The Effect of Natural Hazards on Manufacturing and its Supply Chain

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Direct and Indirect Business Interruption

• Lightning started a small fire at Philips microchip plant
  • Stops production
  • Results in Ericsson being driven out of mobile phones

• In 2016, Toyota suspended much of its production due to earthquakes
  • Just-in-time is lean, but leaves a pretty lean inventory for interruptions

• Supply chains are growing longer → Increased risk
Disaster Impacts

- Disproportionally distributed
  - Ability to absorb losses
  - Location

- Positive and negative effects on economy (i.e. GDP)
  - Damage vs increased demand

- For businesses
  - Revenue losses outweigh asset losses

Data Challenges

• Limited public data
• Tracking is often spotty
  • Example: Fire
• Insurance → proprietary + excludes uninsured damage
• Impact research often focuses on individual incidents
• Limited understanding of manufacturing costs

Modeling Business Interruption

- 8 econometric regression models
  - 4 for manufacturing
    - Payroll
    - GDP
    - Employment
    - Number of Establishments
  - 4 for the total economy
    - Payroll
    - GDP
    - Employment
    - Number of Establishments
Data

- Hazard data
  - Spatial Hazard Events and Losses Database for the United States (SHELDUS)
- Economic data
  - Bureau of Economic Analysis
  - Bureau of Labor Statistics
  - Census – County Business Patterns
- Supply chain data
  - Freight Analysis Framework
- County level data from 2006 to 2016
Shipments by FAF Origin, Lower 48 States (2016)

- 122 Locations
- Shipments categorized by the Standard Classification of Transported Goods systems
- Data on each origin/destination combination
County Hazard Damage: 2006-2016

- Damage is not equally distributed
- Annual frequency
- SHELDUS data
Model

• Cobb Douglas production function
  • $Q = C^{\beta_{x1}} L^{\beta_{x2}} K^{\beta_{x3}} \xi^{\beta_{x4}}$
  • $\ln(Q) = \beta_{x1} \ln(C) + \beta_{x2} \ln(L) + \cdots$
• Linear regression to estimate $\beta$
• 4 dependent variables (i.e., Q in above equation)
  • Payroll
  • GDP
  • Employment
  • Number of Establishments
• Between 5k and 25k observations
• Use simulation to estimate impact
Independent Variables

- **Business impacts due to**
  - Local hazard damage (decreased production ability)
  - Local hazard count (increased demand)

- **Supply chain damage**
  - Weighted damage occurring at the top 25 supply chain locations
  - Top 25 represents 81% of local supplies

- **Supply chain hazard count**
  - Weighted count of hazards occurring at the top 25 supply chain locations

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**Model Characteristics**

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Independent Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payroll (PR)</td>
<td>Lagged dependent variable</td>
</tr>
<tr>
<td>GDP</td>
<td>Interaction of lagged dependent variable and local damage</td>
</tr>
<tr>
<td>Employment (EMP)</td>
<td>Interaction of lagged dependent variable and hazard count</td>
</tr>
<tr>
<td>Establishments (EST)</td>
<td>Lagged independent variable</td>
</tr>
<tr>
<td></td>
<td>Local hazard count</td>
</tr>
<tr>
<td></td>
<td>Local hazard damage</td>
</tr>
<tr>
<td></td>
<td>Hazard damage at top 25 supply chain locations</td>
</tr>
<tr>
<td></td>
<td>Hazard count at top 25 supply chain locations</td>
</tr>
</tbody>
</table>
Results of Regression

- With statistical significance, local hazards reduced
  - GDP
  - Employment
  - #Establishments (i.e., creation and survival)
- With statistical significance, supply chain hazards reduced
  - Payroll
  - GDP
  - Employment

<table>
<thead>
<tr>
<th>Dep. Var.</th>
<th>Local HZRD(_{DMG})</th>
<th>Local ZERO(_{DMG,LOC})</th>
<th>Sup. Chn. SUPCHN(_{TOTAL})</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAN PR</td>
<td>0.0011</td>
<td>0.0072</td>
<td>-0.0043***</td>
</tr>
<tr>
<td>MAN GDP</td>
<td>-0.0063</td>
<td>0.0295**</td>
<td>-0.0101***</td>
</tr>
<tr>
<td>MAN EMP</td>
<td>0.0000</td>
<td>0.0193**</td>
<td>-0.0055***</td>
</tr>
<tr>
<td>MAN EST</td>
<td>-0.0029**</td>
<td>0.0031</td>
<td>0.0006</td>
</tr>
<tr>
<td>ALL PR</td>
<td>-0.0012</td>
<td>0.0031</td>
<td>0.0028***</td>
</tr>
<tr>
<td>ALL GDP</td>
<td>-0.0005</td>
<td>0.0179***</td>
<td>-0.0026***</td>
</tr>
<tr>
<td>ALL EMP</td>
<td>0.0000</td>
<td>0.0098***</td>
<td>-0.0015***</td>
</tr>
<tr>
<td>ALL EST</td>
<td>0.0008</td>
<td>0.0036**</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

* Significant at the 0.01 level
** Significant at the 0.05 level
*** Significant at the 0.1 level
Simulating the Negative impact in a World Without Hazards – *Preliminary Results*

- Supply chain impacts tend to over shadow direct impacts
- Over 30 years, there is a 25% chance that an individual manufacturing establishment is eliminated or prevented from starting
  - 11% chance for all establishments

<table>
<thead>
<tr>
<th></th>
<th>Local</th>
<th>Sup Chn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Payroll</strong></td>
<td></td>
<td>-6.6%</td>
</tr>
<tr>
<td><strong>GDP</strong></td>
<td>-1.1%</td>
<td>-13.3%</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td>-0.4%</td>
<td>-7.2%</td>
</tr>
<tr>
<td><strong>Establishments</strong></td>
<td>-1.0%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Local</th>
<th>Sup Chn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Payroll</strong></td>
<td>-0.1%</td>
<td></td>
</tr>
<tr>
<td><strong>GDP</strong></td>
<td>-0.9%</td>
<td>-3.6%</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td>-0.4%</td>
<td>-2.0%</td>
</tr>
<tr>
<td><strong>Establishments</strong></td>
<td>-0.4%</td>
<td></td>
</tr>
</tbody>
</table>
How can we use this information?

- Cost/benefit information for investment analysis
- Results from our economic studies
  - Publish as reports and journal articles
  - Implemented into a software tool: Manufacturing Cost Guide
Manufacturing Cost Guide: Beta Version

• Free software tool that estimates
  • Average establishment costs
  • Costs by industry and sector

• Evolving tool
  • Periodic updates (e.g., annual)
  • Increasing functionality (e.g., uncertainty analysis)
  • Increasing breadth of cost categories (e.g., maintenance cost)
Welcome to The Cost Guide.

Congratulations on starting your journey to join those with elite manufacturing industry knowledge. No longer will your beliefs about industry be based on anecdotal and nonscientific evidence, but will rather be grounded in data built on a foundation of mathematical, statistical, and empirical evidence. This tool uses a combination of data sources and analysis methods to analyze the US manufacturing industry and its supply chains. Enjoy your data adventure!
What do you want to Examine?

The first step is to choose what you want to analyze. Below are three options:

- **Industry Analysis**: The industry analysis presents data collected from establishments categorized as being in the manufacturing industry. An establishment is a physical location where business or operations are performed. They are categorized by industry using the North American Industry Classification System (NAICS).

- **Supply Chain Analysis - Detail Oriented**: The detailed supply chain analysis uses economic input-output analysis to estimate the contribution that each industry makes to produce a selection of manufactured commodities. It uses data collected from US establishments categorized using the North American Industry Classification System (NAICS). This analysis is referred to as "detailed" because it provides a detailed breakdown of cost categories. The method is further used to estimate a number of other cost categories for producing goods, including:
  - Environmental Impact
  - Energy Consumption by End Use
  - Labor Cost by Occupation
  - Purchases from Other Industries
  - Assets or Capital (e.g., machinery and buildings)

- **Supply Chain Analysis - Imports Oriented**: The imports oriented supply chain analysis uses economic input-output analysis to examine the imports needed for producing commodities in the US. It provides an estimate of imports by industry by country brought into the US manufacturing supply chain. Industries in this analysis are categorized by the Standard Industrial Classification (SIC) system.
Select the output or metrics
Select the output or metrics to be used for the examination.

For Supply Chain Analysis

- **Value Added**: Value added is considered the primary measure of economic activity. This data provides the value added required to produce commodities for intermediate use (i.e., supplies to other industries) and final demand.
- **Environmental Impact**: This analysis provides an estimate of the environmental impact associated with producing intermediate use (i.e., supplies to other industries) and final demand.
- **Identify Industries with High Value Added + Environmental Impact**: This analysis combines the value added analysis and the environmental impact analysis to identify those industries in the supply chain that have a disproportionately high level in both areas.
- **Analysis of Energy use**: This analysis estimates the value of energy used throughout the supply chain to produce intermediate use (i.e., supplies to other industries) and final demand. It further details how the energy was used.
- **Analysis of Labor Compensation by Occupation**: This analysis provides the different types of labor needed from different industries to produce commodities for intermediate use (i.e., supplies to other industries) and final demand.
- **Purchases by Industries**: This table provides the use of commodities by industries. It is the Use table of an input-output model.
- **Assets (i.e., capital) Used**: This table estimates the value of capital needed to produce intermediate use (i.e., supplies to other industries) and final demand.
Select the commodities to be examined.

Select commodities by Group

- Select/Deselect all (this selection takes a moment)
- Food, Beverage, and Tabacco Products (NAICS 311-312)
- Discrete Products (NAICS 313-323, 327-332, 337-339)
- Discrete Tech Products (NAICS 333-336)
- Process Products (NAICS 324-326)

[NAICS Classification]  [Back to Start]  [Submit]

Select commodities individually

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3363A0</td>
<td>Motor vehicle steering, suspension component (except spring), and brake systems manufacturing</td>
</tr>
<tr>
<td>336411</td>
<td>Aircraft manufacturing</td>
</tr>
<tr>
<td>336412</td>
<td>Aircraft engine and engine parts manufacturing</td>
</tr>
<tr>
<td>336413</td>
<td>Other aircraft parts and auxiliary equipment manufacturing</td>
</tr>
<tr>
<td>336414</td>
<td>Guided missile and space vehicle manufacturing</td>
</tr>
<tr>
<td>33641A</td>
<td>Propulsion units and parts for space vehicles and guided missiles</td>
</tr>
<tr>
<td>336500</td>
<td>Railroad rolling stock manufacturing</td>
</tr>
<tr>
<td>336611</td>
<td>Ship building and repairing</td>
</tr>
<tr>
<td>336612</td>
<td>Boat building</td>
</tr>
<tr>
<td>336991</td>
<td>Motorcycle, bicycle, and parts manufacturing</td>
</tr>
<tr>
<td>336992</td>
<td>Military armored vehicle, tank, and tank component manufacturing</td>
</tr>
<tr>
<td>336999</td>
<td>All other transportation equipment manufacturing</td>
</tr>
<tr>
<td>337110</td>
<td>Wood kitchen cabinet and countertop manufacturing</td>
</tr>
<tr>
<td>337121</td>
<td>Upholstered household furniture manufacturing</td>
</tr>
</tbody>
</table>

[Submit]
### Results: Manufacturing Energy Consumption by End Use ($million)

This tab presents the energy needed from each industry to produce the selected commodities. The energy cost is broken into subcategories of what the energy was used for.

- [Energy Use Definitions](#)
- [NAICS Classification](#)

#### NAICS Code | Industry Description | Indirect Uses: Boiler Fuel | Facility Lighting | Facility HVAC | Conventional Electricity Generation | Other Facility Support | Other Nonprocess Use
--- | --- | --- | --- | --- | --- | --- | ---
336340 | Motor vehicle steering, suspension component (except spring), and brake systems manufacturing | 7.075 | 22.157 | 46.651 | 0.000 | 7.521 | 2.332
331110 | Iron and Steel Mills and Ferroalloy Manufacturing | 10.057 | 8.962 | 20.177 | 0.000 | 1.786 | 0.932
331210 | Steel Product Manufacturing from Purchased Steel | 0.423 | 0.399 | 0.755 | 0.000 | 0.131 | 0.024
331310 | Alumina and Aluminum Production and Processing | 0.053 | 0.963 | 1.336 | 0.000 | 0.320 | 0.059
331410 | Nonferrous Metal (except Aluminum) Smelting and Refining | 0.442 | 0.026 | 1.081 | 0.000 | 0.188 | 0.036
331420 | Copper Rolling, Drawing, Extruding, and Alloying | 0.195 | 0.184 | 0.348 | 0.000 | 0.061 | 0.011
331490 | Nonferrous Metal (except Copper and Aluminum) Rolling, Drawing, Extruding, and Alloying | 0.470 | 0.250 | 0.567 | 0.000 | 0.099 | 0.018
Roundup

• Limited data on disaster impact
  • Both positive and negative effects

• Over 30 years, there is a 25% chance that an individual manufacturing establishment is eliminated or prevented from starting

• Manufacturing GDP lost
  (preliminary results)
  • 1.1% due to local hazards
  • 13.3% due to supply chain hazards

• NIST’s Applied Economic Office
  • Implementing manufacturing costs into software
Thank You

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