Disruption Management during Supply Chain Disruptions

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Outline

1. Motivation
2. Research contribution
3. Model and simulation
4. Application
Supply chain risk management

- Qualitative [1, 2]
- Quantitative
  - Production and inventory models [3]
  - Game theory [4]

• Disruptions cause operation plans to deviate
• Disruption management studies optimal way to react in the midst of disruptions
  – What should be done once a disruption occurs?
  – How to minimize the impacts and return to normal production?

What is new with this research?

Mitigation  
Preparedness  
Recovery  
Response  

Supply chain risk management

Decision and actions by suppliers and firms during and after disruption
Research questions

• How can we model the supply chain where
  – Some facilities are inoperable?
  – Other firms experience a supply shortage?

• What can firms do to mitigate the impacts of inoperable facilities and supply shortages?
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Simulation

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
Produce at alternate facility?

- Cost at alternate facility
  - Per-unit cost of producing at alternate facility
  - Fixed cost of moving production to alternate facility

- Expected cost at primary facility
  - Per-unit cost of producing at primary facility
  - Expected lost revenue of not producing

- Probability primary facility opens next period
- Probability supplier’s customers buy from other suppliers

No
Produce at alternate facility?

- Per-unit cost of producing at alternate facility
- Fixed cost of moving production to alternate facility

Cost at alternate facility

- Expected cost at primary facility
- Per-unit cost of producing at primary facility
- Expected lost revenue of not producing

- Probability primary facility opens next period
- Probability supplier’s customers buy from other suppliers

YES
Threshold parameters for supplier

If probability that primary facility will open next period is greater than $\bar{p}$, supplier will not produce at alternate facility.

\[
\bar{p} = \frac{(r - c^+ \theta)}{(c^+ - c)(1 - \theta)}
\]

- Per-unit revenue
- Per-unit cost of producing at alternate facility
- Per-unit cost of producing at primary facility
- Probability supplier’s customers buy from other suppliers
Threshold parameters for supplier

\[ \tilde{p} = \frac{(r - c^+)\theta}{(c^+ - c)(1 - \theta)} \]

If fixed cost of moving production is greater than \( \tilde{C} \), supplier will not produce at alternate facility

\[ \tilde{C} = \frac{(pZ + z)[(r - c^+)\theta - p(c^+ - c)(1 - \theta)]}{p[1 - (1 - p)(1 - \theta)]} \]

Probability primary facility opens next period
Threshold parameters for supplier

\[
\bar{p} = \frac{(r - c^+)\theta}{(c^+ - c)(1 - \theta)} \quad \bar{C} = \frac{(pZ + z)[(r - c^+)\theta - p(c^+ - c)(1 - \theta)]}{p[1 - (1 - p)(1 - \theta)]}
\]

- **Fixed cost of moving to alternate facility**
- **\( \bar{C} \)**
  - **Never produce at alternate facility**
  - **Produce at alternate facility but may wait some length of time**
  - **Never produce at alternate facility**

**Probability of primary facility opening**
Firm’s influence diagram

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

How much to produce?
Modeling insights

• Incorporating business decisions in midst of supply chain disruptions
• Solving for optimal production decisions as function of model parameters
• Measuring impact of preparedness decisions on firm’s ability to respond during disruption
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Supply chain disruption in auto sector
Application inspired by auto sector

- Supplies required for production
- Several model parameters gleaned from news reports
- More precise information needed for cost and revenue parameters
Simulation results

Average production when suppliers do not move to alternate facility

Firm 1
- Unsatisfied demand: 5%
- Demand met by firm: 96%

Firm 2
- Unsatisfied demand: 5%
- Demand met by firm: 87%
- Demand captured by other firms: 3%

Firm 3
- Unsatisfied demand: 6%
- Demand met by firm: 92%
Simulation results

Average production when suppliers do not move to alternate facility

Firm 1
- Unsatisfied demand: 5%
- Demand met by firm: 96%

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

Firm 3
- Unsatisfied demand: 3%
- Demand met by firm: 92%
- Demand captured by other firms: 6%
Simulation results

Average production when suppliers do not move to alternate facility

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

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

Firm 3
- Unsatisfied demand: 8%
- Demand met by firm: 93%

Legend:
- Pink: Unsatisfied demand
- Red: Demand met by firm
- Blue: Demand captured by other firms
Simulation results

Average production when suppliers move to alternate facility

Firm 1
- < 1%
- 99%

Firm 2
- 1%
- 98%

Firm 3
- < 1%
- 99%

Legend:
- Pink: Unsatisfied demand
- Brown: Demand met by firm
- Blue: Demand captured by other firms
### Sensitivity on parameters for Firm 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low</th>
<th>Base</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tradeoff between objectives</td>
<td>Maximizes profit</td>
<td>Equally prefer both objectives</td>
<td>Satisfies demand</td>
</tr>
<tr>
<td>Final goods inventory</td>
<td>0 periods</td>
<td>6 periods</td>
<td>12 periods</td>
</tr>
<tr>
<td>Cost of alternate supplier</td>
<td>Primary supplier + 6</td>
<td>Primary supplier + 3</td>
<td>Equal to primary supplier</td>
</tr>
<tr>
<td>Selling price</td>
<td>Equal to cost</td>
<td>Cost + 1</td>
<td>Cost + 2</td>
</tr>
<tr>
<td>Primary supplier’s recovery (expected time)</td>
<td>36 periods</td>
<td>26 periods</td>
<td>3 periods</td>
</tr>
<tr>
<td>Supply inventory</td>
<td>0 period</td>
<td>2 periods</td>
<td>4 periods</td>
</tr>
<tr>
<td>Customer loyalty (probability firm’s customer does not buy from competitor)</td>
<td>0.01</td>
<td>0.61</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Sensitivity on parameters for Firm 2

- Tradeoff between objectives
- Final goods inventory
- Cost of alternate supplier
- Selling price
- Primary supplier's recovery
- Supply inventory
- Customer loyalty

Percentage of demand satisfied
• Illustrative example reflects actual situation
  – Toyota and Honda’s share of production in North America fell from 10% to 7% each
  – Nissan’s share of production in North America remained constant
  – Detroit 3 automakers increased their share of production in North America by 4%

• Application provides insights into best strategies for response and recovery
  – Buying from an alternate supplier may be a better long-term strategy than inventory
  – Costs of different strategies should be incorporated
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