Quantifying the Impacts of Industry Preparedness Strategies with a Risk-Based Input-Output Model

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Risks of global supply chain
What’s new

- Production decision for supply shortage
- Dynamic model
- Interdependent impacts of firm decisions
- Illustration of supply shortage
- Valuation of different mitigation strategies
Production decision

Primary supplier suffers disruption
Inventory on hand
Alternate supplier at increased cost

1. Reduce production
3. Buy from alternate supplier
4. Substitute a different input

Constant elasticity of substitution production function
Profit
Price
Dynamic model

Firm’s production

- Normal production
- New equilibrium production
- Reduced production

Time
Dynamic model

Firm’s production

- Normal production
- New equilibrium production
- Reduced production

Time
Dynamic model

Firm’s production

Normal production

New equilibrium production

Reduced production

Time
Dynamic model

Firm’s production

Normal production

New equilibrium production

Reduced production

Time
Dynamic model

Firm’s production

Normal production

Reduced production

Time

0

T
Sector inoperability

Direct impacts from supply shortage

\[ q_i(0) = \frac{y^{*}[0,T] - y[0,T]}{x_i,[0,T]} \]

Industry \(i\)'s inoperability

Firm's normal production

Firm's degraded production

Industry \(i\)'s normal production

Interdependent economic analysis

\[
q_{total} = \sum_{k=0}^{\infty} (A^*)^k q(0)
\]

\[
= [\text{diag}(x)]^{-1} A[\text{diag}(x)]
\]

\[
Q = (x_{[0,T]}^T)^T q_{total}
\]

Echelon

n x 1 vector of inoperability

n x 1 vector of inoperability for all industries

Total production losses

Normal production for each industry
Illustration
Case study of manufacturing sectors

- Primary metals
- Electrical appliances
- Petroleum and coal products
- Chemical products
Supply shortage

25% of computer supplies are not delivered
Mitigation strategies

Inventory of computer supplies for 10 days

Alternate supplier at 2x the price

Substitute electrical equipment
Multiregional model

- State interdependency matrices from location quotients
- 62 industries per state
- Commodity flows for 28 industries (Bureau of Transportation Statistics)
Assumptions of dynamic model

- Normal production
- Reduced production

Number of days
Production losses (millions of dollars) for each strategy

Legend
1. No mitigation
2. Inventory
3. Alternate supplier
4. Substitution
5. All mitigation strategies

- Direct (firm) losses
- Indirect losses

Primary metals

Electrical appliances

Petroleum and coal products

Chemical products
Most impacted Texas industries

Production losses by industry (all mitigation strategies)

- Oil and gas extraction
- Construction

Petroleum and coal

Chemicals

Supply shortage in petroleum and coal firm

Supply shortage in chemical firm
Sensitivity on inventory

As percentage of total production losses in base case (all mitigation strategies)

Amount of inventory

- Primary metals
- Electrical appliances
- Petroleum and coal
- Chemicals
Sensitivity on alternate supplier

As percentage of total production losses in base case (all mitigation strategies)

Cost of alternate supplier

Ratio of alternate supplier price to primary supplier price

Percentage of losses

Cost of alternate supplier

Primary metals
Electrical appliances
Petroleum and coal
Chemicals

Ratio of alternate supplier price to primary supplier price

1 1.5 2 2.5 3

60 80 100 120

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Sensitivity on substitution

As percentage of total production losses in base case
(all mitigation strategies)

Ability to substitute electrical equipment for computers

- Primary metals
- Electrical appliances
- Petroleum and coal
- Chemicals

Percentage of losses

Low

Substitution ability

High

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Sensitivity on recovery

As percentage of total production losses in base case (all mitigation strategies)

Primary supplier's speed of recovery

- Primary metals
- Electrical appliances
- Petroleum and coal
- Chemicals

Percentage of losses

Number of days
Sensitivity on key parameters

As percentage of total production losses in base case

- **Inventory**
  - Number of days of inventory vs. inventory costs

- **Cost of alternate supplier**
  - Ratio of suppliers' prices vs. cost

- **Substitution**
  - Substitution ability vs. substitution costs

- **Recovery of primary supplier**
  - Number of days vs. recovery costs
Conclusions

• Model
  – Incorporates firm decisions into interdependency model
  – Explains dynamic production where recovery and firm’s mitigation strategies occur simultaneously
  – Assigns dollar value to each strategy

• Case study
  – Reveals that direct impacts account for 50-80% of production losses
  – Demonstrates importance of inventory
  – Is most sensitive to inventory and recovery
  – Does not incorporate pre-disruption costs of strategies
  – Does not account for increased demand for competitors
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