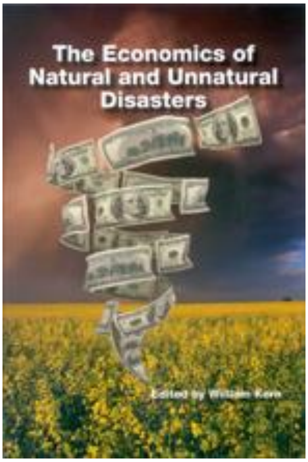
The Economics of Disaster: Retrospect and Prospect



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Chapter 4 (pp. 65-86) in:
The Economics of Natural and Unnatural Disasters
William Kern, ed.
Kalamazoo, MI: W.E. Upjohn Institute for Employment Research, 2010
DOI: 10.17848/9781441678812.ch4

The Economics of Natural and Unnatural Disasters

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Editor

2010

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

Library of Congress Cataloging-in-Publication Data

The economics of natural and unnatural disasters / William Kern, editor.
p. cm.
Includes bibliographical references and index.
ISBN-13: 978-0-88099-362-3 (pbk. : alk. paper)
ISBN-10: 0-88099-362-6 (pbk. : alk. paper)
ISBN-13: 978-0-88099-363-0 (hbk. : alk. paper)
ISBN-10: 0-88099-363-4 (hbk. : alk. paper)
1. Disasters—economic aspects. I. Kern, William S., 1952– II. W.E. Upjohn Institute for Employment Research.
HC79.D45E25 2010
363.34—dc22
2010010590

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.

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The Economics of Disaster

Retrospect and Prospect

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In preparing this chapter, I initially wrote that the economics of hazards and disaster is a subfield of environmental economics. Upon reflection, I crossed that out, replacing it with “the economics of hazards is a subfield of no less than five major fields, including behavioral economics, finance, regional economics, public finance, and environmental economics.” This of course made the retrospective a bit daunting, especially for a chapter of this length. So, in looking back over the last 40 years, I culled a few key ideas that were influential in shaping disaster research over this formative period.

When it came to providing a prospective view, I took the easy path. I limited my coverage to the field that has absorbed my efforts over the past 30 years: that is, the regional and national economic consequences of disaster.

SOME HISTORY

The beginnings of this field can be traced back as far as John Stuart Mill, who, I am embarrassed to admit, preempted much of what I will present in the second half of the paper. Nearly 150 years ago Mill remarked about the economics of disaster, commenting on “what has so often excited wonder, the great rapidity with which countries recover from a state of devastation; the disappearance, in a short time, of all traces of the mischiefs done by earthquakes, floods, hurricanes, and the ravages of war” (quoted in Hirshleifer 1987, p. 79).

Almost a century later, John Kenneth Galbraith corroborated Mill's observations. As director of the Strategic Bombing Survey, Galbraith investigated the impact of Allied bombing raids on the German war machine. The survey concluded that the raids had had little impact. Hamburg recovered nearly 80 percent of its productive capacity within several months after a series of devastating attacks. The bombing raids virtually decimated the city's infrastructure, killed nearly 40,000 people and destroyed 50 percent of the city's buildings (Hirshleifer 1987). Despite these losses, production was only modestly affected.

These early roots provide a glimpse of the field's beginnings. However, it wasn't until the 1960s that four publications helped launch the field: *The Economics of Natural Disasters: Implications for Federal Policy* (Dacy and Kunreuther 1969), *Design of Water-Resource Systems* (Maass et al. 1962), *A Unified National Program for Managing Flood Losses* (U.S. Congress 1966), and "Losses from Natural Hazards" (Russell 1970). Dacy and Kunreuther provided key insights into the economic consequences of disasters (in this case the 1964 Alaskan earthquake). *Design of Water-Resource Systems* set down the procedures for conducting benefit-cost studies of water projects. *A Unified National Program for Managing Flood Losses* encouraged the adoption of a wider range of flood mitigation measures (at least wider than the system of levees and reservoirs the Corps of Engineers had promoted prior to that time) and introduced the idea that flood insurance *might* serve as a mechanism to promote an efficient means of coping with flood hazards. The word *might* is emphasized since the document was wary about insurance, for it was pointed out that an improperly structured insurance program could make things worse. These three publications provided enough starter material to employ a (very) small army of economists for the next 40 years.

From what I gather, Cliff Russell's classic "Losses from Natural Hazards" grew out of his association with the Harvard Water Resources Program and his collaboration with Bob Kates. This association was key since Bob Kates, Gilbert White, and Ian Burton are widely recognized as the field's pioneers. Russell's piece served to convert the basics of water resource economics into the economics of hazard management. In short, he showed that protection from natural events should be adopted so long as the expected marginal benefit (the loss avoided due to protection) exceeded the expected marginal cost of that protection. In hindsight this is not a startling finding, and a direct line can be drawn back to Harvard, particularly the work of Arthur Maass, Maynard M. Hufschmidt, Robert Dorfman, Harold A. Thomas Jr., Stephan A. Marglin, and Gordon Maskew Fair. Despite its simplicity, the idea proved to be a powerful reminder that hazards management involves a balance between costs and losses.

It could be said that Russell's work was foreshadowed by two earlier papers, one by Lester Lave (1963) and the other by Richard Nelson and Sidney Winter (1964). Although their work did not address hazards in the way that Russell did, the framework developed served as a foundation for later work in managing a wide range of hazards. There is of course much more to the story. But a recurring theme in all these works is the interplay of costs and losses, either objective or perceived. The retrospective segment of the paper will thus focus on a few key ideas that grew out of this early body of work. The second part, the prospective view, will concentrate on new avenues of research involving disaster loss. This, in my view, is perhaps the most important yet least understood aspect of the problem.

RETROSPECT

As indicated earlier, there is a vast body of literature to plow through in order to come up with a set of key ideas. Much of what I am about to present is based on the works of Lave (1963), Nelson and Winter (1964), and Howe and Cochrane (1976). All three investigate whether to mitigate losses from a potentially damaging event. They conclude (as did Russell) that the interplay of event probabilities and subsequent consequences shapes that choice. The framework about to be presented draws upon a highly stylized example, one where floods are of a dichotomous nature, and costs, losses, and event probabilities are well known. The presentation assesses the merits of taking action (or not) in view of a short-term flood forecast. It then entertains the possibility that it might be economically advantageous to adopt a more permanent flood mitigation strategy, one that is tied to the probability of flooding alone, ignoring forecasts altogether. Finally, the framework is tweaked to address very long-run changes in climate.

The purpose of this exercise is to demonstrate the power of these simple models. Although not very complex, nor pathbreaking, they offer policymakers valuable insights into how to value meteorological forecasts and even climate change research.

The Value of Forecasts

Should one heed a flood forecast? The answer to this question hinges on the cost of doing something, the loss incurred if a flood occurs (and insufficient protection is afforded), the climatological record, and the accuracy of the forecast. To illustrate, let's begin by characterizing flooding as a dichotomous event: it either occurs or it doesn't (Figure 4.1). Four combinations of flood forecasts and events are shown in Figure 4.1. When forecasts are perfect, P3 and P4 equal zero. But forecasts may be in error; predicted floods fail to materialize, and unpredicted

Figure 4.1 Decision to Adopt Forecast-Sensitive Protection

Probabilities

		Flood forecast	
Flood	No	P1	P2
	Yes	P3	P4

Consequences

		Flood forecast	
Flood	No	0	$C_{\text{short-run}}$
	Yes	Loss	Loss, $C_{\text{short-run}}$

NOTE: Adopt short-run protection if $C_{\text{short-run}} \times (P2 + P4) + \text{Loss} \times P3 < \text{Loss} \times (P3 + P4)$.
SOURCE: Author's calculations.

floods occur. The situation can be visualized as one where sandbags can be added to the levee provided that sufficient lead time is afforded. Whether such a forecast should be used hinges on the expected sum of costs and losses. It makes economic sense to adopt protection and use the forecast if the expected cost of sandbagging, $C(P2 + P4)$, is less than the expected loss, $L(P3 + P4)$.

The Value of Long-Term Protection

One might wonder whether there is a better way to deal with the hazard; a more permanent form of protection might be more efficient. In this case flood forecasts are disregarded in favor of probabilities dictated by the climate. Here the cost of protection is certain and the expected loss is the probability of flooding times loss. Note that these losses and costs are likely to be different from those shown in Figure 4.1, but the interplay of cost and loss is key to adopting protection nonetheless: that is, adopt long-run protection if $C_{\text{long-run}} < L(P3 + P4)$.

A Simple but Powerful Way of Conceptualizing the Hazard Problem

This highly simplistic framework provides some very useful insights into the value of information. One is that it is not always wise to act on a forecast. Errors might be too costly, and doing nothing may be the most economical path. This point is easily demonstrated by asking what a hail forecast is worth to a wheat farmer. Since there are no technically feasible ways of protecting the crop from damage, it follows that the forecast would be worthless (perhaps less than worthless since the farmer would worry about the fate of the crop). The framework also raises the issue of perceptions versus objective measures. If the decision maker is ill equipped to assess the probabilities (as Howard Kunreuther has often pointed out) or does not take into account the full magnitude of losses and costs, then the choice observed will not be the optimal choice. Finally, the value of improving disaster forecasts is a dynamic metric: it hinges on how losses and cost change over time. This may seem a bit abstract, but consider that the current climate change debate revolves around escalating losses observed along the nation’s coastline. At first blush, rising losses could be interpreted to mean that the probabilities have shifted. However, it is just as likely that both the coastal population and the wealth at risk have risen over the past 50 years. The framework just presented allows for either or both. Roger Pielke Jr. (2005) performed a careful analysis of hurricane losses and concluded that rising losses are tied to population and wealth and not to increased frequency and severity. Although there is still a healthy debate about the issue (Emanuel 2005), the cost-loss framework has proven useful in pointing research in the right direction.

A Deeper Look at the Economics of Climate Change

The cost-loss model also lends itself to a deeper analysis of climate change. Although the problem still involves cost, loss, and the probability of disaster, the interpretations are different. The cost of mitigating the effects of climate change is the reduction in economic growth resulting from curtailing CO_2 emissions. The economics of cap-and-trade are pretty clear: investments in cleaner-burning fuels and higher-cost renewables will ratchet growth downward. The cost to GDP is open to debate, but few will argue that the difference in growth paths is the cost of capping emissions. The loss incurred in the event of climatic warming is just as contentious. But much of the debate revolves around the magnitude of loss. There is considerable disagreement regarding the degree to which the climate will change, and predictions of the economic impacts are therefore equally murky. Despite this, no one is arguing that climate change will be benign. If we assume for argument's sake that climate change losses will be disastrous and that anthropogenic CO_2 is in fact the chief culprit, a case can be made for controlling emissions now. Assume that $P_{\text{anthropogenic}}$ is the current assessment regarding the likelihood that anthropogenic CO_2 is the chief cause. Assume too that if emissions are curtailed now, future losses would be mitigated. On the other hand, if no action is taken to control atmospheric carbon, and CO_2 is indeed the causal agent triggering a more varied climate, the decision to do nothing will be irreversible. In contrast, the decision to limit fossil fuel use now can be revisited once the results of climate research become more definitive. This option is reversible if at some later date it is revealed that atmospheric carbon is the product of warming and not the other way around. In the economics literature the benefit of taking action now that may be revised later when updated information is available is referred to as quasioption value.

The factors underlying this decision are the same as those that shaped the use of climate and weather information in the previous cost-loss example. Carbon control is worthwhile if the losses are sufficiently high, the control costs low, and the *a priori* probabilistic assessment of the connection between CO_2 and climate change is high. That is, the decision to curtail anthropogenic CO_2 is optimal if $C_{control}/L_{disaster} < P_{anthropogenic}$. Despite its simplicity, the framework provides a valuable guide for debating climate policy. First, a good case can be made for taking action now despite the uncertainties regarding the causal mechanism. Waiting until these uncertainties are resolved could be the least appealing option. The decision to act now hinges on the cost, the losses, and the current state of knowledge regarding the direction of the causal arrow—that is, the probability that the arrow representing causation points from anthropogenic CO_2 to climate (i.e., anthropogenic CO_2 is causing climate change) rather than from climate to CO_2. Second, the framework properly draws attention to the role of anthropogenic CO_2 rather than to warming itself.

PROSPECTIVE VIEW OF LOSSES

It is clear from the preceding retrospective that losses (either objectively measured or perceived by the decision maker) are crucial to managing natural hazards. However, what constitutes a loss and how losses should be measured remain murky. Before we look at losses in more detail, it is worth taking a moment to reflect on the possibility that the market may have already discounted for locational risk. In other words, the price of housing might already accommodate the location of the property in an area subject to some hazard. If it does, then there is no reason to proceed any further. There has been some debate about this, but in my opinion it is highly unlikely that prospective buyers are well informed about risks of any sort. Howard Kunreuther has spent the better part of his career arguing that decision makers make poor choices because they use simple heuristics. In some cases they totally ignore low-probability events, and in others they overstate the likelihood of high-consequence events. The market for housing (and willingness to pay) reflects this. However, if market prices reflect considerable ignorance and misinformation, it is unwise to utilize them to formulate policy. The recent housing market collapse serves to illustrate this point quite nicely. Despite what orthodox economists claim for the market, I believe, at least for natural hazards, that housing prices provide little useful information regarding willingness to pay for safety. Loss studies are so important precisely because markets provide such unreliable information.

So, what losses are we talking about and how should they be measured? As will be discussed shortly, loss consists of the obvious (damage to buildings, contents, infrastructure, as well as loss of life) and the not-so-obvious (loss of cultural icons, historic monuments, a sense of place, and the indirect economic dislocations stemming from damage). Table 4.1 provides a simple list. I will address each briefly and then move on to regional and national economic impacts, which I will address in more detail.

Property Losses and Deaths

There is a substantial body of work tying wind velocity, ground shaking, and flood depth to property damage and subsequent loss of life. Although empirically estimated damage functions contain a substantial error band, they seem to work fairly well, particularly when damages are aggregated over a wide area. The Federal Emergency Management Agency's HAZUS program (Hazards United States), a sophisticated geographic information system, incorporates such functions for a variety of building types and hazards. In my view, property loss is the least problematic of all the losses. Similarly, there appears to be an empirically verifiable linkage between fatalities and the number of structures destroyed, at least for sudden-onset events such as tornadoes and earthquakes. Thus damage and fatality seem reasonably predictable through available means. The same cannot be said about the other categories of loss I am addressing, including value of life.

The value of a life

Although deaths are predictable, the value attached to each death remains an elusive concept. I realize that this is a highly contentious topic fraught with technical and ethical complexities. Having said that, I want to raise a few issues. Most important, disaster mortality and morbidity models account for statistical lives lost, not identified lives. No one worries about insurance companies that project loss of life and attempt to quantify those losses. An identified life is something quite different, however. No one would or should attempt to assess the value of an identified life. Second, if we are unwilling to attach a value to these so-called statistical deaths, then we might finesse the question by determining how much it costs to preserve a life through protective measures such as land use regulation and improved building codes. It is then up to the public to determine whether the costs are worth it. The benefits of hazard mitigation would have to be weighed against other life-saving options (e.g., dialysis, wellness programs). Although the problems inherent in estimating and valuing loss of life are formidable, they are relatively manageable.

Loss of cultural icons and historic monuments

While a solid foundation exists for the debate over mortality and direct damage to property, the state of knowledge regarding the other losses shown in Table 4.1 pales in comparison. Value is inherent in cultural icons, historic monuments, and a sense of place. Hurricane Katrina did more than destroy the city of New Orleans. The nation lost a cultural heritage that was rich in diversity and steeped in history. Much that has been written about post-Katrina New Orleans bemoans the changes wrought by the storm. The losses suffered go beyond the number of

Table 4.1 An Analysis of Losses

Mortality, morbidity, along with property damage are the best known.
Loss of environmental services, cultural icons, historic monuments, and a sense of place are less well known and understood.
Systemic risk and loss of regional economic activity are also not well understood.

deaths and the damage to buildings inundated because of breached levees, and even beyond New Orleans itself to affect the nation as a whole. Despite the growing body of literature attempting to establish values for nonmarket losses, measurement of iconic value remains a problem. Icons and monuments have market values that are readily measurable through surveys and travel-cost methods. However, such techniques don't reveal their existence value. Research on this rich and intriguing subject is still in its infancy.

Systemic and indirect losses

Systemic and indirect losses are also not well understood. The current financial panic has served to rivet attention on just how large contagion effects and their associated indirect impacts can be. Furthermore, the current economic meltdown underscores an important point. That is, the loss anticipated by any one participant can turn out to be vastly different when interindustry linkages and uncertainty are considered. Or, as Gary Becker said in addressing the 2008 financial meltdown, "While financial specialists understand how individual assets function, even they have limited understanding of the aggregate risks created by the system" (Becker 2008).

This observation bears directly on the cost-loss framework developed earlier, and on willingness to pay for protection. The events of late 2008 and early 2009 have underscored the point that an individual's perceptions are often at odds with systemwide risks. Given this discrepancy, it seems again unwise to rely on market forces to suggest a meaningful measure of willingness to pay for safety. I will spend the remainder of the paper on this topic, emphasizing the likely economic consequences of disaster, how to measure them (including why commonly utilized techniques fail), and why the results of some disasters differ significantly from those of others.

Alternative Ways of Modeling the Regional Economic Response to Shocks

There is currently no clear consensus as to how supply shocks can be successfully modeled. Input-output models have been tried, as have a wide range of alternatives, including computable general equilibrium models, econometric models, and even postevent surveys. They all leave something to be desired. A lot of what I will be discussing relies on a basic understanding of input-output models. A brief discussion of input-output basics is provided in Appendix 4A for those unfamiliar with the technique and its terminology.

Input-output models were designed to explain how final demand changes ripple throughout a region's (or nation's) interconnected sectors. The linkages are rather straightforward. An increase or decrease in demand for one sector's production indirectly boosts or reduces demand for ingredients supplied by other sectors. As a result, a one-dollar change in demand leads to more than one dollar's change in production when all intermediate transactions are accounted for. Input-output models have one fatal limitation: they are incapable of addressing the types of bottlenecks commonly observed after disaster. These models have no way of accounting for the possibility that supplying sectors may lack the capacity to provide needed inputs (leading to forward-linked losses) or, conversely, that producing sectors may lack the capacity to absorb all that their suppliers wish to ship (causing backward-linked losses).

Since the input-output technique implicitly assumes that there are no limits to production, it is incapable of treating the uneven set of supply constraints typically observed after disaster. It would be purely coincidental if the pattern of economic disruption emerging after a natural disaster matched the pre-event production pattern. Therefore, altering final demands to fit postdisaster production patterns would be problematic.

The other techniques just mentioned also have limitations. Computable general equilibrium models (CGEs) are an elaborate form of input-output, with an interindustry table at the core. CGEs permit final demand substitutions as shortages materialize. Unfortunately, the estimates of substitution elasticities embedded in the CGEs are problematic at best, particularly for unique events such as natural disasters. Furthermore, in some cases where a public utility is impacted (such as a water treatment or supply system), there is no meaningful measure of substitutability. CGEs are less useful for that type of loss estimation.

Finally, a shortcoming of both econometric models (particularly time series) and postdisaster surveys is that they are calibrated using a set of unique events. Time series techniques, like *event analysis*, look at the difference between trends with and without a disaster. Although appealing on the surface, event analysis is applied to *an* event. Since it is *an* event, it reflects only the characteristics of that event: the disaster relief policies in place, the pattern of destruction, the nature of the economy, and so on. Therefore, it is difficult to generalize from such an analysis to other potential events. Because of this limitation, event analysis may be useful for forensic studies, but not for policy analysis. A similar criticism applies to postevent surveys. What can one say beyond what the survey indicates about the loss sustained by a particular place, given that it was struck by a particular event at a time when a particular set of disaster relief policies applied? Very little.

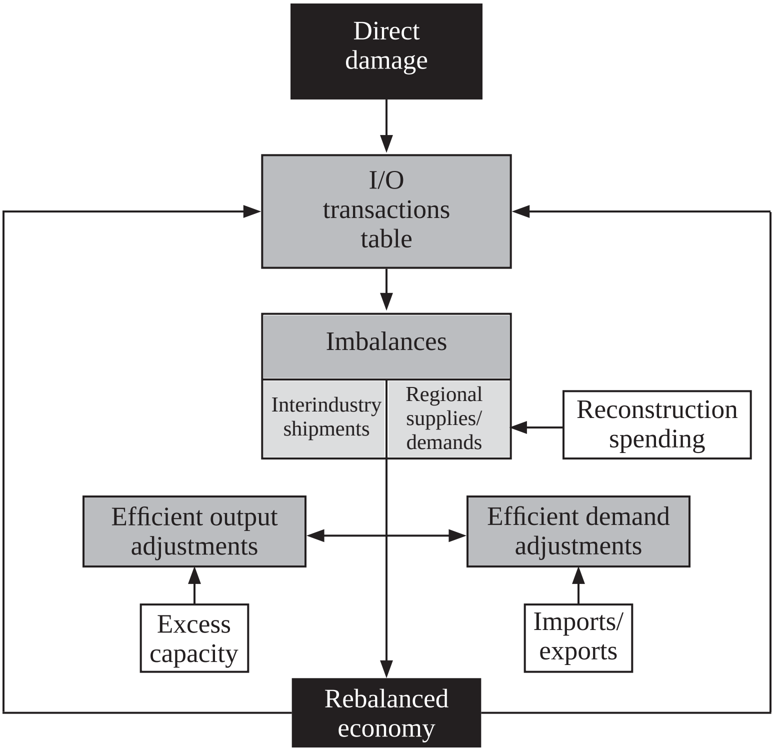
An Algorithm for Analyzing Supply Shocks

An algorithm was developed at Colorado State University to address the shortcomings of the approaches just discussed. As in the case of CGE, the algorithm takes a region's interindustry linkages as its core. It then allows for excess capacity in each sector as a function of the region's rate of unemployment. Furthermore, the algorithm augments internal production with the aid of imports from other regions. Finally, it allows for the stimulative effects of reconstruction spending and the fiscal drag caused by indebtedness. The algorithm then seeks out the best outcome (in terms of regional income) that rebalances the economy. The economy is rebalanced when all excess supplies or demands are eliminated. See Figure 4.2 for a schematic of the rebalancing process.

A simple numerical illustration

I'll use the example input-output table provided in Appendix 4A to analyze a few simple economic shocks. In the simplest shock each sector suffers a proportionate reduction in output. If a disaster eliminates 50 percent of both sectors' capacity, then output in sectors S1 and S2 would be limited to 50 and 75, respectively. The outcome of such a constraint is self-evident. Eventually, shipments to each of the sectors will shrink, as will income to households. They all decline by 50 percent. Household spending for each of the two sectors' products will also shrink by 50 percent. Exports are assumed to shrink proportionately

Figure 4.2 Rebalancing Algorithm



SOURCE: Author's rendition.

as well. The final result is self-evident: the economy will shrink by 50 percent.

This is of course the simplest of cases. Things get a bit more complicated when the pattern of production is limited in some disproportionate way and reconstruction spending amplifies the effects of bottlenecks. In addition, shortages can be avoided through imports or utilizing excess capacity of the region's factories. These are but a few of the options contained in the algorithm.

One last note: the economy can rebalance at many levels. Even in the previous example, balance could have been achieved at 25 percent of predisaster production or even at zero. It is important, therefore, that rebalancing occur in light of some objective. The one that makes the most sense is to rebalance in a way that maximizes the region's post-event income. However, a result that maximizes regional income may not be the one produced by market forces. Since I have called CGE into question (due to unreliable estimates of substitution elasticities, among other problems), I will defend the algorithm's result as the best feasible outcome. This at least provides an envelope of outcomes that policymakers can use to compare different hazards or mitigation strategies.

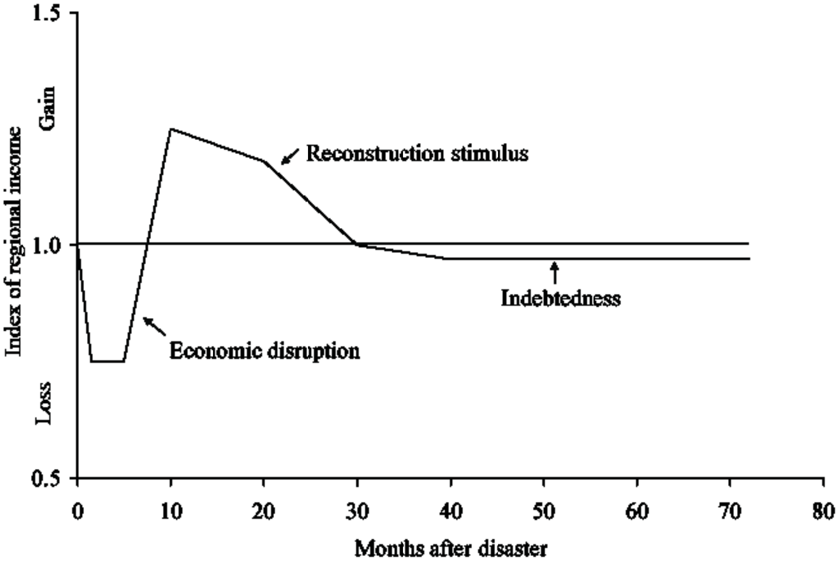
A few additional notes about the algorithm

The CSU algorithm is based on a 20-sector interindustry table, while rebalancing is achieved by an iterative procedure where sectoral outputs are adjusted within the confines of postevent constraints and capacities. Adjustments proceed until the algorithm finds that all other feasible adjustment patterns yield an inferior level of regional income. The process is repeated each month throughout the period of recovery, yielding a measure of how much the region's income is impacted. Finally, the algorithm tracks shifts in interregional trade as rebalancing alters the region's import-export mix. In addition, it accounts for financial liabilities incurred both nationally and regionally. Liabilities are amortized and household demand is adjusted accordingly. The entire process is complex but has been tested and proved to yield reasonable results. A full discussion of the process is beyond the scope of the chapter, but the outlines of a typical result provide some useful insights into how a stricken economy is likely to rebound.

A Prototypical Pattern of Economic Recovery

Figure 4.3 shows what is typically observed after a disaster. Initially there is some disruption of income flows and a decline in spending. Then, as reconstruction begins and damaged sectors are restored, the economy rebounds until gains are observed. In most instances the rebuilding stimulus produces an economic boom exceeding the predisaster level of activity. Eventually recovery is complete and reconstruction spending dries up. If reconstruction is financed externally (via insurance or federal aid), regional income can be expected to subside to the

Figure 4.3 Prototypical Regional Loss Pattern



SOURCE: Author’s calculations.

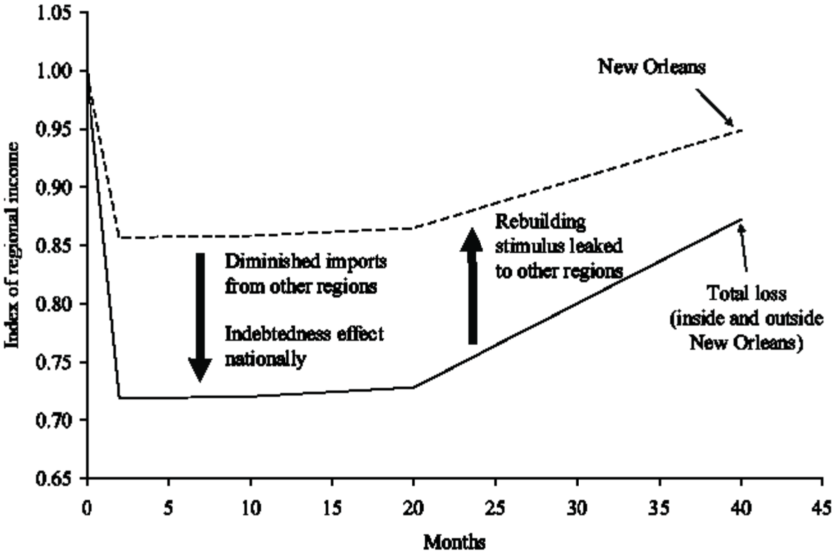
pre-event level. If, however, the region is forced to draw upon savings or borrow, the added debt burden acts as a drag on future income, since households and local government are forced to offset the debt by curtailing spending. Total loss is simply the discounted sum of the stream of losses and gains, as shown in Figure 4.3.

The national pattern looks similar. Disruption ripples to surrounding regions via shifts in imports and exports, the use of extraregional construction talent, and the liabilities incurred nationally.

Hurricane Katrina: An Illustration of How the Model Works

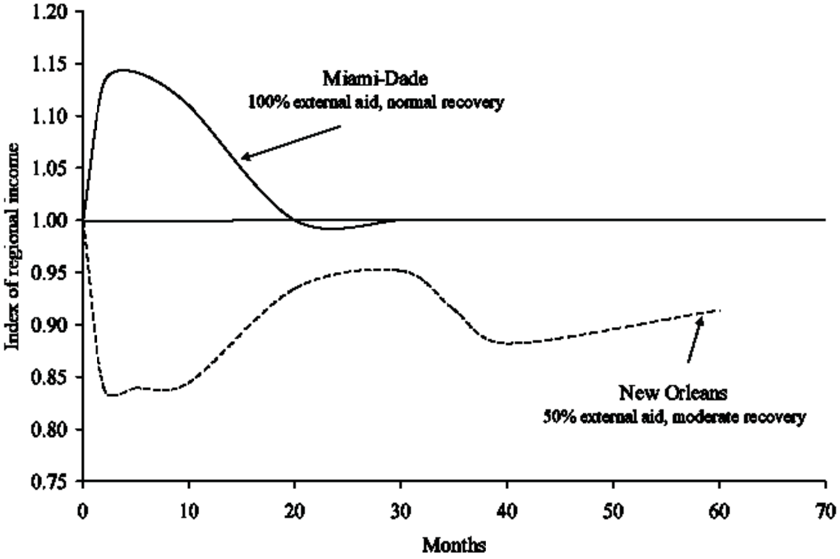
Direct damage to the Gulf region as a result of Hurricane Katrina has been estimated at around $200 billion (give or take $50 billion). This seemingly fuzzy estimate is in fact rather precise given that regional and national economic losses have yet to be tabulated. I took this opportunity to exercise the algorithm in order to come up with an estimate of what Katrina cost New Orleans Parish and the country as a whole. As expected, parish income fell sharply after the storm. Disruptions to tourism, oil and gas operations, and barge traffic rippled throughout the region. This decline was partially offset by an immediate injection of spending for relief and recovery. At the same time that New Orleans proper was in a state of collapse, two conflicting forces that impacted the economies of neighboring regions were set in motion. First, the New Orleans economy was so damaged that some of the relief and reconstruction stimulus leaked to surrounding economies. That is to say, outside construction talent and other related imports were brought into the city to supplement what survived the storm. Economies outside New Orleans benefited as a result. Second, as the New Orleans economy shrank, normal imports into the region declined as well. Figure 4.4 shows the results of the CSU simulation. The upper line shows the recovery path for New Orleans proper, while the lower line provides an estimate of the total loss to both New Orleans and the rest of the nation.

Figure 4.4 Economic Loss Inside and Outside New Orleans (Delayed Reconstruction)



SOURCE: Author's calculations.

Figure 4.5 The Economic Impact of Katrina Contrasted with Andrew



SOURCE: Author's calculations.

One might ask why the New Orleans economy suffered so much. To help answer this question, the economic repercussions of Hurricane Andrew on Miami–Dade County were calculated using the algorithm. Figure 4.5 shows the results. In contrast to Katrina, Andrew produced little long-term impact, a difference attributable to four factors. First, Katrina caused about five times the damage. That alone would explain much of the difference. Second, the New Orleans economy is significantly smaller than the Miami-Dade economy, which could cope with bottlenecks by drawing upon a larger internal excess capacity. Third, since Andrew's winds were the primary cause of damage, property insurance covered most of the loss. Because normal homeowners policies exclude flooding, little of the flood loss (the primary source of damage from Katrina) was insured. Finally, New Orleans faced a housing shortage, so it was difficult to attract outside reconstruction talent. Furthermore, the city became embroiled in a contentious debate concerning how to deal with the ongoing flood hazard. The resulting reconstruction delays still limit the amount of rebuilding that has occurred.

FINAL REMARKS

This chapter has been divided into retrospective and prospective parts. The first part emphasized a few key ideas that, with the aid of hindsight, seem to be logical extensions of water resources economics and the economics of information. Having said that, I am struck by the power of these ideas. I believe that even the simplest of cost-loss models offers valuable insights that are too often lost on policymakers. The confused debate over climate change policy serves to buttress my point. The most puzzling aspect of the literature of the 1960s and 1970s is that so little effort was devoted to categorizing and measuring losses, despite the fact that cost-loss models are worthless without a reasonable loss assessment. Much of this early work was devoted to conceptualizing the problem, where loss was supposed to be self-evident. The second part of the chapter, the prospective view, suggested several topics that need additional attention. Finally, I took a controversial position regarding the use of survey techniques, time series analysis, and CGE. I hold that these methodologies have limited value for predicting how regions are likely to be impacted by unique events. More important, the economic climate has shifted drastically from the time when generous federal aid was available and little excess housing capacity existed. It is dangerous to rely on models that were calibrated using economic conditions that may no longer apply.

Appendix 4A

A Primer on Interindustry Analysis

Input-output tables are the foundation of regional economics. As the name implies, an input-output table traces the flow of products from industry to industry and from industry to households, to government, and for export. It also traces the ingredients inherent in an industry's production (it is, in effect, a recipe). Operational tables can contain as few as 10 sectors or as many as 360. Table 4A.1 shows a simple two-sector table.

The columns represent the shipment of goods from industry to industry, to households, and as exports. The right-hand summation is the total shipped (in the case of each industry), the total income earned (in the case of households) and the total amount imported into the region (in the case of imports). The units shown are typically measured in dollars. So, using the row of the first sector, S1, to illustrate, $20 billion is shipped from the first sector to itself: for example, oil may be used to produce more oil. An additional $45 billion worth is shipped to the second sector, $30 billion to households, and $5 billion exported from the region. The total amount shipped from S1 is therefore $100 billion. The numbers in the first column are interpreted differently. Sector 1's total output is $100 billion (the bottom of column 1). Of this total, Sector 1 contributes $20 billion and Sector 2 contributes $40 billion. Household income in the form of payments for labor and investments amount to another $20 billion of the total, and finally imports of $20 billion from elsewhere make up the remaining part of the total. The shaded area is referred to as interindustry demands. Note that gross shipments must equal supply (gross product) for the economy to be in balance.

Any shock to this economy will begin with a restriction in supply, which then sets a number of adjustments in motion. Declining production means lower income for workers, which reduces household demand for consumer items. Declining production also results in bottlenecks in the production of other interrelated industries. Such restrictions feed back to the sector suffering the initial shock. Although somewhat simple to describe, an operational model requires a complex algorithm, which is briefly described in the main body of the chapter.

Table 4A.1 Example, Input-Output Table: A Typical Interindustry Table

	S1	S2	Households	Exports	Gross shipments
S1	20	45	30	5	100
S2	40	15	30	65	150
Households	20	60	0	0	80
Imports	20	30	20	0	70
Gross product	100	150	80	70	400

NOTE: S1 = industry sector 1; S2 = industry sector 2.

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