Monetary Fund, Organisation for Economic Co-operation and Development, Statistical Office of the European Communities, United Nations Economic Commission for Europe, and World Bank. 2004a. *Consumer Price Index Manual: Theory and Practice*. Geneva: International Labour Organization. http://unstats.un.org/unsd/EconStatKB/KnowledgebaseArticle10130.aspx (accessed April 2, 2014).

———. 2004b. *Producer Price Index Manual: Theory and Practice*. Washington, DC: International Monetary Fund. http://www.cbs.gov.il/price_new/b_1_1link1.pdf (accessed April 2, 2014).

———. 2009. *Export and Import Price Index Manual: Theory and Practice*. Washington, DC: International Monetary Fund. http://www.imf.org/external/np/sta/xipim/pdf/xipim.pdf (accessed April 2, 2014).

Ivancic, Lorraine, W. Erwin Diewert, and Kevin J. Fox. 2011. "Scanner Data, Time Aggregation, and the Construction of Price Indexes." *Journal of Econometrics* 161(1): 24–35.

Jones, Charles, Vineet Garg, and Christopher Sheedy. 1999. *17 Billion Reasons to Say Thanks: The 25th Anniversary of the U.P.C. and Its Impact on the Grocery Industry*. London: PricewaterhouseCoopers. http://idhistory.com/smithsoniancelebration/17BillionReasons.pdf (accessed April 1, 2014).

Kaplan, Greg, and Guido Menzio. 2014. "The Morphology of Price Dispersion." NBER Working Paper No. 19877. Cambridge, MA: National Bureau of Economic Research.

Kennedy, Pagan. 2013. "Who Made That Universal Product Code?" *New York Times*, January 4. http://www.nytimes.com/2013/01/06/magazine/who-made-that-universal-product-code.html?_r=0 (accessed April 2, 2014).

Klier, Thomas H., and James M. Rubenstein. 2009. "Imports of Intermediate Parts in the Auto Industry—A Case Study." Paper presented at the conference "Measurement Issues Arising from the Growth of Globalization," held in Washington, DC, November 6–7.

Kurz, Christopher, and Paul Lengermann. 2008. "Outsourcing and U.S. Economic Growth: The Role of Imported Intermediate Inputs." Federal Reserve Board paper presented at the 2008 World Congress on National Accounts and Economic Performance Measures for Nations, held in Arlington, VA, May 12–17.

Laspeyres, Étienne. 1871. "Die Berechnung einer mittleren Waarenpreissteigerung." *Jahrbücher für Nationalökonomie und Statistik* 16(1871): 296–314.

Maddison, Angus. 2001. *The World Economy: A Millennial Perspective*. Development Centre Studies. Paris: Organisation for Economic Co-operation and Development.

Mandel, Michael. 2007. "The Real Cost of Offshoring." *BusinessWeek*, June 18, pp. 28–34. http://innovationandgrowth.files.wordpress.com/2011/04/offshoring1.pdf (accessed April 3, 2014).

———. 2009. "Growth: Why the Stats Are Misleading." *BusinessWeek*, June 3. http://www.businessweek.com/magazine/content/09_24/b4135000594984.htm (accessed April 2, 2014).

Mandel, Michael, and Susan N. Houseman. 2011. "Not All Productivity Gains Are the Same. Here's Why." In *What Matters*. New York: McKinsey.

McClelland, Robert, and Marshall Reinsdorf. 1999. "Small Sample Bias in Geometric Mean and Seasoned CPI Component Indexes." BLS Working Paper No. 324. Washington, DC: Bureau of Labor Statistics.

Metters, Richard, and Steve Walton. 2007. "Strategic Supply Chain Choices for Multi-Channel Internet Retailers." *Service Business* 1(4): 317–331.

Moulton, Brent R. 1993. "Basic Components of the CPI: Estimation of Price Changes." *Monthly Labor Review* 116(12): 13–24.

———. 1996a. "Bias in the Consumer Price Index: What Is the Evidence?" *Journal of Economic Perspectives* 10(4): 159–177.

———. 1996b. "Estimation of Elementary Indexes of the Consumer Price Index." Paper presented at the annual conference of the American Statistical Association, held in Chicago, August 4–8.

Nakamura, Alice O. 2013. "Irving Fisher's Progeny and the 2008 Financial Crisis." *Journal of the History of Economic Thought* 35(2): 185–197. http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=8913212 (accessed April 2, 2014).

Nakamura, Alice O., Emi Nakamura, and Leonard I. Nakamura. 2011. "Price Dynamics, Retail Chains, and Inflation Measurement." *Journal of Econometrics* 161(1): 47–55.

Nakamura, Emi, and Jón Steinsson. 2008. "Five Facts about Prices: A Reevaluation of Menu Cost Models." *Quarterly Journal of Economics* 123(4): 1415–1464. http://www.columbia.edu/~en2198/papers/fivefacts.pdf (accessed April 2, 2014).

———. 2012. "Lost in Transit: Product Replacement Bias and Pricing to Market." *American Economic Review* 102(7): 3277–3316. http://pubs.aeaweb.org/doi/pdfplus/10.1257/aer.102.7.3277 (accessed April 3, 2014).

Nakamura, Leonard I. 1999. "The Measurement of Retail Output and the Retail Revolution." *Canadian Journal of Economics* 32(2): 408–425.

Oberfield, Ezra. 2013. "Business Networks, Production Chains, and Productivity: A Theory of Input-Output Architecture." Working paper. Princeton, NJ: Princeton University. http://economics.emory.edu/home/assets/Seminars%20Workshops/Seminar_2013_Oberfield.pdf (accessed April 2, 2014).

Paasche, Hermann. 1874. "Über die Preisentwicklung der letzten Jahre nach den Hamburger Börsennotirungen." *Jahrbücher für Nationalökonomie und Statistik* 23(1874): 168–178.

Pakes, Ariel. 2003. "A Reconsideration of Hedonic Price Indexes with an Application to PC's." *American Economic Review* 93(5): 1578–1596.

Pakes, Ariel, and Tim Erickson. 2011. "An Experimental Component Index for the CPI: From Annual Computer Data to Monthly Data on Other Goods." *American Economic Review* 101(5): 1707–1738.

Pashigian, B. Peter. 1988. "Demand Uncertainty and Sales: A Study of Fashion and Markdown Pricing." *American Economic Review* 78(5): 936–953.

Pesendorfer, Martin. 2002. "Retail Sales: A Study of Pricing Behavior in Supermarkets." *Journal of Business* 75(1): 33–66.

Price Statistics Review Committee. 1961. *The Price Statistics of the Federal Government.* Report of the Price Statistics Review Committee. Cambridge, MA: National Bureau of Economic Research. http://www.nber.org/chapters/c6479.pdf (accessed April 7, 2014).

Rees, Albert. 1961. "Alternative Retail Price Indexes for Selected Nondurable Goods, 1947–59." In *The Price Statistics of the Federal Government.* Report of the Price Statistics Review Committee. Cambridge, MA: National Bureau of Economic Research, pp. 137–172. http://www.nber.org/chapters/c6491.pdf (accessed April 3, 2014).

Reinsdorf, Marshall B. 1993. "The Effect of Outlet Price Differentials on the U.S. Consumer Price Index." In *Price Measurements and Their Uses*, Murray F. Foss, Marilyn E. Manser, and Allan H. Young, eds. NBER Studies in Income and Wealth 57. Chicago: University of Chicago Press, 227–254.

———. 1994a. "The Effect of Price Dispersion on Cost of Living Indexes." *International Economic Review* 35(1): 137–149.

———. 1994b. "New Evidence on the Relation between Inflation and Price Dispersion." *American Economic Review* 84(3): 720–731.

———. 1994c. "Price Dispersion, Seller Substitution, and the U.S. CPI." BLS Working Paper No. 252. Washington, DC: Bureau of Labor Statistics.

———. 1998. "Formula Bias and Within-Stratum Substitution Bias in the U.S. CPI." *Review of Economics and Statistics* 80(2): 175–187.

———. 1999. "Using Scanner Data to Construct CPI Basic Component Indexes." *Journal of Business and Economic Statistics* 17(2): 152–160.

Reinsdorf, Marshall B., W. Erwin Diewert, and Christian Ehemann. 2002. "Additive Decompositions for Fisher, Törnqvist, and Geometric Mean Indexes." *Journal of Economic and Social Measurement* 28(1–2): 51–61.

Reinsdorf, Marshall B., and Brent R. Moulton. 1997. "The Construction of Basic Components of Cost-of-Living Indexes." In *The Economics of New Good*s, Timothy F. Bresnahan and Robert J. Gordon, eds. NBER Studies in Income and Wealth 58. Chicago: University of Chicago Press, pp. 397–436.

Reinsdorf, Marshall B., and Jack E. Triplett. 2009. "A Review of Reviews: Ninety Years of Professional Thinking about the Consumer Price Index." In *Price Index Concepts and Measurement*, W. Erwin Diewert, John S. Greenlees, and Charles R. Hulten, eds. NBER Studies in Income and Wealth No. 70. Chicago: University of Chicago Press, pp. 17–83.

Reinsdorf, Marshall B., and Robert Yuskavage. 2014. "Effects of Offshoring and Country Substitution on Measurement of Prices and Productivity." Working paper. Washington, DC: Bureau of Economic Analysis.

Roberti, Mark. 2005. "The History of RFID Technology." *RFID Journal*, January 16. http://www.rfidjournal.com/articles/view?1338 (accessed April 4, 2014).

Senker, Jacqueline. 1990. "Technology and Competitive Strategy in Food Retailing." In *The Strategic Management of Technological Innovation*, Ray Loveridge and Martyn Pitt, eds. Somerset, NJ: John Wiley and Sons, pp. 84–94.

Silver, Mick. 2010. "The Wrongs and Rights of Unit Value Indices." *Review of Income and Wealth* 56(S1): S206–S223.

Statistics Bureau of Japan. 2012. *Outline of the Retail Price Survey*. Tokyo: Statistics Bureau of Japan. http://www.stat.go.jp/english/data/kouri/pdf/outline.pdf (accessed April 4, 2014).

Statistics Canada. 1996. *Your Guide to the Consumer Price Index*. Catalogue No. 62-557-XPB. Ottawa: Statistics Canada. http://www.statcan.gc.ca/pub/62-557-x/62-557-x1996001-eng.pdf (accessed April 4, 2014).

Strassner, Erich H., Robert E. Yuskavage, and Jennifer Lee. 2009. "Imported

Inputs and Industry Contributions to Economic Growth: An Assessment of Alternative Approaches." Paper presented at the conference "Measurement Issues Arising from the Growth of Globalization," held in Washington, DC, November 6–7.

Tran, Allen. 2014. "The Aggregate Impact of Online Retail." UCLA working paper. Los Angeles: University of California, Los Angeles.

United Nations Economic Commission for Europe, International Labour Office, International Monetary Fund, Organisation for Economic Co-operation and Development, Statistical Office of the European Communities, World Bank, and the UK Office for National Statistics. 2009. *Practical Guide to Producing Consumer Price Indices*. New York and Geneva: United Nations. http://www.unece.org/fileadmin/DAM/stats/publications/Practical_Guide_to_Producing_CPI.pdf (accessed April 4, 2014).

United Nations Statistics Division. 2014. National Accounts. New York: United Nations Statistics Division. http://unstats.un.org/unsd/nationalaccount/ (accessed April 8, 2014).

von der Lippe, Peter, and W. Erwin Diewert. 2010. "Notes on Unit Value Index Bias." *Journal of Economics and Statistics* (*Jahrbücher für Nationalökonomie und Statistik*) 230(6): 690–708.

Walsh, Correa Moylan. 1901. *The Measurement of General Exchange-Value*. New York: Macmillan Co.

———. 1921. *The Problem of Estimation: A Seventeenth-Century Controversy and Its Bearing on Modern Statistical Questions, Especially Index-Numbers*. London: P.S. King and Son.

White, Alan G. 2000. "Outlet Types and the Canadian Consumer Price Index." *Canadian Journal of Economics* 33(2): 488–505.

Yuskavage, Robert E., Erich H. Strassner, and Gabriel W. Medeiros. 2008. "Domestic Outsourcing and Imported Inputs in the U.S. Economy: Insights from Integrated Economic Accounts." Paper presented at the 2008 World Congress on National Accounts and Economic Performance Measures for Nations, held in Arlington, VA, May 12–17.

Measuring Globalization

Better Trade Statistics for Better Policy

Volume 1

Biases to Price, Output, and Productivity Statistics from Trade

Susan N. Houseman
and
Michael Mandel
Editors

2015

W.E. Upjohn Institute for Employment Research
Kalamazoo, Michigan

Library of Congress Cataloging-in-Publication Data

Measuring globalization : better trade statistics for better policy / Susan N. Houseman and Michael Mandel, editors.
volumes cm
Includes bibliographical references and indexes.
ISBN 978-0-88099-488-0 (v. 1 : pbk. : alk. paper) — ISBN 0-88099-488-6 (v. 1 : pbk. : alk. paper) —ISBN 978-0-88099-489-7 (v. 1 : hardcover : alk. paper) — ISBN 0-88099-489-4 (v. 1 : hardcover : alk. paper)
1. Commercial statistics. I. Houseman, Susan N., 1956- II. Mandel, Michael J.
HF1016.M44 2015
382.01'5195—dc23
2014047579

W.E. Upjohn Institute for Employment Research
300 S. Westnedge Avenue
Kalamazoo, Michigan 49007-4686

Cover design by Alcorn Publication Design.
Index prepared by Diane Worden.
Printed in the United States of America.
Printed on recycled paper.