Economic applications in disaster research, mitigation, and planning

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Abstract

This chapter examines the contributions of the economics discipline to disaster research, mitigation, and planning. Economics offers modeling techniques for assessing the impacts of disasters, theories of development for understanding the choices that individuals and firms make in selecting residential and business locations, approaches for risk and vulnerability assessment in insurance and disaster planning, and policy insights in each of these areas that are affected by the political economy. The chapter gives particular attention to common and emerging techniques for assessing the indirect economic impacts of disaster events offering an assessment of the strengths and weaknesses of each analytic approach.

Introduction

Economics as a specific discipline, its many sub- and closely related disciplines, and research techniques pervade the systematic study of disasters and their human, social, and monetary impacts. The goal of this chapter is to provide the non-economist a look into how this discipline shapes scholarly and public understanding of disaster impacts, the roles that economic information can play in the *realpolitik* of disaster management and response, and reviews methods of analysis in assessing the impact of disasters.

To accomplish this goal, specific data analysis techniques used to estimate the economic impacts of disasters are presented along with a description of how this information is used to address issues of resource allocation and disaster avoidance. Discussion is presented on issues relating to disaster insurance and the contribution of

economics to risk analysis. Finally, the chapter offers suggestions for expanded or new research approaches that economists should undertake to further contribute to the discipline of disaster management. But first, a historical perspective of the role of economics in disaster research.

A Brief Time in History

Assessing the economic impacts of disasters is a very recent systematic field of study. Disasters have been, and continue to be, human tragedies. History books tell us that more than 2,000 died in the Johnstown, Pennsylvania flood in 1889, the eruption of Krakatoa in 1883 – described as the first catastrophe of the communications age (USGS, 2005) – and the resulting tsunami killed more than 30,000, the Galveston hurricane of 1900 killed more than 6,000 of the island's residents, and of course the 1,503 lives lost in icy North Atlantic waters on that 'night to remember' in 1912. These numbers represent horrific human tolls and each also represents economic losses in the tens or hundreds of millions of dollars. But, it is the loss of life that catches our attention.[1]

In addition, the provision of public monies to help those affected by disasters has been a comparatively recent occurrence. Historically, government policy and/or public sentiment simply did not support monetary aid to disaster victims. Barnett (1999) cites an example from 1887 where President Grover Cleveland in response to an emergency request for $10,000 in aid to Texas drought victims noted that there is no constitutional basis for public funds to be used to offset individual suffering as a result of a disaster.

[1] Of course, these human losses pale in comparison to many of the great disasters such as the 1976 Northeastern China earthquake that killed 240,000, the 40,000 killed in Northwestern Iran in 1990, the 2004 Indonesian tsunami with a death toll exceeding 300,000 and the 1918-1919 flu pandemic that claimed an estimated 30 million lives (Becker, 2005; World Book 2005).

Barnett also observes that even though public policy had changed by 1915 with the advent of federal disaster relief grants and loans, it was many years before the public at large found the receipt of these grants and loans socially acceptable.

Concentrating on the loss of life to describe the magnitude of disasters, combined with public attitudes about the costs of disasters being borne by individuals, there was little demand for comprehensive economic assessments of disasters. One of the few early assessments of the economic impacts of a disaster was published in 1920 estimating the impacts of the Halifax ship explosion of December 1917 (Scanlon, 1988). Little else appears in the academic literature for more than 40 years, but during those years, public policy and public attitudes about disaster relief changed. With these changes came demand for information about the size (impact) of disasters from an economic perspective. If there were to be programs to provide aid to victims of disasters, then the impacts must be quantified.

The development of warning systems broadcast over radio networks and later television gave vital information that has saved innumerable lives. In addition, investments in infrastructure, enhanced construction techniques required by modern building codes, and other physical capital have with one notable exception resulted in fewer deaths due to disasters. For example, following the 1900 hurricane, Galveston Island and almost every structure on the island were raised several feet. Hurricanes have hit Galveston since 1900 but never with anything near the human losses of the 1900 event. As this chapter is being completed, recovery is underway for hurricane Katrina. In the largest disaster to hit a US city since the San Francisco fire, New Orleans, a city of 450,000, was inundated by flood waters after sections of the Mississippi River levee

system failed due to storm-related flooding. (The City of New Orleans sits several feet below sea-level and has been a high-risk area for flooding since its founding in the late 18th century.) Inefficient and ineffective government response is being blamed for many of the city's low-income population not being evacuated. Whether through inability to evacuate, or unwillingness by individuals to evacuate, over 200,000 people were still in the city when the levees broke. Still, less than one-half of one percent of the population perished.

Even with record numbers of people moving into relatively hazardous areas, such as the Florida coast or mud-slide prone hills in central and southern California, until Katrina we have seldom seen more than a few deaths in the US related to natural disasters since the early parts of the 20th century. To justify on-going public aid to victims and expenditures for disaster preparedness and management, efforts turned to estimating the economic impacts of disasters.

Political Economy of Disasters

Prior to the 20th century political economy was the proper name for the discipline of economics. In today's context it means the convergence of politics and economics. In the previous section changing public policy in the US is illustrated by comparing President Cleveland's strict interpretation of the constitution with the later advent of federally funded grants and loans to aid victims of disasters. The economic considerations were, in many respects, the same, but our policy (political) approach had

changed. Economic analysis is at the heart, but is far from the whole, of the *realpolitik*[2] of disasters. From the time of the nation's founding through 1950, the US government enacted 128 pieces of legislation providing relief, mostly in the form of in-kind donations, for victims of disasters (Barnett, 1999). By the 1950s, the US had gone through a fundamental shift in the expected role of government. From the New Deal policies of the 1930s through the G.I. Bill providing for a college education to veterans of World War II, liberal ideas of government responsibility to the nation's citizens was in its ascendancy. The Disaster Relief Act of 1950 and the Small Business Administration Act of 1953 both offered standing programs for disaster relief (Barnett) requiring economic analyses to support budget projections.

Programs of the Great Society of the 1960s and afterwards also included elements of disaster relief and mitigation in housing and introduced formal civil rights considerations in disaster management and planning. In 1953, the federal government provided just 1% of total disaster relief spending. By the mid-1970s that percentage had risen to more than 70% (Barnett, 1999).

Political considerations also influenced the distribution of private relief money. Prior to Hurricane Camille in 1969, the American Red Cross distributed disaster assistance based on economic need. After being heavily criticized in the press and in some political circles, the Red Cross standardized their rules for funds eligibility and removed economic need as a criterion. This can be seen as a reflection of the growing size and political influence of the middle class in the US after World War II. As observed in surveys conducted by Leitko et al. (1980), middle class victims of disasters

[2] *Realpolitik* (literally the "politics of reality" in German) typically refers to a pragmatic, non-idealistic approach to international politics. In my usage it refers to the pragmatic application of politics, influenced by economic considerations, to disaster policy implementation.

view relief as "a corrective to a naturally induced injustice" (page 735) and tend to demand larger amounts of relief regardless of their own resources. This liberal approach to the distribution of disaster relief has survived the increasingly conservative nature of other public assistance in the US since the early 1980s. Leitko, et. al. observed that the public does not see disaster relief as welfare. How else can one politically account for general acceptance at the national level for potentially providing grants and low interest loans to wealthy families whose homes in gated Florida communities are damaged by hurricane events?

The good news about the surprisingly liberal attitudes of the US electorate towards disaster relief and mitigation is that we have had a steady, if not sufficient, stream of economic resources for disaster mitigation, preparation, and management. Of course, this has also been influenced by the *realpolitik* of 9-11 and there will certainly be a shift in federal government spending policy due to failures and perceived failures that led to the New Orleans/Katrina disaster – at least in the short run. The bad news is that federal intervention is increasingly distorting economic decisions at the local level. Kunreuther (1998) notes local governments are not seeking own-source solutions to disaster response needs, such as private sector insurance, because of perceived certainty of federal resource availability. These distortions are also apparent in residential real estate markets.

One of the clear reasons the costs of disasters have escalated rapidly in recent years is a function of the level of development in high risk areas. For example, in 2003, 153 million people, 53 percent of the US total population, resided in coastal counties – an area that comprises just 17 percent of the mainland US land mass (Crossett, et al, 2004).

The coastal population has increased by 33 million in 23 years representing a rapid increase in population density and significant development intrusions into barrier islands and marsh lands that offer natural protection from storm events. Moreover, this population growth does not reflect the growth in the number of second and vacation homes, hotels, and resorts that increasingly fill the coastal landscape. The political reality is that local and state governments are willing to trade the potential for more expensive disaster events, which is offset by federal assistance, for tax base growth.

There are three other ways that political economy approaches can help explain the level and distribution of disaster mitigation and planning funding. The first is the political dimension of who qualifies for post-disaster assistance. The release of federal grants and loans for disaster relief is based on the declaration by the President that a specified region, most often a county, is a "disaster area." The general public largely thinks this designation is about damage to buildings, homes, and infrastructure along the lines of the Fujita Scale of tornadic damage. However, it is the impact the disaster event has on local government that forms the basis for a disaster declaration. In theory, local government or state government are supposed to provide disaster assistance. If demand for assistance and services exceeds local capacities or if local government revenues are substantially threatened, then Federal resources are engaged. If a hotel is damaged by a tornado, as in the case of Fort Worth, Texas, in 2000 (see McEntire, 2002 for a description), local government experiences losses in revenue from sales taxes, hotel occupancy taxes, and property taxes and thus local government's ability to provide services and recovery aid is diminished.[3] This interesting quirk of US disaster policy is

[3] If the building is destroyed or substantially damaged, then taxable property values for improvements and business personal property decrease.

keenly felt by victims of certain types of disasters. Tornadoes can cause widespread damage qualifying the area for Federal disaster assistance. However, if the tornado destroys only houses located along one block, it is doubtful that the revenue of local government would be severely impacted and those victims will not qualify for federal assistance – even though their individual loss is as great as any individual in a much larger disaster.

In practice, presidential disaster declarations can be overt acts of political largess or electioneering. Sylves (1996) noted that in the winter of 1995, President Clinton waived qualification rules repeatedly in making federal funds available to residents and businesses in California as a result of two flood events. The fact that California had a Democratic governor at the time and holds the largest number of electoral votes in presidential races is assumed to have played a role in Mr. Clinton's decision. In the spring of 1996, widespread flooding causing substantial damage occurred across Pennsylvania, yet only six counties were declared eligible for federal disaster assistance. Governor Tom Ridge publicly threatened consequences in the fall elections for federal officials "playing games with Pennsylvania." Very quickly, 58 of 67 Pennsylvania counties received federal disaster area status (Platt, 1999). Platt describes the political influence in federal assistance as "disaster gerrymandering."

Public policy also affects private insurance approaches to economic mitigation of disaster impacts. The insurance industry remains one of the most heavily regulated industries in the US with many states having oversight bodies approving rates based on allowable underwriting profitability.[4] The problem is that the event horizons for disasters

[4] See Klein, R. (1998) for an excellent introduction into insurance industry regulation in the US and regulatory impacts on disaster insurance.

are often long, meaning that the insurer's premiums should account for building risk event reserves over several years. However, accumulating risk event reserves can appear as profits in the short run and are thus the targets of regulators looking to deliver politically popular rate decisions. Moreover, accounting rules and taxing policies on retained earnings hurt insurers' ability to build risk reserves (Andersen, 2004). Together, these policy factors result in wide fluctuations in disaster insurance availability[5] and premiums with the lowest availability/highest rates following disaster events. These higher rates discourage private sector adoption of own-source risk mitigation increasing the dependence on federal level solutions (Klein, 1998). In addition, closely timed disaster events, such as this year's early season hurricane in Florida just 11 months after the last major storm event, place further strains on insurance provider resources that are reflected in subsequent premiums.

The final political economy dimension to disaster research covered here is the potential for overt political considerations in the distribution of disaster relief. Though they specifically studied an Australian case, Butler and Doessel (1980) claim that politics can influence disaster relief in a federalist system of governance. Sverny and Marcal (2002), Scanlon (1988), and McEntire and Dawson (forthcoming) also discuss the politics of disaster relief and preparedness. Some disaster mitigation projects could be considered little more than pork-barrel politics. Moreover, as suggested earlier, there is more than a little of the political economy of wealth redistribution in some disaster policies in the US.

[5] Payouts for claims associated with Hurricane Andrew put several insurance and reinsurance providers out of business.

Several techniques and approaches will be presented in the remainder of this chapter for estimating the economic impacts of disasters and disaster planning and management. However, the application of the findings of these analyses remains an exercise in political economy.

Measuring Disaster Losses

Economists are rarely called on to estimate the direct physical damage caused by disasters. This is a job for engineers, architects, construction specialists, and others. These damages include property damage to buildings and infrastructure, debris removal, and the cost of emergency protective services (McEntire and Cope, 2004). It is the losses associated with employment income and indirect losses that occupy the efforts of economists in the field of disaster research. Though there is some disagreement among scholars as to exactly what counts as indirect costs, they include the loss of business activity due to reduced activities at damaged firms, loss of income in secondary and tertiary employment, and business disruptions not directly attributable to damage. For example, if a manufacturing firm is damaged sufficiently to disrupt production, then they will not require trucking services to deliver raw materials or pick up finished goods, which may impact the employment of drivers. Rose (2004) illustrates indirect effects with the example of a utility plant being damaged resulting in utility customers (businesses) not being able to operate. Cochrane (2004) uses the comparatively simple definitions that direct damage is property damage plus lost income, and indirect damage is anything else. Rose, along with other researchers cited in his study, find that direct and

indirect business interruption losses can be as large as physical losses. Of course, the degree of impact of a disaster depends in large part on the scale of the analysis.

Macroeconomic Analyses

Macroeconomic analysis considers economic events and activities at a national or at least state scale. Dacy and Kunreuther (1969) held that the total national cost of a disaster is the replacement value of the property damaged, regardless of the presence of a relief program. Even when other costs are included, it is a matter of simple division to see that disaster impacts rarely have a meaningful impact on a national economy. Whatever the damage, the divisor is very large. As noted by Mileti (1999), capital markets are simply too large to be disturbed beyond a short period of time by natural disasters.[6] The notable exception would be sustained droughts in countries with an agrarian-based economy (Albala-Bertrand, cited in Horwich, 2000). Nobel Laureate Gary Becker (2005) has noted that even the pandemic flu of 1918-1919 had no major effect on the world economy. To illustrate how this can be, Horwich (2000) offers an example based on the Kobe earthquake.

The Great Hanshin earthquake struck Kobe, Japan on January 17, 1995. In the earthquake and subsequent fires, more than 100,000 businesses were destroyed, 300,000 individuals became homeless, and 6,500 people were killed with total damages estimated at $114 billion (Horwich, 2000). The damage estimate represented about 2.5% of Japanese gross domestic product (GDP) in 1995. Yet within 15 months manufacturing was operating at 98% of the pre-earthquake trend, all department stores and 78% of small

[6] Worthington and Valakhani (2004) using an autoregressive moving average model found temporary shocks to the Australian All Ordinaries Index from brushfires, cyclones, and earthquakes, though the direction of the impacts (positive or negative) varies.

shops had reopened within 18 months, and trade at the port was operating close to pre-earthquake levels within 1 year (Horwich; Landers, 2001). That is a remarkable recovery based on GDP impacts. Similarly, Hurricane Katrina destroyed a sizable proportion of the economic capacity of Louisiana and Mississippi, but these states combine to represent less than 2% of US GDP. The most recent data from the US Department of Labor estimates that Katrina took 230,000 jobs from directly affected areas, but that total national employment for the month of September declined by only 35,000 – little more that a statistical blip on the economic map (Balls and Swann, 2005). Horwich suggests it is more telling to consider the impact of a disaster on economic potential as opposed to economic activity.

Economic potential can be measured by the level of capital stock including unused capacity in the economy. For example, other Japanese ports took on much of the trade activity while Kobe was under repair. In addition, Horwich (2000) suggests that human capital is the dominant economic resource and that, horrible as the losses were, 99.8% of the population in the earthquake impact zone survived. Horwich includes the economic value of life at $2 million per person, plus the $114 billion damage to capital stock, to estimate the capitalized value of the Hanshin earthquake on Japan at $127 billion ($114 billion +(6500*$2 million)). Horwich calculates Japan's total resource value by capitalizing GDP (about $5 trillion in 1995) at a real interest rate of 3% for a total of $167 trillion ($5 trillion/0.03), which includes the value of a highly skilled workforce. Using this approach, the Great Hanshin earthquake had a total impact of 0.08% of the economic potential of the Japanese economy. Much of the economic activity lost due to the physical damage was regained in the form of rebuilding and repair.

While Horwich makes some heroic assumptions in these calculations, they offer a clear indication of the resilience of the economy of large industrialized nations. However, even smaller nations, in terms of economic output, appear to possess economic resilience to disaster events.

One week after the Sumatra tsunami of 2004, the Indonesian and Malaysian stock markets had gained value from the pre-disaster level, the Thai stock market declined only slightly, and the Sri Lankan markets were off a few percent (Becker, 2005). Tavares (2004) using an ordinary least squares regression analysis calculates that natural disasters lower US GDP by 0.052% per year.[7] Of course, the same may not hold true for smaller nations with more specialized economies.

In addition to the previously mentioned agrarian-based economies, Auffret (2003) finds that natural disasters are an important determinant of economic volatility in Caribbean economies, which is attributed, in part, to consumption shocks due to underdeveloped or ineffective risk management mechanisms. Of course, tourism-based economies are subject to market responses to disaster events – or predictions of disaster events – over which they have little control.

The other factor that minimizes the impacts of most disasters is their short duration. Waters recede, storms pass, and eventually droughts break. But for some types of disaster, the threat of an event can have a long-term effect on macroeconomic performance – specifically the threat of terrorism. Tavares (2004) estimates that the continuous threat of terrorist attacks reduces gross domestic product in Israel by 4%. The Basque region of Spain, which has seen decades of separatist terrorist activities, looses

[7] This does not include the impacts of Hurricane Katrina. In comparison, Tavares (2002) found that currency crises decreased average economic output by 1.9% in the nations included in his model.

about 10% of its potential economic activity due to the threat of terrorism. Terrorism impacts national economies in 3 ways: 1) increased risk decreases business insurability meaning that risk is not spread across a greater number of economic actors, 2) trade costs are increased leading to lower levels of international transactions, and 3) increased public and private spending for security and defense decreases capital available for investment (Tavares). Hobijn (2002) estimates that increased security costs incurred after 9-11 has reduced US economic activity by 0.66%.

One area of national level impacts that has received press coverage, but little academic analysis to date, is the impact of disasters on the US energy industry. In 2004, hurricanes in the Gulf of Mexico substantially damaged that region's oil and gas production and transmission capacity. Winds and high waves toppled or dislodged the moorings for offshore rigs, and hurricane-spawned underwater mudslides destroyed sections of transmission pipelines. This damage resulted in lower domestic energy supplies that increased the market price for oil and gas and was reflected in the cost of gasoline, diesel, and fuel oil that rippled throughout the US economy.[8] Damage sustained by refineries located in the New Orleans region along with off-shore oil production losses as a result of Katrina and subsequent flooding is currently blamed for adding as much as 40 cents to the price of a gallon of gasoline at the pump. These impacts, though temporary, should be formally assessed.

The resilience a given economy has to disaster events is, of course, largely dependent on national resources committed to mitigation, planning, and response. Horwich (2000) reports comments by noted disaster researcher Fred Cuny stating that if

[8] Access to fuel became a problem for FEMA in getting supplies to victims of the Florida hurricanes of 2004.

the earthquake that hit San Salvador had instead hit San Francisco, it would have rattled the china, not killed 1,500 people. As national income rises, disaster costs tend to rise, but relative costs as well as the number of lives lost decrease (Dacy and Kunreuther, 1969; Freeman et al., 2003).

However, aggregated analyses at the macroeconomic level miss the intensity of regional and local impacts that create comparative winners and losers when disaster strikes. In addition, macro level analysis often fails to identify and address disaster impacts and vulnerability across populations at differing income levels. As an overall economy gains wealth, it is often the case that low income populations are forced to reside in lower-cost / higher-risk areas compounded by their inability to afford insurance (Barnett, 1999; Scanlon, 1988; Vatsa, 2004). The stark, often horrific, images of the low-income victims of Hurricane Katrina and their disproportionate death rate and loss of most all worldly goods has brought into focus how disaster events can disproportionately affect the poorest segments of our population. Even when the national or regional economy recovers in terms of production and employment, specific localities, groups, and individuals may still be paying the price of disasters.

It is said that all politics are local. Given the earlier assertion that politics intertwines disaster economics and policies, it is reasonable to assume that the politics of disaster are often local. This is one reason why the preponderance of studies examining the economic impacts of disasters are conducted at the local or regional level.

Microeconomic Analysis of Disaster Impacts

It is well documented that the cost of disasters are rising, though care must be taken when making comparisons across time and when translating impacts across

different currencies. Mileti (1999) reports the following disaster cost estimates based on a review of several studies:

- Loma Prieta Earthquake 1981 $10 Billion
- Hurricane Hugo 1989 $6 Billion
- Hurricane Andrew 1992 $20 Billion
- Northridge Earthquake 1994 $25 Billion

Mileti also cites an analysis that looked back at the 1923 Tokyo earthquake and estimated total damages at $1 Trillion in 1995 US Dollars (USD). That estimate stretches credulity considering that just a few years after the earthquake Japan had the excess economic capacity to begin a massive military buildup. As noted, the damage estimate of the Kobe earthquake in 1995 was $114 billion USD based on simple currency exchange rates. However, if purchasing parity adjustments are made to the damage estimate, Horwich (2000) reports the cost estimate is $64 billion – a 44% reduction. Nonetheless, there is pervasive evidence that disasters are becoming more economically costly. Current assessments of private and public liabilities for rebuilding New Orleans in the wake of Hurricane Katrina exceed $200 billion. Yet, there are mitigating factors and evidence to suggest that the impacts are not always as large as advertised.

Tomsho (1999) reports on one of the most common factors that complicates the assessment of damage costs of disaster events – the Jacuzzi effect. The Jacuzzi effect occurs specifically when homeowners add new or improved features to their dwellings during disaster repairs. Of course, this ability to rebuild and restructure is one of the primary reasons that post disaster regional economies often improve their performance in the long term. As noted by Horwich (2000): “Restored economies will not be a replica of the pre-disaster economy. Destruction of physical assets is a form of accelerated depreciation that hastens adoption of new technologies and varieties of investment” (page

530). In addition, federal grants and low-interest loans act as economic stimuli with effects similar to transfer payments. The Charleston, South Carolina economy received $370 million in unexpected income after Hurricane Hugo in 1989 that helped the local economy to perform better than expected in 7 of the 10 quarters following the disaster event (Tomsho). But, as suggested earlier, the overall effect masked a great deal of disruption and volatility. Some businesses were permanently destroyed while new businesses opened. New Orleans, a city that had been suffering economic decline for decades prior to Katrina, may never recover its economic base beyond tourism and petro-chemicals according to some forecasters.

The main contribution that micro-economic analysis can bring is an understanding of the dynamics of the economic churn that is sparked by a disaster event. Which industries are most heavily impacted? Which are most likely to gain? A few years ago while riding in a taxi in Derry, Northern Ireland (Londonderry if you are of loyalist persuasion), the driver observed to me that the first people on the scene of a terrorist bombing in his city are often the construction contractors preparing their repair bids. Even if this is a bit of an Irish yarn, it clearly points out that some industries and businesses will see potentially huge increases in their business activities resulting from disasters. By understanding the dynamics of the total economic impacts of disasters, we can more efficiently allocate disaster response resources so that those in need are the ones that are served. In addition, through predictive models using this information, we can make better decisions regarding disaster preparedness and pre-event mitigation strategies (Mileti, 1999; Gordon et. al., 2005).

There are several data analysis techniques used to assess the indirect and income effects of disasters. These techniques include surveys, econometric models, Box-Jenkins time series analyses, input-output models, general equilibrium models, and economic accounting models (Cochrane, 2004; Chang, 2003; Zimmerman et. al., 2005).

Surveys provide direct information from those impacted or in close association with those directly affected by disasters. They can be flexible in design to accomplish simple data gathering (How much will it/did it cost to rebuild your facility?) to more in-depth approaches (How did you finance your rebuilding? Have you lost customers because of down time? Are you looking to relocate your business?). Tierney (cited in Rose and Liao, 2005) uses surveys to assess impacts on businesses of the 1993 mid-west floods and the Northridge earthquake. The largest problem with survey approaches is non-response bias. The researcher cannot know if the respondents are truly representative of the broader population of disaster victims. Given the psychological trauma associated with disasters, the researcher would have to be diligent in assessing response reliability – respondents' answers may change if questioned immediately after the event versus 6 months later. There could be issues of strategic behavior in the responses such as exaggerating losses in the hope of attracting additional aid. There are also potential logistics problems with surveys. Researchers may not have access to the disaster area immediately and may be unable to locate victims later. Moreover, the most appropriate survey medium would likely be in-person interviews, which are expensive and time consuming. Still, surveys offer the best opportunity for obtaining direct, relevant data.

Econometric modeling approaches can be used when there is substantial data readily available for the affected region. Using a variety of regression techniques, the fully-partialed[9] effects of a disaster event can be modeled as an intrusion on a series of data. However, data availability can be a problem. Much of the economic data that would be used are gathered and published with substantial lags, this approach may not be practical until 2 or 3 years after the event. Of course, predictive models can help us understand post-disaster dynamics, but most econometric approaches do not easily account for product substitution, immediate changes in the imports of goods, or the non-linear nature of production functions inevitable when an economy receives a significant shock. Still, several researchers have offered credible analyses using regression techniques including Ellison, et al (1984), Cochrane (1974), and Guimaraes, et al (1993), among many others.

One econometric modeling approach is to use variations of hedonic pricing models. Hedonic models (derived from the term hedonism) account for preferences in purchasing decisions. These models are most commonly used in real estate research to described why some homes are more desirable (higher priced) even when other factors such as size and features are the same. MacDonald et. al., (1987) use a hedonic model to assess housing value impacts of being located in a flood-risk area. Brookshire et. al., (1985) examined hedonic price gradients based on earthquake safety attributes for housing. This modeling approach could add valuable insights into consumer behavior, especially if standard housing price models are adapted for longitudinal studies to

[9] Fully-partialed means that other factors affecting the economy are controlled for statistically so that the estimates relate to only those costs associated with the disaster.

examine changing hedonic factors in cases of recurring disaster events, such as housing prices in Florida after multiple major hurricanes.

A variation on the intrusion model method is an Auto-Regressive Integrated Moving Average (ARIMA) model. This analytic technique takes a Box-Jenkins approach to time series analysis. A Box-Jenkins analysis uses previous values of the study variable to predict the next value. Data analysis software packages use complex algorithms to account for secular trends in the data (are overall prices rising or falling?), the correlation between current and previous observations, seasonal variations, and other factors. For example, in examining the impacts of a tornado event on local retail sales, the analyst considers trends and patterns in a series of relevant data. The ARIMA model would control for a trend that total retail sales have generally risen over several years, the seasonal variations for Christmas, back-to-school, and other especially busy times, and the fact that if a retailer is successful one month, they will likely be successful the following month. The ARIMA model provides a prediction for what retail sales should be, which can then be compared to what actually happened after the disaster. The difference is an estimate of the disaster's impact on retail sales. The biggest weakness of this approach is being able to account for confounding concomitant events – such as a large retailer closing about the same time as a disaster for unrelated reasons. Because ARIMA models do not require the gathering of data for large numbers of relevant variables, the approach is very cost effective. Enders et al., (1992) uses an ARIMA model to assess losses in the tourism industry due to terrorist events while Worthington and Valakhani (2004) use this modeling technique to estimate the impacts of disasters on the Australian All Ordinaries averages. Due to its relative simplicity but powerful

analytical strengths, this data analysis methodology should be more widely used in disaster research.

Input/output (I/O) models are based originally on the work of Wassily Leontief in the 1930s in which the flow of goods across industries are captured using transaction matrices. For any given commodity there are raw materials, goods, and services purchased as inputs in the production process. Based on economic surveys, we know, on average, which industries produce which commodities and services. These models then provide a description of how demand-satisfying production creates upstream and downstream economic activities. For example, a writing pad is made of backing, paper, ink for the lines, and glue to bind the pages. There are firms that produce each of these inputs. In addition, the paper converter (manufacturer of goods converted from raw paper) hires accountants, computer services firms, and trucking companies, buys advertising space in trade publications, and purchases a host of other goods and services to support its business operations. The I/O models then use data from government organizations such as the Bureau of Labor Statistics to reflect relationships between labor demand for production activities and prevailing salaries, wages, and benefits to estimate not only the value of economic activity associated with a given level of production for a commodity, but how many jobs are supported and how much is paid in labor earnings.

National-level I/O models can be adjusted for regional economies by allowing for some activities to "leak" out of the economy. If the ink used to print lines on a tablet is not produced locally, then spending for that good does not impact the local economy and the related jobs and income are created elsewhere. However, being more precise, in a large regional economy there is likely to be at least one company that makes the ink, but

that does not mean that company gets 100% of local market ink sales. Therefore, the regional I/O models estimate the proportion of total spending for intermediate goods that stay in the regional economy (expressed as regional purchasing coefficients). An I/O model may or may not include the economic activities (purchases) of households, though most do. The models produce three types of impact assessments: direct, indirect, and induced. Direct effects can be thought of as direct purchases by the industry being described. Indirect effects include purchases by related companies in the supply chain, such as the ink manufacturer buying office supplies from a local retailer. The induced effects capture the economic activity created by employees spending a portion of their earnings in the local economy for goods and services. When you add the direct, indirect, and induced impacts, expressed as coefficients, you can get a total effect greater than 1.0, which is the economic multiplier. For example, demand for $100 worth of writing pads in the Houston economy could create a total of $160 worth of local economic activity when all three types of impacts are summed.

Unfortunately, the multiplier effect works when production is added and when production is lost. If the paper converter's plant is damaged or destroyed, the related indirect and induced impacts spread across the regional economy.

The popularity of I/O modeling approaches has grown with the use and affordability of personal computers. There are two major off-the-shelf I/O models available on the market. One is produced by the Bureau of Economic Analysis of the US Department of Commerce, and the other is called an IMPLAN model developed by the Minnesota IMPLAN Group. Both models are cost effective and offer modeling capability at the county level. The IMPLAN model allows the user more flexibility in

adjusting regional purchasing coefficients and offers estimates of economic activity at a highly disaggregated level – as many as 528 different industry categorizations. In addition, at the basic level, I/O models are relatively easy to use and can be used to quickly obtain an initial impact estimate.

The greatest weaknesses of I/O models are that they are static (measuring economic relationships at a particular point in time), the highly disaggregated impacts sometimes require heroic assumptions, and they are linear. If a new firm has come to town, or an existing firm has departed since the data base year, the regional purchasing coefficients may be wrong. Because detailed data for individual firms is masked in economic surveys, calculating very detailed industry estimates requires using national level data that may not accurately reflect local economic relationships. Finally, I/O models do not easily account for product substitutions, and the coefficients are fixed, which likely will not reflect reality in the aftermath of a disaster. Nonetheless, if used appropriately I/O models can provide reasonable estimates, not exact calculations, and are a valuable addition to the disaster researcher's toolkit. For an example of I/O modeling in disaster research see Rose, et al (1997) in which the indirect regional economic effects are simulated for an earthquake event that damages electricity generating infrastructure.

I/O models can also include social accounting matrices (SAM) that expand the I/O model calculations to include transfer payments, value-added accounting, and the ability to examine distributional impacts across households at various income levels. Cole (2004) uses a SAM I/O model to project potential impacts of damage to the electric industry in upstate New York to aid regional disaster planning.

Another adaptation of I/O modeling uses econometric techniques to address some of the weaknesses noted above. The improvements include better coefficients that more accurately reflect local economic conditions and the ability to alter those coefficients to adjust for the structural economic changes that would attend a major disaster. This approach iteratively feeds back and forth from the I/O to the econometric portions of the model. Of course, the increased complexity and accuracy come with a price. The base models are more sophisticated than typical I/O models and thus are substantially more expensive. In addition, operating and adjusting the parameters is not typically accomplished by the end-user without extensive training and experience. Greater input data requirements and sophisticated user input mean that this model requires more time to complete an impact analysis. Therefore, these hybrid models usually do not offer details for as many industries as covered by I/O models.

The most widely used commercially available econometric-I/O hybrid model is REMI. However, a review of the disaster literature did not find any published articles using this model. Nonetheless, many state economic planning bodies have contracted access to the REMI model that could be used for disaster planning and impact analysis. For example, a REMI model could assess the regional and state level economic impacts of a tornado where repair services are being performed by a combination of firms previously located in the local economy, firms that open a permanent office in the region, and firms that send in 'guest workers' for as long as there is sufficient demand.

Another recent adaptation of an I/O model was developed by the Center for Risk and Economic Analysis of Terrorism Events at the University of Southern California. This model begins with an IMPLAN model of the Los Angeles area (multiple counties),

then applies a regional disaggregation model to allocate induced impacts across the region at the municipal level. The disaggregation model uses journey-to-work and journey-to-non-work (shop) transportation matrices that also account for intraregional freight flows (Gordon et al., 2005). However, because the base data of IMPLAN does not reach the sub-county level, this model aggregates the 509 IMPLAN industry sectors into 17 sectors. Still, this modeling approach could improve our ability to forecast or estimate how the economic impacts of a disaster event affect individual municipalities in a large metropolitan area. For example, Gordon et al. use the model to assess where the greatest economic disruptions would occur within the Greater Los Angeles area if there were terrorist attacks on the ports of Long Beach and Los Angeles.

The methodology being increasingly used in disaster research over the past few years has been computable general equilibrium models (CGE). Advocates of this modeling approach assert that CGE models are much more accurate than I/O models because they can incorporate a range of input substitutions and different elasticities of supply and demand can be applied across different tiers of economic activity (Rose & Liao, 2005). If a given input in a production process is no longer available in a post disaster environment, but can be easily imported from another region, then the CGE model more accurately estimates the direct, indirect, and induced effects of this change. However, this level of flexibility is very data intensive. Therefore, CGE models rarely cover more than a few industrial sectors. In addition, CGE models emphasize equilibrium states – a situation not likely to be the case in the aftermath of a significant disaster.[10] Among recent disaster-related research, Wittner et al. (2005) use a dynamic regional CGE model in a simulation modeling exercise on the effects of a disease or pest

[10] Rose (2004) offers a partial solution to this weakness in CGE modeling.

outbreak, while Rose and Liao (2005) demonstrate how CGE models can be used to value pre-event mitigation. Rose (2004) reviews at least three other studies that use CGE models for analyzing disaster impacts and policy responses. Because of its intensive data requirements and practical limitation on the number of industries that can be effectively analyzed at one time, CGE approaches to disaster impact modeling are better suited to *a-priori* assessments of potential impacts for planning purposes.

FEMA offers an impact assessment software that uses a combination of I/O, hybrid-I/O, and CGE modeling approaches to estimate direct and indirect economic impacts of disasters. The HAZUS-MH model is available for download from the FEMA website, but does require a geographic information system (GIS) model for input and output operations (FEMA, 2005). The HAZUS model is highly flexible allowing users to do a relatively quick and simple analysis using preprogrammed assumptions about the local economy (not recommended), to having to engage in detailed data gathering that would likely require the services of subject matter experts. The portion of the model that estimates indirect economic disaster impacts starts with IMPLAN data matrices and then employs adjustment algorithms similar to those described for hybrid-IO and CGE models. While the HAZUS model does offer many solutions to the problems of I/O impact analysis, it does not offer much in the way of industry detail aggregating the total regional economy into 10 basic industrial sectors that correspond to 1-digit Standard Industrial Code classifications. The HAZUS technical manual, available by request from FEMA, offers a case study based on the Northridge earthquake as well as simulation studies showing applications of the HAZUS model.

Finally, the economic accounting approach to estimating the impacts of disaster events differ from other approaches covered in this section in that it explicitly includes the valuation of human life and injuries. The economic accounting approach also draws from other methodologies to estimate business losses using case based analysis (surveys), GDP estimates (econometric), or I/O models. These two elements are then added to estimates of physical losses to estimate the total economic impacts of a disaster (Zimmerman et al., 2005). The greatest challenge for the economic accounting method is valuing human life. The US National Safety Council uses a loss of life value of $20,000 compared to the Environmental Protection Agency that calculates the value of lost lives at $5.8 million each. The Special Master for the Department of Justice overseeing claims related to the terrorist attacks on the World Trade Centers has used life values ranging from $250,000 to $7 million (Zimmerman et al.).

There are a number of weaknesses in the study of the economic impacts of disasters pointed to by many of the researchers cited above. Mileti (1997) and Cochrane (2004) both lament that most disaster impact studies only include losses that can be measured in transactions. The loss of historic monuments, memorabilia, cultural assets, and the hidden cost of trauma are rarely quantified (Mileti, 1997). In addition, Cochrane cautions against confusion over causality of a post-event loss, using too limited a time frame, and double counting losses among others. McEntire and Dawson (forthcoming) have called for formalizing an approach to document volunteer disaster responders' efforts. These researchers note that volunteer time can be used in federal grant matching requirements. Standardized methods of valuing volunteer time should be used in

calculating the total economic impacts of a disaster event. While volunteers do not draw compensation, the time they spend in disaster response does have an opportunity cost.

Even with some weaknesses, there have been great strides in the analytic approaches to estimating the economic impacts of disaster events at the macro- and micro-economic levels. The challenge is to continue to improve the accuracy of our impact models, while keeping the methods computationally reasonable and having the ability to provide timely information to disaster management planners, political leaders, and responders.

Insurance

While insurance has its own academic and professional research literature, economics provides data, modeling techniques, and research methodologies to the study of disaster-related insurance markets. Most obviously are the techniques described above for estimating damage, especially indirect damage, following a disaster event. For example, of the $32.5 billion in insurance payouts as a result of the 9-11 terrorist attacks, $11 billion was for business interruption claims (Kunreuther & Michel-Kerjan, 2005). On the cutting edge of research techniques, Chen et al. (2004) employ neural network modeling to help predict house survival in Australian bushfires. In addition, simulation modeling for risk and economic losses is being used to establish premium levels, the degree to which risk spread is required, and the viability of insurance related derivative instruments (Andersen, 2004). One of these derivative instruments is an interesting market-based approach for addressing insurer exposures to the rising costs of disasters.

Catastrophe bonds (cat-bonds) are investments meant to spread the risk of insurance loss due to disaster events. As explained by Andersen (2004), these bonds are issued (sold) to investors. The proceeds of the bond sales are placed in high-grade investments that are relatively liquid (can be sold quickly) and have low interest rate sensitivity to serve as collateral for debt service payments. The holding entity issues insurance contracts and receives income from the policy premiums. Insurance claims are paid from policy proceeds as well as the investment portfolio resources. At maturity, the investors receive the full principal of the bond only if insurance payouts have not been made. For example, cat-bonds have been issued to spread the risk of insuring against FIFA's potential losses if the 2006 World Cup (soccer) tournament in Germany is cancelled due to terrorism. Unfortunately, Kunreuther and Michel-Kerjan (2005) note that cat-bonds have not been broadly accepted by the market. Similarly, the Chicago Board of Trade and the Bermuda Commodity Exchange both tried issuing disaster related financial derivatives through options and futures contracts but saw little market interest and have subsequently stopped trade in these financial instruments.

Political economy elements can also be seen in the disaster insurance market. Given huge losses and uncertainty about further attacks, the terrorism reinsurance market effectively stopped functioning in the months immediately after 9-11. Recognizing the connection between business growth and availability of insurance, Congress passed the Terrorism Risk Insurance Act (TRIA) of 2002 that provides up to $100 billion of reinsurance coverage for international terrorism events in the US (Kunreuther & Michel-Kerjan, 2005).[11] However, once it became clear that no further attacks were imminent, the insurance market re-established itself. Brown et al. (2004) judge that TRIA has been,

[11] Unless reauthorized, TRIA expires in 2005.

at best, value neutral for insurers and is seen as an impediment to market-based solutions by companies in the banking, construction, transportation, and other industries. Policymakers' concern about insurance market responses in the immediate aftermath of disasters has been a subject for discussion since the early 1990s, which saw huge industry losses in consecutive years as a result of hurricane Andrew (1992), the mid-west floods (1993), and the Northridge earthquake (1994) (Barnett, 1999). But, aside from TRIA, there has been no meaningful congressional action on these concerns.[12] At the state level, California and Florida have created risk pools to promote insurance availability in their disaster-prone areas (Barnett).

Regional Development Theory

There is a small but growing literature drawing connections between regional development and disaster planning, though the efforts are far from concerted. McEntire (2004) calls on disaster researchers to integrate development theory into their own research. As an example, he draws on the works of Max Weber and Karl Marx to show potential insights into disaster studies. Perhaps one of the greatest opportunities is to use current regional development thought to help explain consumer behavior in the face of disaster risk.

For many of us who do not live in the great state of Florida, we wonder why the state continues to have a fast growing real estate market in light of repeated disaster events over the past several years. A preliminary attempt at providing an explanation for this phenomenon requires multiple research disciplines. First is the acknowledgement

[12] Interestingly, Kunreuther and Michel-Kerjan (2005) report that more companies are purchasing terrorism insurance because executives fear they could be sued under provisions of the Sarbanes-Oxley Act if their firm suffers an uninsured attack.

from the social-psychology field that researchers do not understand peoples' responses to low probability events (Ganderton et al., 2000). However, it can be reasonably hypothesized that individuals expect either government or insurance resources to make them effectively whole in the case of disaster. This is supported by Kleindorfer and Kunreuther's (2000) finding that even with low costs and reasonable time periods for investment recovery, most consumers will not spend money for risk mitigation measures. Moreover, the probability of sustaining life-threatening injuries is likely perceived as virtually nil – at least when considering loss of life incident rates resulting directly from hurricanes. So that may explain why individuals are willing to risk hurricane damage to gain the environmental and recreational amenities of the Florida peninsula.[13] But that begs the question of why do businesses locate where there is a greater risk of physical damage and activity loss to go along with higher costs for insurance coverage?

Richard Florida offers a potential explanation in his writing about the "creative class." Florida (2002) asserts that business site location decisions are increasingly driven by the presence of cultural, recreational, and environmental amenities. In other words, site locations used to be based on proximity to raw materials and/or markets, now it is more about being in a location where potential employees want to live. Therefore, businesses locate where they have the greatest advantage in attracting the most talented workers, even if it is in an area with a higher probability of a disaster event. While Florida's theories are not universally accepted by regional economists, there is supporting evidence in the behavior of some firms. This suggests that the level of economic exposure to disasters will continue to rise until individuals perceive greater disincentives for moving to disaster prone areas. Berz (1994) and other researchers have called for

[13] The obvious question deals with the impact of Katrina on individuals' location decisions.

greater use of building restrictions in coastal and riparian zones and other market interventions to slow growth in disaster prone areas; however, there is little political support for these suggestions.

The danger of wildfire losses from increasing development encroachment into forested lands are another notable disaster risk. The social, political, and economic conditions that can lead to greater exposure to catastrophe in areas that attract residential development because of environmental amenities are illustrated by Diamond (2005) for the Bitterroot River Valley of Montana.

It has been suggested that the threat of terrorism will impact urban land forms. Glaeser and Shapiro (2002) note that there are three types of effects that the threat of terror can have on urban design: promoting density, promoting dispersion, and increasing costs of transportation. Density in urban design is promoted through the psychology of safety in numbers. A highly dense population center offers a safe harbor where individuals enjoy mutual protection. Conversely, the same high population density makes cities a more efficient target for terrorists, which suggests that dispersing urban centers is appropriate. The third factor considers average transportation costs that favor high density urban designs. Glaeser and Shapiro conclude that, with a few exceptions, these factors balance out, and the threat of terrorism does not materially affect urban form. Rossi-Hansberg (2004) suggests that in theory, bid-rents in areas with a higher probability of physical destruction would decrease to account for increased risk and thus impact property investment decisions and change the physical structure of a city. However, this theoretical approach does not appear to fully account for insurance and

government assistance – suggesting again that current government disaster policy may be supporting increasingly inefficient real estate markets in disaster prone areas.

Disaster Planning

In addition to the applications of economic theory and research techniques described previously, there are a few other ways that the discipline of economics contributes to disaster planning. For example, Rose (2004) has offered measures of economic resilience – the capacity of an economy to absorb or diminish the effects of shocks – that can enhance the ability of planners and disaster responders to enable individuals and communities to avoid some potential losses. The distribution of mitigation funds could be made based on measures of economic vulnerability and event risks (Adrianto and Matsuda, 2004; Cole, 2004).

Of course, the threat of terrorism occupies much of the efforts of disaster planners in our post-9/11 political environment. Data analysis techniques from the economic discipline are being employed to assess the risk and responses to the threat of terrorism such as spectral analysis to examine cycles of events, vector autoregressive techniques for quantifying patterns of attack, and game theory approaches for predicting the likelihood of attacks and the effect of deterrence strategies (Lapan and Sandler, 1988; Sandler et al., 1991; Arce and Sandler, 2005; Averett, 2005).

Finally, with increases in funding for disaster planning in the past few years, there is need for disaster planners to have access to the knowledge of regional economists and economic development theory and practice. For example, Dekle et. al. (2005) have developed a site location tool to assess potential locations for disaster recovery centers.

While the physical location of disaster recovery centers and centers for disaster research will continue to be influenced by the political economy, we can hope that sound, practical reasons, such as promoting the effectiveness of the delivery of disaster response services, will remain the primary site location factor.

Conclusions

Offering the reader a reasonably brief overview of the use of economic research methods and techniques for the study of disasters and disaster management inevitably results in omissions, incomplete descriptions, and failure to recognize the contributions of many talented and insightful scholars. However, this chapter has presented an overview of the contributions of the economic discipline to understanding the costs of disasters, the analysis of private insurance markets, and theories and research techniques used in various phases of disaster management planning. In addition, it has illustrated how political considerations affect disaster policy and the distribution of relief funds. Even so, there is a great deal left in the field of disaster management that could be aided through the application of economy theory and research techniques.

Mileti (1999) specifically calls for the creation of a national database of losses and vulnerability that would serve as a communications feedback loop for communities, researchers, emergency managers, and government. There have been some that have suggested standardizing the approach used to estimate economic losses from disasters. However, from a practical standpoint, it is better to allow for flexibility in research technique for two reasons. First, the choice of cost estimation technique should consider the information need – how fast are the estimates needed, on what scale, and to what

depth? Second, standardization will certainly serve to stifle innovation in new, probably better, ways to assess the economic impacts of disasters.

We should continue to employ economic theory and modeling to address issues of efficiency, equity, and consistency in disaster mitigation and response. Under current policies the overall scope of a disaster has too great of an influence in deciding the funds made available to individuals in need. In addition, disaster costs are rising due to rapidly growing populations in coastal and other high risk areas, local zoning and building codes that do not adequately address disaster risks, increasingly inefficient real estate markets that are distorted by spreading the risk of locating in disaster prone areas to all taxpayers, and spin-offs of a growing economy such as increases in the shipment and use of hazardous materials.

Addressing critical information needs to disaster planners, policy makers, and responders will continue to challenge economists. Working in concert with researchers from disciplines such as sociology, geography, anthropology, engineering and others, economists can address information needs and offer guidance on maximizing our ability to mitigate disaster impacts.

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