

# Resilience to Disasters: Reducing Losses Through Public-Private Partnerships

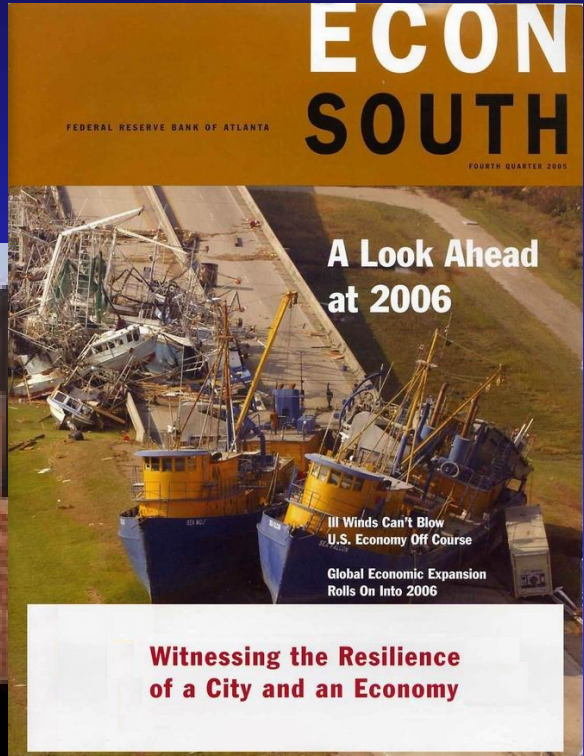
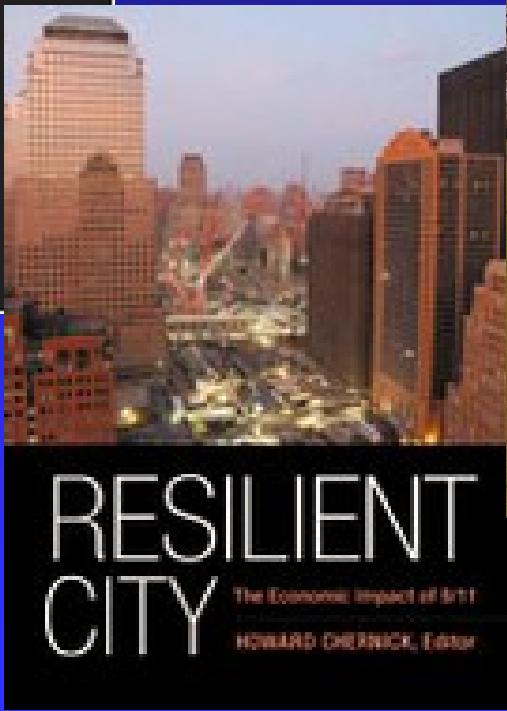
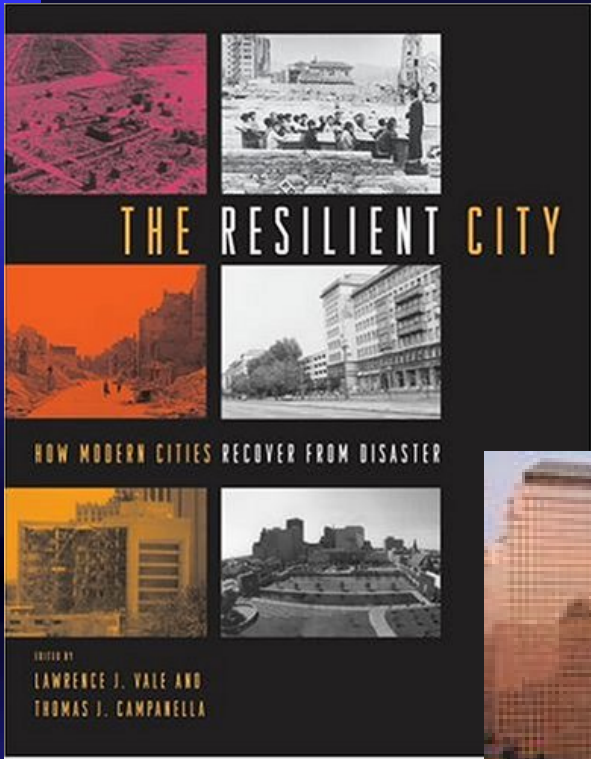
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# Key Questions

- Is resilience a meaningful concept?
- Is resilience multi-dimensional?
- Can resilience be rigorously defined?
- Can resilience be empirically measured?
- How effective has resilience been to date?
- How to obtain synergies in public/private?

# Overview

1. Define resilience
2. How to measure resilience
3. Effectiveness of resilience at the firm level
4. How resilience can be enhanced or depleted
5. Examples of innovations in resilience
6. Discuss public-private partnerships

# Economic Resilience

## General Definition:

- *static*: ability of a system to maintain function when shocked
- *dynamic*: speed of a system to recover from a shock

## Types of Resilience:

- *inherent*: normal ability during a crisis to cushion against damages (input substitution, market reallocation)
- *adaptive*: ingenuity during a crisis (increased substitution possibilities, market strengthening)

# Resilience at 3 Levels

- Microeconomic -- individual behavior of firms, household, organizations
- Mesoeconomic -- economic sector, individual market, cooperative group
- Macroeconomic -- all individuals units & markets combined (including interactive effects)

# Micro Level: Self Reliance and Expert Help

- Firms have motivation to cope with crisis for reasons of survival
- Recent disasters have spawned a new “business continuity” industry
- Still, businesses don’t operate in isolation

Company Executive: “In short, companies have started to realize that they participate in a greater ecosystem—and that their IT systems are only as resilient as the firms they rely on to stay in business.”

# Macro Level Resilience of Markets

- Market price changes reallocate resources to highest value use (not necessarily gouging)
- Non-interruptible electricity service premia can be built into system in advance
- Price signals can guide administrative decree to ration resources to highest use
- Imports and exports help relieve imbalances

# Disaster-Resistant vs. Disaster-Resilient

*Disaster-Resistant Community* refers to the objective of mitigation undertaken prior to the disaster.

*Disaster-Resilient Community* refers to improved workings of post-disaster response, recovery & reconstruction.

# Mathematical Definition: Direct Economic Resilience

$$DER = \frac{\% \Delta DY^m - \% \Delta DY}{\% \Delta DY^m}$$

where

$\% \Delta DY^m$  is the maximum percent change in direct output

$\% \Delta DY$  is the estimated percent change in direct output

# The Path to Recovery

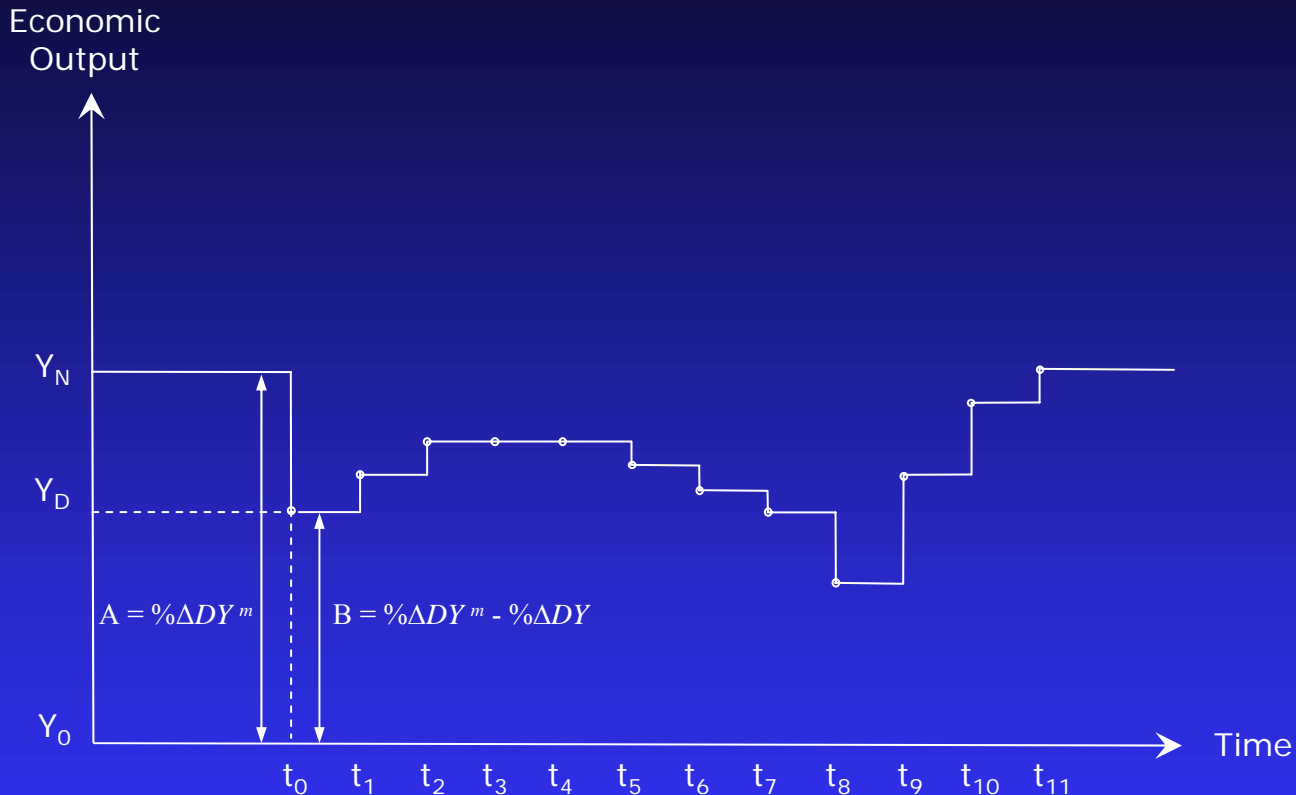


FIGURE 1. STATIC AND DYNAMIC RESILIENCE IN THE CONTEXT OF BUSINESS INTERRUPTION

- Recovery has 2 aspects:
  - repair/reconstruction (capacity increases)
  - resilience (productivity changes)

# Features of the Definition

- Focus on flows after the initial shock
- Linear reference point may not be so arbitrary--reflects zero flexibility
- Dynamics of recovery has 2 aspects
  - rebuilding of the capital stock
  - restoring loss of function

# CGE Modeling

## CES Production Functions

$$Y_j = A_1 \cdot (\alpha_1 \cdot M^{-\rho_1} + \beta_1 \cdot KLE^{-\rho_1})^{-1/\rho_1} \quad 1^{\text{st}} \text{ Tier}$$

$$KLE = A_2 \cdot (\alpha_2 \cdot L^{-\rho_2} + \beta_2 \cdot KE^{-\rho_2})^{-1/\rho_2} \quad 2^{\text{nd}} \text{ Tier}$$

$$KE = A_3 \cdot (\alpha_3 \cdot K^{-\rho_3} + \beta_3 \cdot E^{-\rho_3})^{-1/\rho_3} \quad 3^{\text{rd}} \text{ Tier}$$

$$E = A_4 \cdot (\alpha_4 \cdot (A_{4EL} \cdot EL)^{-\rho_4} + \beta_4 \cdot F^{-\rho_4})^{-1/\rho_4} \quad 4^{\text{th}} \text{ Tier}$$

$$F = A_5 \cdot (\alpha_5 \cdot OG^{-\rho_5} + \beta_5 \cdot GU^{-\rho_5} + \gamma_5 \cdot RP^{-\rho_5})^{-1/\rho_5} \quad 5^{\text{th}} \text{ Tier}$$

where:

$Y_j$  is output of sector  $j$

$A_i$  is the technology parameter of tier  $i$ ,  $A_i > 0$

$\alpha_i, \beta_i, \gamma_i$  is the factor distribution parameters of tier  $i$ ,  $0 \leq \alpha_i, \beta_i, \gamma_i \leq 1$

$\sigma_i$  is the constant elasticity of substitution of tier  $i$ ,  $\sigma_i = 1/(1 + \rho)$

$K, L, E, M$  are capital, labor, energy, material aggregates

$KLE$  is the capital, labor, and energy combination

$KE$  is the capital and energy combination

$F$  is the aggregate of oil/gas, gas utilities, and refined petroleum

$OG$  is the oil and natural gas aggregate

$GU$  is gas utilities

$RP$  is refined petroleum

$EL$  is electricity

# Estimates of Business Resilience

- Tierney (1995): 77% for Northridge EQ
- Rose & Lim (2002): 95% for Northridge EQ
- Rose & Liao (2005): 89% for Portland EQ
- Rose et al. (2006): 86% for LA Terrorism

# Individual Resilience Options

Table 1. Relative Prominence of Resilience Adjustments

Resilience Factor	Water	Electricity
Conservation	1.0	6.1
Adaptive Substitution	1.6	3.9
Inventories/Storage	3.0	—
Alternative Sources	—	28.1
Importance	58.7	28.7
Production Rescheduling	75.5	79.4
Total	91.0	89.6

# Limitations of Estimates

- Measured *potential* resilience vs. actual
  - bounded rationality
  - market failures
- Measured limited contexts
  - no customer property damage (terrorism)
  - limited damage (earthquakes)

# Resilience in Face of Catastrophes

Action	Example	Ordinary Effectiveness	Effectiveness in Catastrophe
<b>Inherent Resource Substitution</b>	bottled water for piped water	minor	lowered because substitutes less available
<b>Adaptive Resource Substitution</b>	drilling new water wells	minor to moderate	lowered by limited substitution options
<b>Inherent Import Substitution</b>	importing bottled water	minor	lowered if transport network damaged
<b>Adaptive Import Substitution</b>	importing trucked water	moderate	lowered if transport network damaged
<b>Adaptive Conservation</b>	using less water by recycling	minor to moderate	weakened by property damage
<b>Resource Inventories</b>	using stored water	minor	weakened by property damage
<b>Production Rescheduling</b>	making up lost production afterward	moderate to immense	weakened by property damage

# Business Strategy

- Until recently
  - mitigation (flood-proofing, security services)
  - recovery (mobilization, clean-up, repair)
- New theme: *Business Continuity*
  - combination of the above (*resilience*)
  - minimize need for recovery

# Survey (continued)

Which of the following business and personnel aspects does your disaster recovery plan address? (Check all that apply.)

IT system continuity/recovery	97%
Business processes continuity/recovery	80%
Employee work relocation	63%
Employee home/family relocation plans	11%
Local emergency service contacts	63%
Location of emergency resources	34%
Weather-related disaster safety procedures	51%
Bio/chemical disaster safety procedures	33%

# Optimal Level of Resilience

- It would first appear optimal level is 100%
- But must compare costs & benefits
  - current resilience is low-cost, cost-saving
  - enhancements at the margin are attractive
  - resilience preservation is attractive

# Resilience is Underutilized

- o Market Failure (general)
  - myopia
  - lack of information
  - moral hazard
  - market interdependence
- o Market Failure (public goods)

# Public Goods Market Failures

- *Resilience* is primarily a demand-side consideration with private good attributes
- *Mitigation* is primarily a supply-side consideration with public good attributes
- But infrastructure is key to maintenance & preservation in a broad-based context  
=> additional role for gov't in resilience

# Promoting Optimal Level Incentive, Disincentive & Partnership

- Hazard mapping, awareness & warning
- Disseminate best-practice experiences
- Limit aid where resilience not implemented
- Recompute interruptibility premiums--social