Measuring Economic Resilience to Disasters: An Overview[i]

Adam Rose[1]

[1]University of Southern California

Contact: adamzros@price.usc.edu

Keywords: Economic theory, Static and dynamic resilience, Inherent and adaptive resilience, Operational metrics

Introduction

Researchers and decision-makers in the disaster field are evenly split on the definition of resilience. One group utilizes the concept to refer to any action taken to reduce disaster losses. This group, with a large representation by engineers, focuses primarily on mitigation with an eye to reducing the frequency and magnitude of disasters and strengthening property to prevent damage (see, e.g., Bruneau et al., 2003). The broader definition has also been adopted and applied more evenly by major panels assessing resilience research and practice, such as the National Research Council, which defines resilience as: "The ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events" (NRC, 2012; p. 16).

Another group, with a large representation by social scientists, focuses primarily on actions implemented after the disaster strikes (Tierney, 2007; Rose, 2007; Cutter, 2016). This group takes the meaning of resilience more literally, referring to its Greek language root, whose definition is "to rebound." They also acknowledge that resilience is a process, whereby steps can be taken before the disaster to build resilience capacity, but resilient actions do not take place until afterward. Examples would include emergency drills, purchase of back-up electricity generators, and lining up alternative suppliers of critical inputs. Here the focus is not on property damage, which has already taken place, but rather the reduction in the loss of the *flow of goods and services* emanating from property, or *capital stock*. The former is often measured in terms of gross domestic product (GDP) and employment, and is typically referred to as business interruption, or BI (Tierney, 1997). BI just begins at the point when the disaster strikes, but continues until the system has recovered or reached a "new normal", which is typically coming to be considered a sustainable level of activity. Measuring BI is thus much more complicated, because it involves matters of the duration and time-path of recovery, both of which are strongly affected by the behavioral responses of public and private decision-makers (Rose, 2004).

This chapter focuses on the measurement of economic resilience. Economic resilience is more focused than community resilience (e.g., Norris et al., 2008), but on par with resilience in other disciplines (e.g., organizational behavior, planning, engineering, ecology), with which it shares more

---

[i] This paper is part of the IRGC Resource Guide on Resilience, available at: https://www.irgc.org/risk-governance/resilience/. Please cite like a book chapter including the following information: IRGC (2016). Resource Guide on Resilience. Lausanne: EPFL International Risk Governance Center. *v29-07-2016*

commonalities than differences (Rose, 2007). It is closely related to the literature on business continuity (Sheffi, 2005; Herbane, 2010), as both foci on the continued functioning of individual firms and their recovery from disaster. The latter has a strong focus on cyber/information technology considerations, and on that score is far ahead of the literature on economic resilience, with a few exceptions (see, e.g., Rose, 2015).

Defining Economic Resilience

There are many definitions of resilience, but Rose (2007) and others have found more commonalities than differences. We offer the following general definitions of resilience, which capture the essence of the concept, and then follow them up with definitions that capture the essence of economic considerations. Following Rose (2004, 2007), and paralleling two seminal approaches to resilience in the literature on ecology, we distinguish two major categories of resilience:

In general, Static Resilience refers to the ability of the system to maintain a high level of functioning when shocked (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 (Pimm, 1984). *Dynamic Economic Resilience* is the efficient use of resources over time for investment in repair and reconstruction. Investment is a time-related phenomenon—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 completely restore damaged capacity and is therefore not likely to lead to complete recovery.

Note that economic resilience can take place at three levels of analysis:

- Microeconomic (operation of individual businesses, households, government agencies, e.g., conservation of or substitution for critical inputs, use of inventories or excess capacity, relocation, production rescheduling)
- Mesoeconomic (operation of industries and markets, e.g., the resource allocating mechanism of the price system)
- Macroeconomic (operation of the economy, e.g., supply-chain adjustments, importation of critical inputs, fiscal and monetary policy)

A key asset in analyzing economic resilience is that it can be done in the context of well-established theory relating to the behavior of producers/consumers/government agencies, markets, and entire economies. Formal derivations of resilience relationships have demonstrated their usefulness (see, e.g., Rose and Liao, 2005).

Another important delineation in economic resilience, and resilience in general, is the distinction between inherent and adaptive resilience (Tierney, 2007; Cutter, 2016). Inherent resilience refers to resilience capacity already built into the system, such as the ability to utilize more than one fuel in an electricity generating unit, the workings of the market system in offering price signals to identify scarcity and value, and established government policy levers. Adaptive resilience is exemplified by undertaking conservation that was not previously thought possible, changing technology, devising market mechanisms where they might not previously exist (e.g., reliability premiums for electricity or water delivery), or devising new government post-disaster assistance programs. It is important to realize that a good amount of resilience is already embodied in the economy at various levels, and that policies should be designed to capitalize rather than obstruct or duplicate this capacity. At the same time, policy should also be geared to rewarding both types of resilience.

An Operational Metric and Initial Measurement

The next step is to translate these definitions into something we can measure. For static resilience, this can be done in terms of the amount of BI prevented by the implementation of a given resilience tactic or set of tactics comprising a resilience strategy. For dynamic resilience, the metric would be the reduction in recovery time in addition to the reduction in BI, though obviously the former influences the latter. In both cases one needs a reference point or baseline to perform the measurement. For static resilience this would be the maximum potential BI loss in the absence of the resilience tactic, while for dynamic resilience it would be the duration and time-path of economic activity in the absence of resilience in relation to investment in repair and reconstruction.

Several studies have measured resilience using this and related metrics. Rose et al. (2009) found that potential BI losses were reduced by 72% by the rapid relocation of businesses following the September 11, 2001 terrorist attacks on the World Trade Center. Rose and Wei (2013) found that a reduction in potential BI from a nine-month closure of a major US seaport could be as high as 66% from the implementation of several types of resilience, most notably ship rerouting, use of inventories, and production rescheduling. Xie et al. (2016) estimated that BI losses could have been reduced by 30% and recovery time by one year with an increase in investment funds and acceleration of their timing in the aftermath of the Wenchuan earthquake in China.

Other studies have found the extensive potential of economic resilience. Kajitani and Tatano (2009) found extensive resilience possibilities among Japanese manufacturing firms in response to utility lifelines disruptions caused by disasters. Other specialized studies have developed methodologies for examining the potential of specific resilience strategies, such as the use of inventories (Barker and Santos, 2008). Moreover, resilience capabilities have been built into major hazard loss estimation models and software such as the HAZUS Direct Economic Loss Module and Indirect Economic Loss Module (2016) and the Economic Consequence Analysis Tool (E-CAT) (Rose et al., 2016).

Future Research in Resilience Measurement

In addition, measures of resilience effectiveness can serve as weights in compiling a resilience index, used as part of formal decision-making tools (Larkin et al., 2105). Today, practically every such index, economic or otherwise, has assumed equal weight across individual indicator components. Another advantage of the approach discussed above is that resilience is aligned with actionable variables, which are most applicable to economic recovery (Rose and Krausmann, 2013). Many resilience indices still conceive of resilience as the flip side of vulnerability, and are heavily dominated by background variables (e.g., unemployment rates, literacy rates, percent minorities) that cannot be changed in the short run.

For risk management purposes, it is important to know not only the effectiveness of resilience tactics but also their costs. Work is only beginning in this area, but we have some general indications of the values of this metric. For example, conservation typically means producing a given amount with fewer inputs, and thus can be cost-saving. Substitution of critical inputs can often be accomplished at a minimal cost, as can importing these goods from other countries or regions. The cost of inventories is not the value of the goods and services, but simply their carrying cost. At higher levels of analysis, the workings of the price system offers costless signals as to the value of factors of production that can assist resource reallocation decisions. At the same time, resilience tactics have the advantage over mitigation, because they need only be applied if the disaster has actually struck, while mitigation requires advance expenditures for a disaster that may never materialize. On the other hand, most mitigation tactics, once put in place, can protect against many types of disasters over a number of years, while most resilience tactics are a one-shot expenditure and benefit.

The combination of effectiveness and cost measures can be transformed into cost-effectiveness metrics that can be used to identify the greatest return on investment expenditures. If effectiveness can be translated into dollar terms, rather than just percentage reductions, one can then obtain an estimate of benefits for a more comprehensive benefit-cost analysis to allocate resources across a range resilience tactics and threats (Rose, 2016).

Research is currently under way to measure both static and dynamic economic resilience through surveys of businesses. This research emanates from the economic theory foundations mentioned above and the crafting and administering of surveys in the aftermath of SuperStorm Sandy, which affected the New York City Metropolitan region in 2011.[2]

---

[2] This research is being carried out by the author, Noah Dormady, Kathleen Tierney, Liesel Ritchie and Charles Huyck, and is being sponsored by the US National Science Foundation and by the US Department of Homeland Security Critical Infrastructure Resilience Institute (CIRI). The author wishes to thank these organizations for their funding support of this article.

Annotated Bibliography

Barker, K., & Santos, J. (2009). "Measuring the Efficacy of Inventory with a Dynamic Input–Output Model," *International Journal of Production Economics* 126(1): 130–43.
Example of specialized study of a major economic resilience tactic.

Bruneau, M., Chang, S., Eguchi, R., Lee, G., O'Rourke, T., Reinhorn, A., Shinozuka, M., Tierney, K., Wallace, W., & von Winterfeldt, D. (2003). "A Framework to Quantitatively Assess and Enhance Seismic Resilience of Communities," *Earthquake Spectra* 19: 733–52.
Classic paper on multiple dimensions of community resilience, though only a perfunctory treatment of the economic dimension.

Cutter, S. (2016). “The Landscape of Disaster Resilience Indicators in the USA,” *Natural Hazards* 80: 741-58.
Major insights into resilience, primarily from a geography perspective

Cutter, S., Burton, C., & Emrich, C. (2010). “Disaster resilience indicators for benchmarking baseline conditions,” *Journal of Homeland Security Emergency* Management (online journal) 7 (Article 51).
Example of a resilience index based primarily on vulnerability indicators.

Federal Emergency Management Agency (FEMA). (2016). Multi-hazard Loss Estimation Methodology (HAZUS®MH MR4) http://www.fema.gov/library/viewRecord.do?id=3726.
Widely used hazard loss estimation software.

Hallegate, S. (2014). "Modeling the Role of Inventories and Heterogeneity in the Assessment of the Economic Costs of Natural Disasters," *Risk Analysis* 34(1): 152-167
Example of specialized study of a major economic resilience tactic.

Herbane, B. (2010). “The evolution of business continuity management: A historical review of practices and drivers,” *Business History* 52(6): 978-1002.
Summary of business continuity practice.

Holling, C. (1973). “Resilience and stability of ecological systems.” *Annual Review of Ecology and Systematics* 4: 1–23.
Classic article on resilience focused on maintaining functionality.

Kajitani, Y., & Tatano, H. (2009). “Estimation of Lifeline Resilience Factors based on Empirical Surveys of Japanese Industries,” *Earthquake Spectra* 25(4): 755-76.
Measurement of resilience in Japanese manufacturing firms.

Larkin, S. Fox-Lent, C., Eisenberg, D., Trump, P., Wallace, S., Chatterton, C., & Linkov, I. (2015). “Benchmarking agency and organizational practices in resilience decision making,” *Environment Systems and Decisions* 35(2): 185–195.
Article on resilience in U.S. federal government agency decision-making.

National Research Council (NRC). (2012). *Disaster Resilience: A National Imperative.* Washington, DC: National Academies Press.
Consensus summary of key resilience concepts, and measurement.

Norris, F., Stevens, S., Pfefferbaum, V., Whyche, K., and Pfefferbaum, R. (2008). “Community resilience as a metaphor, theory, set of capacities and strategy for disaster readiness,” *American Journal of Community Psychology* 41: 127–50.
Classic article on community resilience.

Pimm, S. L. (1984). “The complexity and stability of ecosystems,” *Nature* 307(26): 321–26.
Classic article on resilience emphasizing a rapid return to equilibrium.

Rose, A. (2004). “Defining and Measuring Economic Resilience to Disasters,” *Disaster Prevention and Management* 13(4): 307-14.
Provides basic economic principles underlying resilience.

Rose, A. (2007). "Economic Resilience to Natural and Man-made Disasters: Multidisciplinary Origins and Contextual Dimensions," *Environmental Hazards* 7(4): 383-95.
Compares economic resilience concepts and definitions with those in several other disciplines.

Rose, A. (2015). “Measurement of Cyber Resilience,” Center for Risk and Economic Analysis of Terrorism Events (CREATE), University of Southern California (USC), Los Angeles, CA.
Initial inquiry into the economics of cyber resilience.

Rose, A. (2016). “Benefit-Cost Analysis of Economic Resilience,” *Oxford Research Encyclopedia of Natural Hazard Science*, forthcoming.
Provides details of concepts and measurement strategies for risk management of resilience.

Rose, A., & Krausmann, E. (2013). “An Economic Framework for the Development of a Resilience Index for Business Recovery,” *International Journal of Disaster Risk Reduction* 5(October): 73-83.
Presents a conceptual basis for an economic resilience index with an emphasis on actionable variables.

Rose, A., & Liao, S. (2005). “Modeling Resilience to Disasters: Computable General Equilibrium Analysis of a Water Service Disruption,” *Journal of Regional Science* 45(1): 75-112.
Presents a derivation of parameterization of resilience tactics in the context of economic production.

Rose, A., & Wei, D. (2013). “Estimating the Economic Consequences of a Port Shutdown: The Special Role of Resilience,” *Economic Systems Research* 25(2): 212-32.
Case study of resilience to a shutdown of a major seaport, with consideration of a wide array of economic resilience options.

Rose, A., Oladosu, G., Lee, B., & Beeler Asay, G. (2009). "The Economic Impacts of the 2001 Terrorist Attacks on the World Trade Center: A Computable General Equilibrium Analysis," *Peace Economics, Peace Science, and Public Policy* 15: Article 6.
Measurement of economic resilience in the aftermath of 9/11, with a focus on business relocation.

Rose, A., Prager, F., Chen, Z., & Chatterjee, S. (2016). *Economic Consequence Analysis Tool* (*E-CAT*). Tokyo: Springer.
Advanced software to estimate the economic consequences of disasters, with an emphasis on resilience and behavioral responses.

Sheffi, Y. (2005). *The Resilient Enterprise*. Cambridge, MA: MIT Press.

Classic case studies of resilience at the level of the individual firm.

Tierney, K. (1997). “Impacts of Recent Disasters on Businesses: The 1993 Midwest Floods and the 1994 Northridge Earthquake,” in B. Jones (ed.), *Economic Consequences of Earthquakes: Preparing for the Unexpected*. Buffalo, NY: National Center for Earthquake Engineering Research.
Summary of classic surveys to measure business interruption losses, with some consideration of resilience

Tierney, K. (2007). “Businesses and Disasters: Vulnerability, Impacts, and Recovery,” *Handbook of Disasters*. Heidelberg: Springer.
Major insights into resilience from a sociological perspective.

Xie, W., Rose, A., He, J., Ali, T., Wei, W., & Li, S. (2016). “Dynamic Economic Resilience and Economic Recovery: A Quantitative Assessment,” Peking University.
One of the first attempts to measure dynamic economic resilience at the macroeconomic level.