Input Linkages and the Transmission of Shocks: Firm-Level Evidence from the 2011 Tōhoku Earthquake

Christoph Boehm Aaron Flaaen Nitya Pandalai Nayar

University of Michigan

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Any opinions and conclusions expressed herein are those of the author(s) and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed.
Question 1: What is the role of trade and multinational production (MP) in business cycle comovement?
  - Fact 1: Trade and MP large and growing
  - Fact 2: High degree of business cycle synchronization among OECD countries
Question 1: What is the role of trade and multinational production (MP) in business cycle comovement?
- Fact 1: Trade and MP large and growing
- Fact 2: High degree of business cycle synchronization among OECD countries

Question 2: Do imported input linkages matter for spillovers?
- Transmission is governed critically by the production elasticity of substitution

\[ x_t = \left[ (1 - \mu) \frac{1}{\psi} F_{D,t}(\cdot) \frac{\psi-1}{\psi} + \mu \frac{1}{\psi} I M_t \frac{\psi-1}{\psi} \right] \frac{\psi}{\psi-1} \]
Outline and Preview of Results

What we do:
- Evaluate the effect of shocks to imported inputs on production
- Use new firm-level data: multinational status and input trade
- Natural experiment: March 2011 Tōhoku Earthquake

Results:
- Most directly impacted firms: JPN multinationals
  - Reduced form result: elasticity of roughly zero
- Structural estimates of production function:
  - Elasticity of 0.2 between Japanese and other material inputs;
    0.03 between materials and capital/labor

Implications:
- Calibrated IRBC model with complementarity of multinational input trade ↑ value-added comovement by as much as 18 p.p.
Related Literature

- Global Organization of the Firm (Horizontal vs Vertical FDI)
  - Ramondo, Rappoport and Ruhl (2011), Hanson, Mataloni and Slaughter (2005)

- Multinationals/Vertical Integration and Business Cycle Comovement

- Effects of Trade/MP on volatility/productivity
2011 Tōhoku Earthquake

- Earthquake measured 9.0 $M_w$
- Tsunami: Wave Heights Exceeding 7m
- 1% of Physical Capital Damaged or Destroyed
- Significant death toll
- Widespread power outages

Source: USGS
Large Drop in Japanese Industrial Production

![Graph showing deviations from trend (HP-Filtered) for Japanese industrial production from Jul.2010 to Jan.2012]
U.S. Imports from Japan Fall
Dip in U.S. Industrial Production

![Graph showing deviations from trend for U.S. Durable Goods Production and U.S. Manufacturing Production from July 2010 to January 2012]
1. The 2011 Tōhoku event in context
   ▶ Background and aggregate impacts

2. Firm-level analysis
   ▶ Empirical evidence for transmission mechanisms

3. Structural model of input linkages
   ▶ Key assumptions
   ▶ Estimation
   ▶ Identification

4. Implications
**Census Data: Description**

- Longitudinal Business Database: restricted to manufacturing firms
  - Annual employment/payroll (quarterly values taken from BR)
- LFTTD: trade in goods by source/destination
- Census of Manufacturers (CM): inventories and sales (2007)

- Two novel extensions to these data resources
  1. Multinational indicators from international corporate directories: LexisNexis and Uniworld
     - Multinationals in Census
     - Matching Procedure
  2. Separation of firm-level imports by expected use: CM Products Trailer File
     - Details
Firm-Level Exposure to Japan

Ownership vs Exposure
**Event study specification: Treatment Effects**

**Goal:** The average treatment effect of being Japanese affiliate

- Use other multinationals as control group
- Propensity score reweighting [Details]
Goal: The average treatment effect of being Japanese affiliate

- Use other multinationals as control group
- Propensity score reweighting

\[ V_{i,t}^M = \alpha_i + \sum_{p=-14}^{9} \gamma_p E_p + \sum_{p=-14}^{9} \beta_p E_p JPN_{i,p} + u_{i,t} \]

- \( V_{i,t}^M \): int. imports of firm \( i \) in month \( t \) (after removing linear, firm-specific trend through Feb. 2011);
- \( E_p \): indicator for month relative to Tōhoku event (March 2011);
- \( JPN_{i,p} \): indicator for Japanese-owned firm.
U.S. Affiliates of Japanese Multinationals

Alternative Specification

Standard Errors
1. The 2011 Tōhoku event in context
   ▶ Background and aggregate impacts

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4. Implications
Model

Production Function

\[ x_{it} = \phi_i \left[ \mu_i^{\frac{1}{\zeta}} \left[ (k_{it})^\alpha (l_{it})^{1-\alpha} \right]^{\frac{\zeta-1}{\zeta}} + (1 - \mu_i)^{\frac{1}{\zeta}} M_{it}^{\frac{\zeta-1}{\zeta}} \right]^{\frac{\zeta}{\zeta-1}} \]

where

\[ M_{it} = \left( \nu_i^{\frac{1}{\omega}} (m_{i-t}^J)^{\frac{\omega-1}{\omega}} + (1 - \nu_i)^{\frac{1}{\omega}} (m_{i-t}^J)^{\frac{\omega-1}{\omega}} \right)^{\frac{\omega}{\omega-1}} \]

- \( m_{i-t}^J \): Japanese intermediate inputs with weight \((1 - \nu_i)\)
- \( m_{i-t}^{-J} \): non-Japanese intermediate inputs with weight \(\nu_i\)
- \( \omega \): elasticity of substitution between intermediates
- \( \zeta \): elasticity of substitution between intermediates and capital-labor aggregate
**Model**

**Assumptions**

- Two six month periods
  - Pre-Tsunami: firm optimizing, FOCs hold
  - Post-Tsunami: Delivery of Japanese inputs possibly exogenous, can’t use FOCs for estimation
- Post-Tsunami, the capital stock is fixed
- The production function always holds

**Structural Estimation**

- Back out $\nu_i$ and $\mu_i$ from FOCs with data from pre-Tsunami period, and the $\phi_i$ from data on production
- Estimate the production function directly with these values and data for post-Tsunami period for elasticities
Estimation

Our output proxy is defined such that:

\[
\kappa_i = \frac{V_{it-1}^{NA}}{p_{it-1}x_{it-1}}
\]

We assume that post-Tsunami:

\[
\ln V_{it}^{NA} = \ln \kappa_ip_{it}x_{it} + u_{it}
\]

\[
= \ln (\kappa_i \phi_i) + \ln \left( \left[ \mu_i \xi \left( p_{it}^x K_{it}^\alpha L_{it}^{1-\alpha} \right)^{\xi-1} \right. \right. + \left. \left. (1 - \mu_i) \xi (p_{it}^x)^{\xi-1} (M_{it})^{\xi-1} \right]^{\xi-1} \right) + u_{i,t}
\]

where \( u_{it} \) is a normal error, and \( E [u_{it} | X_i] = 0 \).

Under this exogeneity assumption, the above equation can be estimated via maximum likelihood.
## Estimation Results

### Elasticity Estimates

<table>
<thead>
<tr>
<th></th>
<th>Japanese Multinationals</th>
<th>Non-Japanese Multinationals</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega$</td>
<td>0.201</td>
<td>0.624</td>
</tr>
<tr>
<td>$(\text{elast. } m^J &amp; m^{-J})$</td>
<td>(0.133)</td>
<td>(0.164)</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>0.032</td>
<td>0.038</td>
</tr>
<tr>
<td>$(\text{elast. } M &amp; k, l)$</td>
<td>(0.279)</td>
<td>(0.142)</td>
</tr>
<tr>
<td>Number of Firms</td>
<td>105</td>
<td>304</td>
</tr>
</tbody>
</table>

Source: CMF, LFTTD, DCA, and UBP

Bootstrapped Standard Errors
### Estimation Results

#### Sample Details

<table>
<thead>
<tr>
<th></th>
<th>Japanese Multinationals</th>
<th>Non-Japanese Multinationals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Firms</td>
<td>105</td>
<td>304</td>
</tr>
<tr>
<td>Share of Total Trade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JPN int imports</td>
<td>0.60</td>
<td>0.23</td>
</tr>
<tr>
<td>Non-JPN int imports</td>
<td>0.02</td>
<td>0.66</td>
</tr>
<tr>
<td>N.A. exports</td>
<td>0.08</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Source: CMF, LFTTD, DCA, and UBP
OUTLINE

1. The 2011 Tōhoku event in context
   ▶ Background and aggregate impacts

2. Firm-level analysis
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3. Structural model of input linkages
   ▶ Key assumptions
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4. Implications
Other Results, Robustness, and Implications

Other Results / Robustness

- Mis-measurement of Firm Production
- Inventories
- Price Movements
- Domestic Inputs
- Strategic Interaction
- Geographic Heterogeneity

Implications

- External Validity
- Results from calibrated IRBC model
External Validity

Other foreign affiliates exhibit similar importing behavior:

- 12 percent of cost due to imported inputs from source country
- 45 percent of imports from source country
- Large majority is intra-firm

A low elasticity for imported inputs by foreign affiliates is not that surprising:

- 70 percent of input trade is intra-firm (specialized products embodying firm-specific knowledge)
- Affiliate trade is highly complex: import $\approx 230$ unique (HS10) products each month
Implications for IRBC Models
Implications for IRBC Models

HOME

Final Goods

FOREIGN

Intermediate Inputs

Intermediate Inputs

(ψ low)

Final Goods

(ψ low)
Implications for IRBC Models

HOME

HD

FM

HX

HM\textsubscript{INT}

FOREIGN

FM\textsubscript{INT}

FX

FD

HM

Intermediate Inputs

(ψ low)

Final Goods

Intermediate Inputs

(ψ low)
Implications for IRBC Models

- HOME
  - HD
  - HX
  - HM_{INT}

- FOREIGN
  - FM_{INT}
  - FX
  - HD
  - HX
  - HM

Intermediate Inputs (ψ low)

Intermediate Inputs

(ψ low)

Final Goods

Combined via Armington elasticity

Combined via Armington elasticity
## Model Moments

<table>
<thead>
<tr>
<th>Model Moment</th>
<th>Data</th>
<th>Baseline</th>
<th>No M.P.</th>
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</thead>
<tbody>
<tr>
<td>Contemporaneous Correlation of:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$GDP^H, GDP^F$</td>
<td>0.59</td>
<td>0.20</td>
<td>0.02</td>
</tr>
<tr>
<td>$C^H, C^F$</td>
<td>0.23</td>
<td>0.34</td>
<td>0.38</td>
</tr>
<tr>
<td>$EX^H, EX^F$</td>
<td>0.63</td>
<td>0.53</td>
<td>0.11</td>
</tr>
<tr>
<td>$EX^H_{INT}, EX^F_{INT}$</td>
<td>?</td>
<td>0.64</td>
<td>—</td>
</tr>
<tr>
<td>$TB^H, GDP^H$</td>
<td>-0.17</td>
<td>0.65</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Impulse Responses
CONCLUSION AND DISCUSSION

Summary and Key Findings:

- We estimate the elasticity of substitution for imported inputs
- Natural experiment to overcome classic identification problem
- Evidence for the transmission of the shock to the U.S. via the rigid supply chains of multinational firms

Implications:

- Complementarities in cross-country inputs an important “real” source of cross-border spillovers
- Potential for the propagation of shocks to upstream/downstream firms
- Policies affecting supply linkages must be announced sufficiently prior to implementation to prevent disruptions
<table>
<thead>
<tr>
<th>Country</th>
<th>U.S. GDP</th>
<th>World GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Australia</td>
<td>0.62</td>
<td>0.49</td>
</tr>
<tr>
<td>Austria</td>
<td>-0.07</td>
<td>0.75</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.23</td>
<td>0.78</td>
</tr>
<tr>
<td>Canada</td>
<td>0.81</td>
<td>0.84</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.34</td>
<td>0.80</td>
</tr>
<tr>
<td>Finland</td>
<td>0.26</td>
<td>0.82</td>
</tr>
<tr>
<td>France</td>
<td>-0.07</td>
<td>0.80</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.12</td>
<td>0.72</td>
</tr>
<tr>
<td>Italy</td>
<td>0.29</td>
<td>0.65</td>
</tr>
<tr>
<td>Japan</td>
<td>0.07</td>
<td>0.71</td>
</tr>
<tr>
<td>Korea, Rep.</td>
<td>0.02</td>
<td>0.17</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.60</td>
<td>0.73</td>
</tr>
<tr>
<td>Norway</td>
<td>0.49</td>
<td>0.43</td>
</tr>
<tr>
<td>Spain</td>
<td>-0.02</td>
<td>0.66</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.41</td>
<td>0.86</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.40</td>
<td>0.74</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.47</td>
<td>0.80</td>
</tr>
</tbody>
</table>

**Median** | 0.29 | 0.74 | 0.35 | 0.68 |

Source: International Financial Statistics, IMF.
We measure $\psi$ using $\frac{d\ln x}{d\ln M^J}$:

$$\frac{d\ln x_t}{d\ln M_t^J} = \frac{\mu^{\frac{1}{\psi}} \left( \frac{M_t^J}{F_D(\cdot)} \right)^{\frac{\psi-1}{\psi}}}{\left( (1 - \mu)^{\frac{1}{\psi}} + \mu^{\frac{1}{\psi}} \left[ \frac{M_t^J}{F_D(\cdot)} \right]^{\frac{\psi-1}{\psi}} \right)}$$

Assuming i) constant relative input prices, ii) an aggregate input bundle $M^J$ that reflects an optimal mix of subcomponents, and iii) $M^J$ is (weakly) scarce, then $\frac{d\ln x}{d\ln M^J}$ is a monotone function of $\psi$:

$$\frac{\partial}{\partial \psi} \frac{d\ln x_t}{d\ln M_t^J} < 0 \quad \text{and} \quad \lim_{\psi \to 0^+} \frac{d\ln x_t}{d\ln M_t^J} = 1$$
Data on Multinational Firms

1. BEA Surveys
   - Only multinational firms, not linked to universe of other firms in the U.S. (Hence, no comparison groups)
   - Linking across years is problematic

2. Identification via Foreign Trade Transactions (LFTTD)
   - Unable to distinguish U.S.-based vs Foreign-based multinational firms
   - Ignores ownership levels (threshold is fixed at 6-10%)
   - Rules out non-trading multinationals by assumption

3. Others
**INTERNATIONAL DIRECTORIES OF CORPORATE ACTIVITY**

Utilize directories of international corporate structure to supplement existing firm-level datasets

1. LexisNexis Directory of Corporate Affiliations
   - Contains both U.S. based and Foreign-based parent firms, including all affiliates, regardless of location.
   - Disadvantages: Inclusion criteria has revenue threshold (> 10 million 1994-2002; > 1 million 2003-2011)

2. Uniworld Business Publications
   - Two Directories: 1) Directory of Foreign Firms Operating in the U.S. and 2) American Firms Operating in Foreign Countries
Classifying Firm-Level Trade

- CMF-Products Data: product-level shipments by establishment
- **Step 1:** Construct set of “final goods” products for a given industry. Let:
  - $X_{pj}$ total shipments of product $p$ in industry $j$
  - $X_j$ total shipments in industry $j$
  - Then $S_{pj} = \frac{X_{pj}}{X_j}$ is share of industry output by product $p$
  - Final goods for industry $j$ are any $p$ where $S_{pj} \geq W$
Classifying Firm-Level Trade

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  - Final goods for industry $j$ are any $p$ where $S_{pj} \geq W$

- **Step 2:** Classify a firm $i$’s imports ($M_{ij}$) (non-Census years):

\[
\begin{align*}
M_{ij}^{int} &= \sum_{p \notin P_j} M_{ipj} \\
M_{ij}^{fin} &= \sum_{p \in P_j} M_{ipj}
\end{align*}
\]

where $P_j = \{ p \mid S_{pj} \geq W \}$.
Classifying Firm-Level Trade: Example

NAICS Industry 333120: Construction Machinery Manufacturing

- Final Product: Product 333120 Construction Machine Manuf.
  - Share of total Production in Industry 333120 is 0.81.
  - Consists of Power Cranes, Shovels, Excavators, Coal Haulers, Mixers, Pavers, Tractor Shovel Loaders, Construction Wheel and Crawler Tractors, Motor Graders

- All others classified as intermediates. These *could* include:
  - 333612 - Mechanical Speed Changers, Gears
  - 336350 - Transmissions and Parts
  - 333996 - Fluid Power Pumps
  - 332912 - Fluid Power Valves
  - 333924 - Portable Loading Docks
  - 333513 - Die-Casting Machines (Punching, Shearing, Bending, etc)
  - 333613 - Power Transmission Equipment (Plain Bearings, Clutches, Couplings, Joints, Drive Chains)
## Classifying Firm-Level Trade: Results

Sensitivity to Threshold Value $W$:

<table>
<thead>
<tr>
<th>Threshold Values</th>
<th>$W = 0$</th>
<th>$W = 0.1$</th>
<th>$W = 0.2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Final Good Products per Industry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>19</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mean</td>
<td>25</td>
<td>1.52</td>
<td>1.14</td>
</tr>
<tr>
<td>Min</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Max</td>
<td>154</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Implied Share of Intermediate Inputs</th>
<th>Imports</th>
<th>Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imports</td>
<td>60.9</td>
<td>63.90</td>
</tr>
<tr>
<td>Exports</td>
<td>52.0</td>
<td>54.96</td>
</tr>
</tbody>
</table>
Probabilistic Record Linking to U.S. Census Bureau Business Register

- No common firm or establishment identifier requires matching based on name and address information.
- Due to misspellings, alternate name and address conventions, etc., one must allow for non-exact matches.

Utilize a multi-variable weighted bigram matching algorithm

- Assigns score based on the percentage of bigram matches between two potential records in corresponding datasets.
- Use name, street address, city, state, and zip code.
- In general, only accept matches with > 95% matching score.
- Supplement with “Clerical Review” to maintain high degree of accuracy and coverage.
## Details on Probabilistic Record Linking


<table>
<thead>
<tr>
<th></th>
<th># of Establishments</th>
<th>Matched to B.R.</th>
<th>Percent Matched</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>112,346</td>
<td>81,656</td>
<td>0.73</td>
</tr>
<tr>
<td>U.S. Multinationals</td>
<td>22,500</td>
<td>16,396</td>
<td>0.73</td>
</tr>
<tr>
<td>Foreign Multinationals</td>
<td>10,331</td>
<td>7,555</td>
<td>0.73</td>
</tr>
</tbody>
</table>
Output (Proxy) of JPN Affiliates

The graph shows the output (proxy) of Japanese firms and 95% confidence intervals relative to months relative to the earthquake. The data is represented in millions of USD.
Pairing with GIS Information

- **DCA Data:** Geocode JPN addresses of any firm with U.S. operations
- **Pair with earthquake intensity measure** (inverse distance-weighted avg within 10km radius)
- **Firm-level averages in Japan, mapped to U.S. locations**
Transmission of Shock: Which Firms?

Which Firms Were Affected?

- Define disruption to output (proxy) as:
  - $X_{ik}^D = 1$ | N.A. exports 20% below trend for Apr-Aug 2011

Evaluating Probability of Disruption (Probit)

$$Pr(X_{ik}^D = 1) = \Phi [\beta_1 JPN_{ik} + \beta_2 Exposed_{ik} + \beta_3 MMI_{ik} + \gamma_k]$$

- $JPN_{ik} = 1$ if firm is a Japanese affiliate
- $Exposed_{ik} = 1$ if firm has 2010 “cost” share $\geq 0.05$
- $MMI_{ik} = 1$ if average of JPN affiliates experience $\geq 4.5$ MMI
## Transmission of Shock: Which Firms?

<table>
<thead>
<tr>
<th></th>
<th>JIMP Disrupted ($J_{ik}^D = 1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Japan</td>
<td>0.707***</td>
</tr>
<tr>
<td></td>
<td>(0.092)</td>
</tr>
<tr>
<td>Exposed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>JPN*Exp</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>MMI</td>
<td>0.346***</td>
</tr>
<tr>
<td></td>
<td>(0.069)</td>
</tr>
<tr>
<td>Ports</td>
<td>0.248</td>
</tr>
<tr>
<td></td>
<td>(0.211)</td>
</tr>
<tr>
<td>Industry F.E.</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>2451</td>
</tr>
</tbody>
</table>

*** p < 0.01, ** p < 0.05, * p < 0.1
## Transmission of Shock: Which Firms?

<table>
<thead>
<tr>
<th></th>
<th>NAEXP Disrupted ($X_{ik}^D = 1$)</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Japan</td>
<td>0.443***</td>
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<td>Exposed</td>
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<tr>
<td>JPN*Exp</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>MMI</td>
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<td>(0.068)</td>
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<tr>
<td>Ports</td>
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<td>(0.224)</td>
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<tr>
<td>Industry F.E.</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>2451</td>
</tr>
</tbody>
</table>

*** $p < 0.01$, **$p < 0.05$, * $p < 0.1$
**Inverse Propensity Score Re-Weighting**

Use size (pre-shock) and industry to balance out control group

<table>
<thead>
<tr>
<th></th>
<th>Japanese Firms</th>
<th>Other Multinationals</th>
<th>Balancing Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>t</td>
</tr>
<tr>
<td><strong>Average (in thousands USD)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N.A. Exports</td>
<td>3,505</td>
<td>3,413</td>
<td>0.38</td>
</tr>
<tr>
<td>share intra-firm</td>
<td>72.0</td>
<td>52.2</td>
<td></td>
</tr>
<tr>
<td>Intermediate Input Imports</td>
<td>8,076</td>
<td>7,597</td>
<td>0.87</td>
</tr>
<tr>
<td>share from Japan</td>
<td>70.0</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>share intra-firm</td>
<td>86.0</td>
<td>21.7</td>
<td></td>
</tr>
<tr>
<td>Industry (Avg)</td>
<td>–</td>
<td>–</td>
<td>0.009</td>
</tr>
</tbody>
</table>
Alternative Specification
# Composition of Japanese Imports by Japanese Multinationals

<table>
<thead>
<tr>
<th>Japanese Multinationals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share Intermediate</td>
</tr>
<tr>
<td>of which</td>
</tr>
<tr>
<td>share Related-Party</td>
</tr>
</tbody>
</table>

Source: CMF, LFTTD, DCA. The data are for year 2007
**Effects on Domestic Labor Inputs**

\[
\Delta \text{emp}_{j,t} = \sum_{i=-3}^{3} \gamma_i E_i + \sum_{i=-3}^{3} \beta_i E_i D_{j,i} + u_{j,t}
\]

where:

- \(\Delta \text{emp}_{j,t} \equiv \ln(\text{emp}_{j,t}/\text{emp}_{j,t-4})\): employment (payroll)
- \(E_i\): corresponds to each calendar month
- \(D_{j,t}\): equals one if firm is owned by Japanese parent company.

**Result:** No \(\beta_i\) significant surrounding Tōhoku event. No quantitatively meaningful movements.
Prices

\[ m_{p,j,t} = \alpha_{pj} + \sum_{i=-19}^{9} \gamma_i E_i + \sum_{i=-19}^{9} \beta_i E_i D_{j,i} + u_{j,t} \]

where:

- \( m_{p,j,t} = \log M_{p,j,t} \): unit values of product \( p \), firm \( j \), month \( t \)
- \( \alpha_{pj} \): firm \( \times \) product fixed-effects,
- \( E_i \): corresponds to each calendar month
- \( D_{j,t} \): equals one if firm is owned by Japanese parent company.

Result: No \( \beta_i \) significant surrounding Tōhoku event. No quantitatively meaningful movements.
Yen per USD (Index Feb 2011=1)
Strategic Interaction

N.A. Production

U.S. Sales

U.S. Inventory

Imported Sales/Inventory

Deviation from Trend

Months Relative to Impact

Deviation from Trend

Months Relative to Impact

Deviation from Trend

Months Relative to Impact

Deviation from Trend

Months Relative to Impact

-3 -2 -1 0 1 2 3 4 5 6 7 8

-3 -2 -1 0 1 2 3 4 5 6 7 8

-3 -2 -1 0 1 2 3 4 5 6 7 8

-3 -2 -1 0 1 2 3 4 5 6 7 8

Non-Japanese

Japanese

Non-Japanese

Japanese

Non-Japanese

Japanese

Non-Japanese

Japanese

-0.5 0 0.5

-0.5 0 0.5

-0.5 0 0.5

-0.5 0 0.5
Bootstrapped Standard Errors

![Graph showing the density of the elasticity of JPN inputs with non-JPN material inputs. The graph compares Japanese Affiliates (solid line) and Non-Japanese Firms (dashed line).]
Bootstrapped Standard Errors

Density

Elasticity of Material Inputs with K/L (ζ)

Japanese Affiliates

Non-Japanese Firms
**Multiple Products: Example**

\[ M_t^J = \left[ (1 - \eta)^{\frac{1}{x}} m_1^{\frac{x-1}{x}} + \eta^x m_2^{\frac{x-1}{x}} \right]^{\frac{x}{x-1}} \]

**A Simple Example With 2 Inputs**

<table>
<thead>
<tr>
<th>Input 1 ((m_1))</th>
<th>Input 2 ((m_2))</th>
<th>Measured Imports ((\hat{M}^J))</th>
<th>Effective Imports(^1) ((M^J))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>80</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>After</td>
<td>70</td>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td>Percent Drop</td>
<td>0.125</td>
<td>0.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>

\(^1\) Using equation above where \(\eta = 0.8\) and \(\chi = 0.2\).
Multiple Products: Example
MULTIPLE PRODUCTS: EXAMPLE

![Graph showing the relationship between Product-Level Imported Input Elasticity (ξ) and Domestic Elasticity (ψ). The graph includes multiple curves for different values of dlnx/dlnM^j: 0.3, 0.5, 0.7, 0.9, and 1.1.]
Deviations from Optimal Input Allocations

Constructing a firm-level measure of the input mix from Japan:

- Assume that each firm $j$ has an optimal bundle of JPN inputs at time $t = s^*$

- Construct the share of JPN imports for each product code $p$:
  $s_{p,t}^j$

- Then we can define the distance from optimal input allocation as:

  $$DO_t^j = \sum_{p=1}^{P} (|s_{p,t}^j - s_{p,s}^j|)$$

- where $P$ is the total number of products.
Does our proxy accurately capture firm production in the U.S.?

- Automotive sector contains model-line production data at a monthly frequency

- Run identical specification using production data:

\[ Q_{i,t} = \alpha_0 + \alpha_i + \sum_{p=-14}^{9} \gamma_p E_p + \sum_{p=-14}^{9} \beta_p E_p JPN_{i,p} + u_{i,t} \]
Assessing the Proxy for Production

![Graph showing the fraction of pre-shock level vs. months relative to earthquake. The graph compares Output Proxy (NA Exports) and Auto Output.]
**Intermediate Input Inventories**

Why do input inventories not absorb or cushion the shock?

Answer: Very low levels of intermediate input inventories

- for Japanese affiliates: roughly a 3-week supply of material input inventories (2007, Census of Manufacturers)
- consistent with well-known “lean” production philosophy

Potential Puzzle: With such a rigid supply chain, one would expect higher degree of inventory holdings as buffer against disruptions.
Auto Sector Data: Description

Ward’s Automotive Database (2000-2012)

- Monthly North American plant/model line
- Covers universe of assembly operations of finished cars and light trucks
- Includes:
  1. Production (plant and model-line)
  2. Inventories (model-line)
  3. Sales (model-line)
- Inventories and sales include origin of production
- Also: monthly production by model line for Japan
Production: North America
SALES: NORTH AMERICA

The graph shows the sales trends of automotive units in North America from September 1998 to February 2015. It compares the sales of Japanese Autos, Non-Japanese Autos, and All models over time.

- **Japanese Autos**: Represented by the black line, the sales trend shows significant fluctuations, with peaks around May 2001 and November 2006.
- **Non-Japanese Autos**: The blue dotted line indicates a trend that generally follows a downward trajectory with some fluctuations, particularly noticeable in May 2001 and August 2009.
- **All**: The red line, while consistent with the overall trend, also shows significant variation, with notable peaks around November 2006 and May 2012.

The y-axis represents auto units in thousands, and the x-axis shows the months from September 1998 to February 2015.
Impulse Response: Neg. TFP Shock in Home

Domestic Firm Output

Exporters Output

Mult Intermediate Output

Mult Affiliate Output
Impulse Response: Neg. TFP Shock in Home

GDP (Value-Added)

Consumption

Home Exports

Foreign Exports

Percent Change

Periods Following Shock

Percent Change

Periods Following Shock

Percent Change

Periods Following Shock

Export (Int)

Exports (Final)

Exports (Total)