Resilient Responses to Catastrophes Impacting Critical Urban Infrastructure

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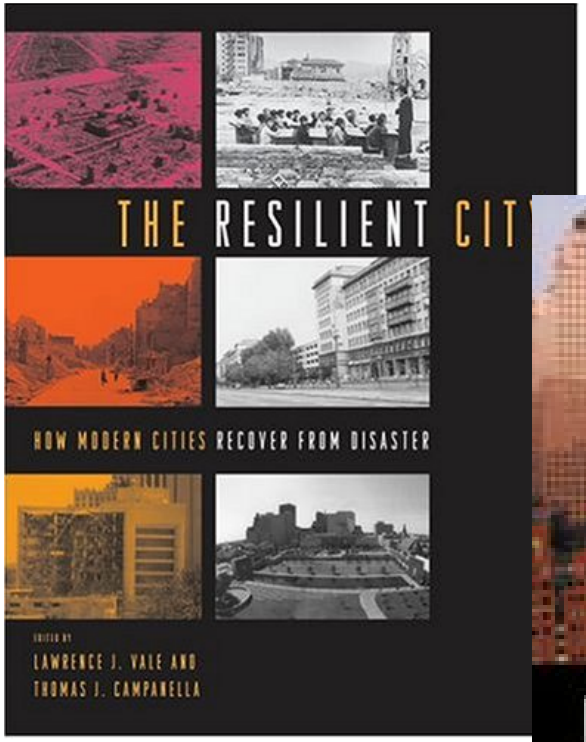
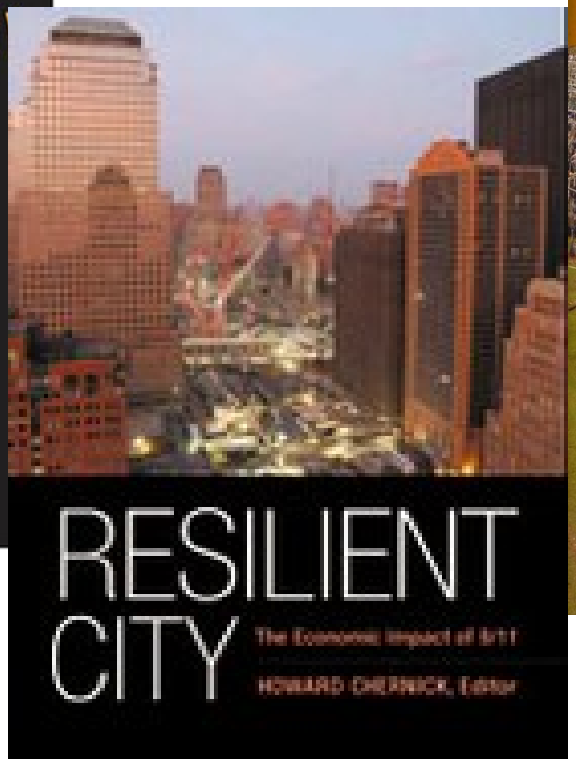
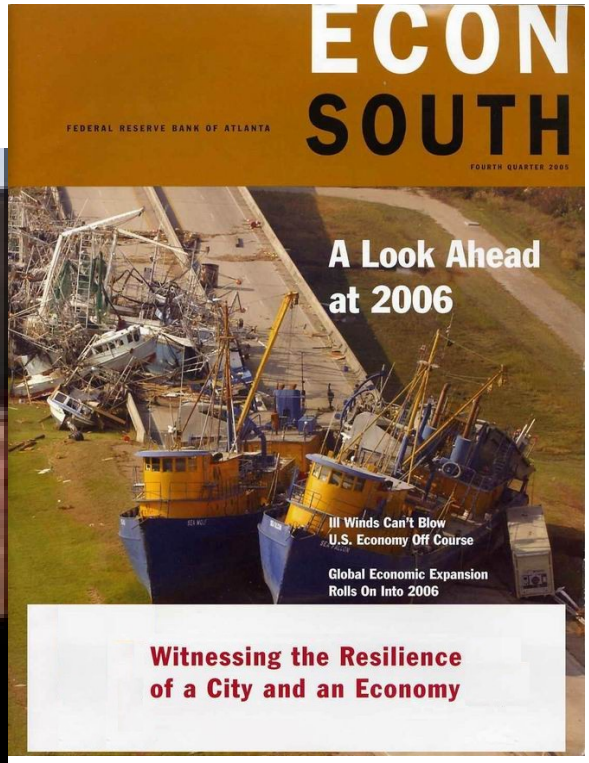
Everywhere you turn, there's a book or article on resilience to disasters:







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How Do You Spell Resilience? New Yorkers Bounce Back From Hurricane Sandy

New Yorkers are known for their resilience. But Hurricane Sandy was a whack on the side of the head. The devastation, especially from flooding, is extensive. Subways, tunnels and bridges are closed. So are the public schools and the New York Stock Exchange. We are accustomed to being a city of neighborhoods, but also being connected with each other. Now we are living in isolation, separated from fellow New Yorkers by a body of water.

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Nuclear Energy Facilities Prove Resilience During Hurricane Sandy

Thirty-four nuclear energy facilities in the path of Hurricane Sandy have responded well and safely to this powerful storm, demonstrating their resilience against severe natural forces.

Key Questions

- Is resilience a meaningful concept?
- Can resilience be rigorously defined?
- Can resilience be empirically measured?
- How effective has resilience been to date?
- Can resilience be enhanced or depleted?

Overview

- Define economic resilience
- Illustrate an operational metric
- Summarize findings on effectiveness
- Discuss enhancement & depletion
- Discuss implications for urban infrastructure
- Emphasize balancing mitigation & resilience

Static Economic Resilience

- General Definition: Ability of a system to *maintain a high level of function* when shocked.
- Econ Definition: *Efficient* use of *remaining resources* at a given point in time.
- Examples:
  - *inherent*: back-up generators, shifting operations to branch plants
  - *adaptive*: technological change, Draconian conservation

Dynamic Economic Resilience

- General: *Ability & speed* of a system to *recover.*
- Economic: *Efficient* use of resources over time for investment in repair and reconstruction.
  - investment is time-related: act of setting aside resources potentially used for current consumption to re-establish productivity in the future (including enhancing robustness & resilience)
  - static resilience does not completely restore capacity

Resilience at 3 Levels

- Individual Business, Utility or Household
  - supplier side: system redundancy
  - customer side: use of inventories, back-up generators
- Market
  - efficient allocation of resources via price signals
  - contingent business interruption insurance
- Regional & National Economy
  - countervailing policies (fiscal & monetary)
  - importing scarce commodities

Loss Estimation Paradigm Shift

- Can't prevent all disasters or it's too costly, but can reduce some losses *after* the disaster strikes
- Infrastructure *services* should be the focus
  - *Stocks* (property damage) at point of disaster
  - *Flows* (business interruption) begin immediately & continue until the economy has recovered.
- BI losses are often as large as property damage
  - have both behavioral & policy dimensions
  - more complicated than property damage
- Resilience reduces BI losses

Motivations for Resilience: Self-Reliance/Expertise/Interdependence

- Businesses & households cope well with crisis for reasons of survival
- Recent disasters have spawned a new "business continuity" industry
- Also, no businesses operates in isolation:

  IBM Exec: "Companies have realize that they participate in a greater ecosystem . . . that their IT systems are only as resilient as the firms they rely on to stay in business."

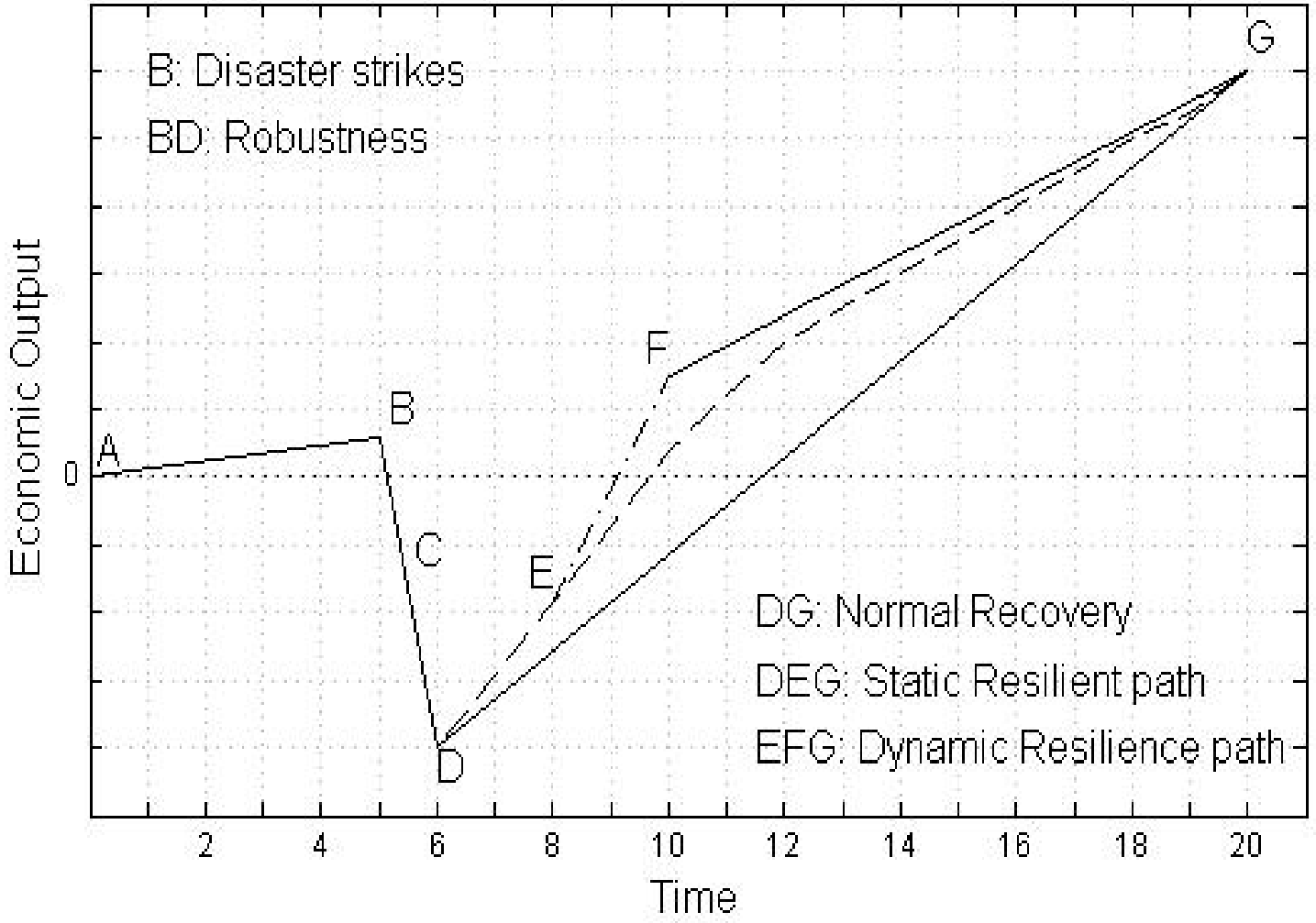
- Need to build on these motivations

Measuring Econ Resilience of 9/11

- 95% of WTC area firms relocated after 9/11
- If all of firms went out of business, direct business interruption (BI) loss = $58.4B
- If all relocation were immediate: BI = 0
- Firms relocated within 8 months: BI = $16.1B
- *Metric*: Avoided Loss ÷ Max Potential Loss

  $42.3B ÷ $58.4B = 72%

Key Aspects of Resilience



Individual Resilience Options for Water & Power Systems

(2-week Outage in LA; % Potential Avoided BI Losses)

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

Resilience to Port Disruptions
(90-day Port Arthur Disruption; Avoided BI Losses)

Strategic Petroleum Reserve	2.4%
Ordinary Inventories of all goods	17.0
Conservation by Customers	3.0
Import Ship Rerouting	23.1
Export Diversion (to replace imports)	7.0
Production Rescheduling (Recapture)	25.4
Total	67.0%

Implications

- Many effective resilience tactics exist.
- *Customers* have *more & less costly resilience* options than suppliers
- Resilience has *cost advantages* over mitigation
  - many inexpensive options
  - don't need to implement until event occurs
- Need to *balance* mitigation & resilience

Changing Resilience

- Enhancement (resilience as a process)
  - investment
  - information dissemination
  - planning & drills
  - incentives
- Erosion (with size & duration of disaster)
  - difficulty in sustaining resilience
  - finite capabilities
  - interdependent infrastructure
  - disincentives

Conclusion

- Mitigation still key (in part because of irreversibilities relating to loss of life & unique eco-systems)
- Resilience is a worthy *second line of defense*
  - it is effective
  - it is low cost
  - it is self-motivated
- Resilience applies to producers & consumers
- Resilience is yet another way we can *all* contribute to reducing losses from disasters

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