Simulating Severe Supply Chain Disruptions with Multiple Suppliers and Firms

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Interdependent economy
Supplier’s facility is closed

Move production to alternate facility?

Yes

Firms receive required supplies

Yes

Buy from alternate supplier?

No

Supplier’s facility reopens?

No

Finished goods inventory?

No

Demand not satisfied or customers buy from other firms

No

Supply inventory?

No

Supply shortage for firms

Yes

Yes

Supplier’s facility is closed
Firm’s decision

How much to produce?

- Inventory on hand
- Selling price
- Cost of alternate suppliers
- Maximize profit in current period
- Satisfy demand
- Value
- Time when suppliers’ facilities reopen
- Customer loyalty
- Customer loyalty
- Inventory on hand
- Selling price
- Cost of alternate suppliers
- Maximize profit in current period
- Satisfy demand
- Value
- Time when suppliers’ facilities reopen
- Customer loyalty
## Results in automobile sector

Average percent of total demand satisfied

<table>
<thead>
<tr>
<th></th>
<th>Maximize profit and no alternate facility</th>
<th>Sacrifice profit to meet demand and no alternate facility</th>
<th>Sacrifice profit to meet demand and alternate facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford, GM, and Chrysler</td>
<td>91.7</td>
<td>98.7</td>
<td>99.0</td>
</tr>
<tr>
<td>Toyota and Honda</td>
<td>68.7</td>
<td>86.7</td>
<td>93.4</td>
</tr>
<tr>
<td>Nissan</td>
<td>82.5</td>
<td>92.7</td>
<td>96.1</td>
</tr>
</tbody>
</table>

Research extension

- Previous work had 4 suppliers and 3 firms
- Can we extend the simulation to include more firms and suppliers?
- Extend to multiple industries with multiple firms
  - Automobile
  - Electronics
  - Chemical
Previous work

Chemical products
- Hydrogen peroxide
- Anode graphite for lithium ion-battery
- Ethylene-propylene-diene rubber
- Poly-propylene

Silicon wafer
- Semiconductor
  - Micro-processor
  - Chip for controlled machining

Electronic materials
- Electrolytic copper foil
- Synthetic quartz

Liquid crystal panel

Automotive

Industry machine

Home electronics

Simulation extension

- 6 suppliers and 6 firms (Toyota, Honda, Nissan, GM, Ford, Chrysler) in automobile sector
- 5 suppliers and 6 firms (Apple, Sony, Nokia, HTC, Huwei)
- 1 semiconductor firm
- 9 suppliers in chemical industry
## Preliminary results (concept demonstration)

Average percent of total demand satisfied

<table>
<thead>
<tr>
<th>Industry</th>
<th>Maximize short-term profit and no alternate facility</th>
<th>Sacrifice profit to meet demand and no alternate facility</th>
<th>Sacrifice profit to meet demand and alternate facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobile</td>
<td>57.9</td>
<td>87.2</td>
<td>95.7</td>
</tr>
<tr>
<td>Electronics</td>
<td>38.9</td>
<td>98.1</td>
<td>99.4</td>
</tr>
<tr>
<td>Chemical</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Semiconductor</td>
<td>44.3</td>
<td>97.3</td>
<td>100</td>
</tr>
</tbody>
</table>
Chemical industry impact

Average percentage of demand satisfied

- Blue circle: Automobile
- Red diamond: Electronics
- Orange square: Semiconductor
- Purple star: Rensesas

No slack in production vs. 20% slack in production
Further research

• Create more complex model of supply chain to simulate disruption after tsunami
• Find better input data
• Explore interdependencies among industries
  • How does one industry’s supply chain disruption impact other industries?

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BACKUP
Simulation results
Average production when suppliers do not move to alternate facility

Firm 1
- 96% Unsatisfied demand
- 5% Demand met by firm
- 5% Demand captured by other firms

Firm 2
- 87% Unsatisfied demand
- 5% Demand met by firm
- 8% Demand captured by other firms

Firm 3
- 92% Unsatisfied demand
- 3% Demand met by firm
- 6% Demand captured by other firms
Simulation results
Average production when suppliers do not move to alternate facility

Firm 1
- 96% satisfied
- 5% unsatisfied

Firm 2
- 87% satisfied
- 5% unsatisfied
- 8% captured by other firms

Firm 3
- 92% satisfied
- 3% unsatisfied
- 6% captured by other firms
Simulation results
Average production when suppliers do not move to alternate facility

Firm 1
- Unsatisfied demand: 2%
- Demand met by firm: 4%
- Total: 93%

Firm 2
- Unsatisfied demand: 5%
- Demand met by firm: 87%
- Total: 93%

Firm 3
- Unsatisfied demand: 2%
- Demand met by firm: 93%
- Total: 93%

Legend:
- Pink: Unsatisfied demand
- Dark: Demand met by firm
- Blue: Demand captured by other firms
Simulation results
Average production when suppliers move to alternate facility

Firm 1
< 1%

Firm 2
98%

Firm 3
99%

Legend:
- Pink: Unsatisfied demand
- Brown: Demand met by firm
- Blue: Demand captured by other firms
Supply chain risk management

- Mitigating risk of supply chain disruption vs responding to disruption
- More realistic model of company behavior
- Use of game theory for severe supply chain disruptions