Measuring Economic Resilience: Recent Advances and Future Priorities

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I. Introduction

The use of the term resilience in the context of natural disasters and terrorism has increased exponentially over the last 20 years. The term is in such widespread use today, and has been applied so broadly, that it is in danger of merely becoming a popular buzzword, which is undercutting its substance and usefulness.

Over the past 10 years, researchers at the Center for Risk and Economic Analysis of Terrorism Events (CREATE), have answered the following important questions (see, e.g., Rose et al., 2007; Rose, 2009; Rose and Krausmann, 2013):

- Is resilience a meaningful concept? Yes it is, especially from an economic perspective.
- Can resilience be rigorously defined? Yes, though it is complex and has multiple dimensions.
- Can resilience be empirically measured? Yes, and an operational metric has been established and successfully applied in several contexts.
- How effective has resilience been today? It has been very effective, and moreover has been relatively low-cost and hence cost-effective.
- Can a meaningful resilience index be established? Yes, if it has solid conceptual grounding, is based on actionable variables, and appropriate weights for individual indicators can be specified.

This paper briefly explains how the aforementioned critical questions surrounding economic resilience have been answered, modeled, and applied over the past decade. We first define economic resilience, including some of its major subtleties. Next we present an operational metric of resilience and summarize the application of the metric by CREATE researchers and others in measuring resilience in case studies of simulated and actual events. We then turn to the discussion of the cost-effectiveness and cost-benefit analysis of resilience. We conclude with a discussion of priorities for future research.

II. Defining Economic Resilience

Following Rose (2004; 2009) we begin with basic definitions and their relation to more general concepts of resilience and definitions in related fields. These comparisons indicate that there are commonalities than differences across various fields, especially with regard to the essence of the definitions.

In general, Static Resilience refers to the ability of the system to maintain a high level of functioning when shocked (see, e.g., Holling, 1973). Static Economic Resilience is: the efficient use of remaining resources at a given point in time. It refers to the core economic concept of coping with resource scarcity, which is exacerbated under disaster conditions.

In general, Dynamic Resilience refers to the ability and speed of the system to recover (see, e.g., Pimm, 1984). Dynamic Economic Resilience is: the efficient use of resources over time for investment in repair and reconstruction. Investment is a time-related phenomena—the act of setting aside resources that could potentially be used for current consumption in order to re-establish
productivity in the future. Static Economic Resilience does not restore damaged capacity and is thus not likely to lead to full recovery.

Note that the definitions are couched in terms of functionality, typically measured in economics as the flow of goods and services, such as Gross Domestic Product (GDP) or broader measures of human well-being, as opposed to property damage. It is not the property (capital stock) that directly contributes to economic welfare but rather the flows that emanate from these stocks. Two things should be kept in mind. First, while property damage takes place at a point in time, the reduced flow, often referred to on the production side as business interruption (BI), begins at the time of the disaster but continues until the system has recovered or attained a “new normal.” Second, the recovery process, and hence the application of resilience, depends heavily on the behavior of economic decision-makers and on public policy. Of course, recovery is a multi-faceted activity. It is not as simple as, for example, just automatically rebuilding a school destroyed by an earthquake, hurricane, or armed attack.¹

Another important distinction is between inherent and adaptive resilience. The former refers to aspects of resilience already built into the system, such as the availability of inventories, excess capacity, substitutability between inputs, and contingent contractual arrangements accessing suppliers of goods from outside the affected area (imports). Resilience capacity can be built up through these means and is then accessed after the disaster. Adaptive resilience arises out of improvisation under stress, such as Draconian conservation otherwise not thought possible (e.g., working many weeks without heat or air conditioning), changes in the way goods and services are produced, and new contracting arrangements that match customers who have lost their suppliers with suppliers who have lost their customers.

Economic resilience takes place at three levels:

- Microeconomic (individual business, household, or government)
- Mesoeconomic (individual industry or market)
- Macroeconomic (combination of all economic entities, including their interactions)

At the microeconomic level, on the business supplier side, static economic resilience includes redundant systems, improved delivery logistics, and planning exercises. Several options also exist on the business customer side. Broadening the supply chain (see, e.g., Sheffi, 2005) by expanding the range of suppliers in place or on a contingency basis is an increasingly popular option. Another is conservation of resources made all the more scarce by the disaster. Conservation is only minimally inherent because economists typically assume that most available efficiencies in resource use are currently being utilized; thus, most resilient conservation options pertain to adaptive applications. All inputs (capital, labor, infrastructure services, and materials) can be conserved. The major obstacle is the necessity of the input in the production process. Other resilience tactics include input and import substitution, use of inventories and excess capacity, cross-training workers, relocation, and production recapture (working overtime and extra shifts when functionality is restored to make up lost production).²

At the mesoeconomic level, resilience can bolster an industry or market and include, for instance, industry pooling of resources and information and innovative pricing mechanisms. What is often less appreciated

¹ We note that research on resilience is split into two camps. About half of the researchers view resilience as any action that can reduce losses from disaster, ranging from pre-disaster mitigation to post-disaster recovery. Not surprisingly, this group is dominated by engineers, whose work is primarily in the area of mitigation (see, e.g., Bruneau et al., 2003; Haines, 2007). The other camp focuses on resilience as actions following a disaster. Steps can be taken to enhance resilience, acknowledging that it is very much a process, but such measures are usually not implemented until afterward (e.g., stockpiling of critical materials, development of emergency plans). Recent events, such as the World Trade Center attacks and Hurricane Katrina, indicate that BI can be as large as or larger than property damage following a disaster. We focus on the second approach, noting that much of our analysis is applicable to mitigation as well.

² Most of the resilience tactics associated with businesses are applicable to government and household operations as well, with some modification (see Rose, 2009).
is the inherent resilience of market prices that act as the “invisible hand” to guide resources to their best allocation in the aftermath of a disaster (see, e.g., Horwich, 1995). Some pricing mechanisms have been established expressly to deal with such a situation, as in the case of non-interruptible service premia that enable customers to estimate the value of a continuous supply of electricity and to pay in advance for receiving priority service during an outage. The price mechanism is a relatively costless guide to redirecting goods and services. Price increases, to the extent that they do not reflect “gouging,” serve the purpose of reflecting highest value use, even in the broader social setting. Moreover, if the reallocation violates principles of equity, the outcomes can be adjusted by income or material transfers to the needy.

At the macroeconomic level, resilience is very much influenced by interdependencies between sectors. Consequently, macroeconomic resilience is not only a function of resilience measures implemented by single businesses but is also determined by the actions taken by all individual companies and markets, including their interaction. Examples of resilience options at the macro-level would be economic diversity to buffer impacts on individual sectors and geographic proximity to economies not affected by disaster to facilitate access to goods or aid. Others include fiscal (e.g., infrastructure spending to boost the affected economy) and monetary policy (e.g., keeping interest rates low to stimulate private sector reinvestment). The macro-level overlaps with the popular focus on “community resilience” and represents a more holistic picture (Norris et al., 2008).

The previous examples relate primarily to Static Economic Resilience. Dynamic Economic Resilience is applicable at all three levels as well in terms of expediting the recovery process and enhancing its outcome. At the micro-level this can be promoted through rapid processing of insurance claims and arranging financing so as to facilitate repair and reconstruction. At the meso and macro levels it includes hastening and improving the economic effectiveness of the recovery process by improving logistics and coordinating recovery across sectors. Cross-cutting all three levels is adapting to changing conditions by promoting flexibility and translating short-run practices into sustainable ones through a continuous learning process (see, e.g., Zolli and Healy, 2012; Rose, 2014).

III. An Operational Metric

Following Rose (2004; 2009), we provide an admittedly crude but operational metric of resilience. Direct Static Economic Resilience (DSER) refers to the level of the individual firm or industry (micro and meso levels) and corresponds to what economists refer to as “partial equilibrium” analysis, or the operation of a business or household entity itself. Total Static Economic Resilience (TSER) refers to the economy as a whole (macro-level) and would ideally incorporate what is referred to as “general equilibrium” effects, which include all of the price and quantity interactions in the economy, macro-aggregate considerations, and the ramifications of fiscal, monetary and security policies related to the disaster.

An operational measure of DSER is the extent to which the estimated direct output reduction deviates from the likely maximum potential reduction given an external shock, such as the curtailment of some or all of a critical input. In essence, DSER is the percentage avoidance of the maximum economic disruption that a particular shock could bring about.

We illustrate the application of the definition with the following case study by Rose et al. (2009), who estimated the national and regional economic impact of the September 11, 2001, terrorist attack on the World Trade Center. The researchers refined available data indicating that more than 95 percent of the businesses and government offices operating in the WTC area survived by relocating, primarily to Mid-town Manhattan or across the river in Northern New Jersey. Had all of these firms gone out of business, the potential direct economic loss in terms of GDP would have been $43 billion. However, relocation was not immediate, taking anywhere from a few days to as long as eight months for the vast majority of firms. Rose et al. (2009) calculated this loss in GDP at $11 billion. They were then able to apply the resilience definition

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3 Resilience is sometimes conflated or confused with related terms such as vulnerability and sustainability. The reader is referred to Rose (2013; 2014) for a more detailed discussion.
provided in this Section to estimate that the effectiveness of relocation as a resilience tactic in the aftermath of the 9/11 attacks was 72 percent ($43 minus $11, divided by $43).

Several studies have examined economic resilience in actual disasters or with the use of simulation studies. The major pioneer is Tierney (1997), who surveyed businesses in the aftermath of the Northridge Earthquake and Midwest Floods. Rose and Lim (2002) translated Tierney's findings into specific measures of resilience of the Los Angeles electricity system. They identified such factors as time-of-day-use, electricity "importance" (dependence), and production recapture as key to understanding why businesses that averaged a X% reduction of electricity were able to continue operation at much less than a X% reduction in their production goods and services. In fact, they found that these micro-level tactics resulted in a reduction of business interruption losses by more than 90 percent of baseline estimates, a level consistent with Tierney’s survey responses.

Several other simulation studies have been undertaken to estimate the effects of resilience on losses from disasters, using the metric presented in the previous section. Kajitani and Tatano (2009) used a survey to estimate the resilience of Japanese industries to various types of lifeline disruptions from disasters. Their findings are the most definitive to date on a broad spectrum of resilience tactics. Rose et al. (2007) estimated the resilience of the Los Angeles water and power systems to a two-week outage due to a terrorist attack. They found that resilience could be as high as 90 percent, primarily due to production recapture. Rose and Wei (2013) examined such resilience tactics as excess capacity, inventories, and export diversion to reduce potential losses from a 90-day shutdown of a major U.S. seaport complex in a regional economy dominated by petrochemical production. They also examined the effectiveness of major government policies such as accessing the Strategic Petroleum Reserve, but found it likely to be of limited help at the cost of considerable political capital. Overall, they found that the implementation of these resilience tactics could reduce GDP losses by more than 70 percent.4

V. Cost-Effectiveness and Cost-Benefit Analysis of Resilience

To make prudent resource management decisions, one must consider the cost of each resilience tactic as well as its effectiveness. One tactic might be capable of reducing more than twice the BI losses of another, but if it costs 10 times as much to implement, the former is not the better option.

We begin with a general overview of cost considerations. Most adaptive Conservation more than pays for itself when it represents a productivity improvement, such as an increase in energy-efficiency (producing the same amount but with less energy). A more general definition of Conservation (reducing the amount of an input irrespective of its effect on output) can incur net positive costs. Input Substitution requires a small penalty for using a less optimal input combination. Import Substitution involves an increase in costs from utilizing higher-cost sources and/or increasing transportation distances. Relocation can be somewhat expensive if it involves a physical move; however, increasing the role of telecommunications, and the prospects for working in cyberspace and tele-commuting, have significantly decreased this cost. Emergency Planning Exercises take little time and incur relatively low costs. Production Rescheduling involves the payment of overtime wages.

Some resilience tactics are primarily inherent, and simply await their utilization once the disaster strikes. The cost of inventories is just the carrying charge and not the value of the inventories themselves, which simply replace resources that would’ve been paid for otherwise. Excess Capacity involves a similar cost,

4 The context in which the disaster strikes and resilience is implemented also has an influence on effectiveness. Relevant factors include the disaster type, magnitude, and recovery duration, as well as background conditions relating to the economy, such as its economic health at the time of the disaster and its geographic location. For example, inventories are finite and more likely to run out in disasters for which the duration of recovery is long. Production recapture also erodes over time, as customers begin to seek other suppliers. Excess capacity is dependent on the business cycle (e.g., one reason that relocation was so effective after the WTC attacks was because New York City was in the throes of a recession, which then provided a great deal of vacant office and some manufacturing space).
though some excess capacity is often planned in order to enhance business flexibility or to accommodate downtime for maintenance; these aspects should not be charged to disaster resilience.

Once the cost per unit of effectiveness, expressed in percentage terms or in terms of dollars of net revenue from business interruption loss prevention, is determined the options should be ranked from lowest cost to highest, and would likely yield the standard increasing marginal cost curve. Note, however, that since most conservation more than pays for itself, the function begins in the negative cost range.

Resilience can be couched in a benefit-cost analysis (BCA) framework by considering its rewards as well. At the micro level, the benefits are the net revenue of business interruption losses avoided. At first this might best be represented by a horizontal marginal benefit (MB) curve, reflecting equal additional increments of benefits for each percentage increase in resilience. The optimal level of resilience would be at the point at which the marginal cost and marginal benefit curve intersect. Even without a precise numerical example, we can draw some insights from the example. All cost-saving resilience options would be taken, because they yield guaranteed net benefits. Also, given the relatively low cost of many of the tactics, at least in some of their initial applications, it is likely that a fairly high level of resilience would be chosen. Of course, this would best be juxtaposed to mitigation opportunities as well.

VI. Future Research

We offer the flowing topics as priorities for future research:

1. Measuring Static and Dynamic Economic Resilience in Practice. Very few studies have actually measured resilience in the aftermath of a disaster, and instead, analysts and policy makers have been overly dependent on simulation analysis. The author, in conjunction with colleagues Kathleen Tierney, Noah Dormady and Charles Huyck, are engaged in two major studies to help rectify this issue. We are being supported by the new DHS-supported Critical Infrastructure Resilience Institute (CIRI) to develop a conceptual framework and conduct survey research on static economic resilience in the aftermath of SuperStorm Sandy. This study will be based on many of the concepts presented in this paper. We are also being supported by the National Science Foundation to undertake a study of dynamic resilience in the aftermath of Sandy. In this case, we are examining the potential and speed of recovery. This project revolves around the key questions: 1) Will the business invest in repair and reconstruction, 2) If so, in what location, 3) Will the new investment include major productivity enhancements, and 4) Will the investment result in reducing vulnerability to future disasters? Again, a survey will be administered to collect the major portion of the data.

2. Identifying Obstacles to Resilience. The simulation studies cited above are biased towards estimating resilience at its maximum effectiveness. This outcome is unlikely due to the disarray accompanying most disasters, administrative obstacles, and personal failings. Moreover, Rose (2009) has analyzed the erosion of resilience during large disasters as inventories are depleted, extreme conservation becomes onerous, and opportunities for production recapture decline as customers abandon their traditional suppliers who are unable to deliver within a time threshold. Research is needed on the extent of these obstacles and identifying ways to overcome them.

3. Evaluating Inherent Resilience Potential. It is important to identify resilience that is inherent in the survival mechanisms of businesses and households from those that require government policy assistance. This way, future recovery efforts can better capitalize on existing capabilities and minimize duplication of government services. The focus of government can then be on facilitating this inherent resilience by removing obstacles to private enterprise, reducing wait times for assistance, and more effectively targeting its role.

4. Compiling Resilience Indices Based on Actionable Variables. Recently, interest has shifted to identifying individual resilience indicators that can be aggregated into an overall index. This has emanated in part from the successful compilations of vulnerability indices. Several well-intentioned examples of resilience indices include Cutter et al. (2010) and Sherrieb et al. (2010), but many of their components are background...
conditions and many are not in fact important to the resilience of individual businesses or the economy as a whole during the crucial early stages of the recovery process. Specifically, resilience is not just the flip-side of vulnerability. A resilience index is not only useful to study the recovery process, but also to improve it. This speaks to the importance of actionable variables. More research is needed to identify indicators that really matter to business decisions in the short-run.

References


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