INTERNATIONAL LINKAGES AND THE CHANGING NATURE OF INTERNATIONAL BUSINESS CYCLES

Wataru Miyamoto  Thuy Lan Nguyen
University of Hong Kong  SF Fed & Santa Clara University

CBMMW – Norges Bank
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INTERNATIONAL LINKAGES

- Change in total trade shares: Increase in openness in most countries
  - (Exports+Imports) over VA in manufacturing increased from 80% in 1970 to nearly 250% in 2007 at median.
International Linkages

- Change in trade partners
  - Example: US trades more with China and Mexico than with Japan in 2007

![USA Manufacturing Trade Partners](chart.png)

- USA Manufacturing Trade Partners
  - Canada
  - China
  - Japan
  - Mexico
The median 10-year rolling over standard deviations of the HP-filtered output, consumption and investment in 23 countries between 1970 and 2007.
Our Paper

Question: To what extent does change in international input-output linkages affect business cycles in different countries?

Approach: Build a 24-country 2-sector augmented IRBC model

- Match with World IO table changes from 1970–2007
- Decompose total effects of World IO table changes into several channels

Answer:

- Changes in international input-output linkages explain 15% of drop in output volatilities at median in the baseline
  - Compare to about 40% in the data

- The effects are heterogeneous across countries
- International linkages tend to stabilize domestic volatilities but more risk from foreign shocks
- Estimates depend on degrees and mechanism of transmission in the model
RELATIONSHIP BETWEEN INTERNATIONAL LINKAGES AND OUTPUT VOLATILITY

- 2 country 2 sector model: Canada and the US
- Varies trade shares in manufacturing sector

Baseline

Larger Foreign Shocks
World IO changes & Changing Volatilities

Total

International Linkage

Sector Size

- Model: Median
- 25-75
- 10-90
- Data: Median
WORLD IO CHANGES & CHANGING OUTPUT VOLATILITIES: HETERGENEITY

All countries Relative Sizes

Canada

US

Mexico

1980 1990 2000

1980 1990 2000

1980 1990 2000

Total
International Linkage
Sector Size
**Multipliers Over Time**

\( \omega(\text{year}) \) based on entire World IO Table change

![Graphs showing multipliers over time for various countries](image-url)
FULL PRESENTATION
RELATED LITERATURE

- Accounting volatility changes using network structure

- Trade, Diversification, and Volatilities
  - di Giovanni and Levchenko (2009), Caselli et al. (2017)

- International Business Cycle Comovement

- Role of intermediate good trade
  - Burstein et al. (2008), di Giovanni and Levchenko (2010), Bems et al. (2015)
MODEL OVERVIEW

▶ 24-country, 2-sector augmented International Real Business Cycle Model
  ▶ To capture the input-output linkages within and across countries and generate endogenous transmission of shocks across countries

▶ Additional Features
  ▶ Intermediate goods trade across countries and sectors
  ▶ Variable capacity utilization
  ▶ Variable markup generated by firms’ entry and exit
  ▶ Investment adjustment cost
**Production Overview**

- **(C,I)**
  - Manufacturing/Nonmanufacturing
  - Local Industry $l \in (0, 1)$
  - Firms $N$

- **(C,I)**
  - Manufacturing/Nonmanufacturing
  - Local Industry $l \in (0, 1)$
  - Firms $N$
Final and Intermediate Goods Production

- Final good firms produce consumption goods:

\[
C(i) = \left[ \sum_{s=1}^{S} (\omega_{CF}(s, i)) \right] \frac{1}{\gamma_F} \left( f_C(s, i) \right)^{\frac{\gamma_F-1}{\gamma_F}} \frac{\gamma_F}{\gamma_F-1} \text{ sectoral final composite good}
\]

\[
f_C(s, i) = \left[ \sum_{j=1}^{I} (\omega_{Cf}((j, s), i)) \right] \frac{1}{\gamma_f} \left( f((j, s), i) \right)^{\frac{\gamma_f-1}{\gamma_f}} \frac{\gamma_f}{\gamma_f-1} \text{ shipment from country } j \text{ to } i
\]

- Similar for Investment \( I(i) \) and Intermediate goods \( M(i) \)
Firms have market power, modeled by firms’ entry and exit (Jaimovich and Floetotto (2008 JME))
Variable markup: depending on states of business cycles, high in slumps and low in booms
▶ Each local industry has a limited number of firms
▶ Local output $L(i, s|l)$ where $l \in [0, 1]$

\[
L(i, s|l) = N_f(i, s|l)^{-\frac{1}{\gamma_L-1}} \left[ \sum_{k=1}^{N_f} q(i, s|l,k) \gamma_L^{-1} \right]^{\frac{\gamma_L}{\gamma_L-1}}
\]

▶ Raw sector output is given by:

\[
Q(i, s) = \left[ \int_0^1 L(i, s|l) \frac{\gamma_Q^{-1}}{\gamma_Q} \, dl \right]^{\frac{\gamma_Q}{\gamma_Q-1}}
\]
Production technology for each firm $f$:

$$q(i,s|l,f) = \left[ \omega_q(i,s)^{\frac{1}{\gamma_q}} \left( A(i,s) K(i,s|l,f)^{\alpha} H(i,s|l,f)^{1-\alpha} \right)^{\frac{\gamma_q-1}{\gamma_q}} + (1 - \omega_q(i,s))^{\frac{1}{\gamma_q}} (M(i,s|l,f))^{\frac{\gamma_q-1}{\gamma_q}} - \phi(i,s) \right]^{\frac{\gamma_q}{\gamma_q-1}}$$

Productivity process:

$$\ln A_t(i,s) = \rho_A \ln A_{t-1}(i,s) + e_t^A(i,s)$$
HOUSEHOLDS

\[ \max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C(i), H(i)) \]

subject to budget constraint:

\[ C_t(i) + p_t^l(i)I_t(i) + \mathbb{E}_t \varepsilon_t(i)r_{t,t+1}B_{t+1}(i) \leq W_t(i)H_t(i) + R_t^k(i) (u_t(i)K_t(i)) + \varepsilon_t(i)B_t(i) \]

Capital accumulation:

\[ K_{t+1}(i) \leq (1 - \delta(u_t(i))) K_t(i) + I_t(i) \left( 1 - S \left( \frac{I_t(i)}{I_{t-1}(i)} \right) \right) \]
Resource Constraints

\[ n(i)Q(i,s) = \sum_{j=1}^{I} n(j) [f_C((i,s),j) + f_I((i,s),j)] \]

\[ + \sum_{j=1}^{I} \sum_{k=1}^{S} n(j) m((i,s),(j,k)) \]

where \( n(i) \) is the size of country \( i \).

Additionally, \( \sum_{s=1}^{S} H(i,s) = H(i) \) and \( \sum_{s=1}^{S} K(i,s) = u(i)K(i) \)
SHOCK TRANSMISSION: TWO-COUNTRY TWO-SECTOR MODEL
RELATIONSHIP BETWEEN INTERNATIONAL LINKAGES AND OUTPUT VOLATILITY

- 2 country 2 sector model: Canada and the US
- Varies trade shares in manufacturing sector
MODEL MECHANISM: WHY VOLATILITY STABILIZED

Domestic positive productivity shock

- Supply side: domestic firms try to use more intermediate inputs
  - More openness ⇒ need foreign intermediate inputs which is not supplied more as no change in foreign productivity ⇒ constrain production relative to closed economy case

- Demand side: foreign households/firms try to import domestic goods
  - More openness ⇒ more dependent on foreign demand ⇒ foreign demand does not increase much as foreign economy is not directly impacted by productivity shock ⇒ constrain demand for domestic goods relative to closed economy case
RELATIONSHIP BETWEEN RELATIVE SECTOR SIZE AND OUTPUT VOLATILITY

SD of VA: Country 1

Size of Sector2/Sector1
**Calibration: Data**

- Data for 23 countries between 1970 and 2007
  - Australia, Austria, Belgium, Brazil, Canada, China, Germany, Denmark, Spain, Finland, France, UK, Greece, India, Ireland, Italy, Japan, Korea, Mexico, Netherlands, Portugal, Sweden, USA

- Several data sources:
  - NBER–UN and CEPII detailed bilateral trade data
  - World IO table from Johnson and Noguera (2016)
  - OECD quarterly data on output, consumption, investment
  - World Bank WDI national account data
  - UN data for gross and value added data
## Calibration

Common parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.96</td>
<td>Discount factor</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.36</td>
<td>Labor share parameter</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.1</td>
<td>Depreciation rate</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>2</td>
<td>Inverse of IES</td>
</tr>
<tr>
<td>$\nu$</td>
<td>1</td>
<td>Inverse of Frisch labor supply</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>0.1</td>
<td>Wealth effect parameter</td>
</tr>
<tr>
<td>$\frac{\delta''}{\delta_u} u$</td>
<td>0.05</td>
<td>Inverse utilization elasticity</td>
</tr>
<tr>
<td>$\gamma_F$</td>
<td>1</td>
<td>ES between sectoral goods</td>
</tr>
<tr>
<td>$\gamma_f$</td>
<td>1</td>
<td>ES between home and foreign goods</td>
</tr>
<tr>
<td>$\epsilon_{\text{markup}}$</td>
<td>0.12</td>
<td>Elasticity of markup</td>
</tr>
<tr>
<td>$s$</td>
<td>0.1</td>
<td>Investment adjustment cost</td>
</tr>
<tr>
<td>$\rho_A$</td>
<td>0</td>
<td>Shock persistence</td>
</tr>
</tbody>
</table>
Calibrate productivity shock standard deviations

- Let \( \omega \) be the vector of steady state parameters that include all share and size parameters in IO table.

- Calibrate \( \omega \): Average of World IO table (1984–1993)
  - Midpoint of the sample
  - Average to eliminate the effects of business cycles

- Match the standard deviations of sectoral value added in each country

\[
\sigma_{data} VA(i, s) = \sigma_{model} VA(i, s)
\]
## Model Fit

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard deviations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>1.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Consumption</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Investment</td>
<td>3.8</td>
<td>3.3</td>
</tr>
<tr>
<td>Manufacturing real value added</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Non-manufacturing real value added</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Autocorrelation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>0.32</td>
<td>0.26</td>
</tr>
<tr>
<td>Consumption</td>
<td>0.35</td>
<td>0.23</td>
</tr>
<tr>
<td>Investment</td>
<td>0.39</td>
<td>0.47</td>
</tr>
<tr>
<td>Manufacturing real value added</td>
<td>0.25</td>
<td>0.12</td>
</tr>
<tr>
<td>Non-manufacturing real value added</td>
<td>0.32</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Notes: The second moments reported in both the model and the data are taken as median across countries using HP filtered data between 1971 and 2007.
# Decomposition: World IO Table

**Table:** General World IO table

<table>
<thead>
<tr>
<th></th>
<th>CA s1</th>
<th>CA s2</th>
<th>US s1</th>
<th>US s2</th>
<th>CA final</th>
<th>US final</th>
<th>GO</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA s1</td>
<td>$M_{11}$</td>
<td>$M_{12}$</td>
<td>$M_{13}$</td>
<td>$M_{14}$</td>
<td>$F_{11}$</td>
<td>$F_{12}$</td>
<td>$Q_1$</td>
</tr>
<tr>
<td>CA s2</td>
<td>$M_{21}$</td>
<td>$M_{22}$</td>
<td>$M_{23}$</td>
<td>$M_{24}$</td>
<td>$F_{21}$</td>
<td>$F_{22}$</td>
<td>$Q_2$</td>
</tr>
<tr>
<td>US s1</td>
<td>$M_{31}$</td>
<td>$M_{32}$</td>
<td>$M_{33}$</td>
<td>$M_{34}$</td>
<td>$F_{31}$</td>
<td>$F_{32}$</td>
<td>$Q_3$</td>
</tr>
<tr>
<td>US s2</td>
<td>$M_{41}$</td>
<td>$M_{42}$</td>
<td>$M_{43}$</td>
<td>$M_{44}$</td>
<td>$F_{41}$</td>
<td>$F_{42}$</td>
<td>$Q_4$</td>
</tr>
<tr>
<td>VA</td>
<td>$V_1$</td>
<td>$V_2$</td>
<td>$V_3$</td>
<td>$V_4$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GO</td>
<td>$Q_1$</td>
<td>$Q_2$</td>
<td>$Q_3$</td>
<td>$Q_4$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: $M$ is $IS \times IS$, $V$ is $IS \times 1$, $Q$ is $IS \times 1$ and $F$ is $IS \times I$. 
Experiment 1: World IO Table Change

- Fix shock processes
- We solve the model corresponding to each year
- Denote $\omega(\text{year})$ to be the steady state for each year
- Calibrate $\omega(\text{year})$ using 11-year rolling mean WIOT and solve model
  - Mean of WIOT 1985-1995 $\rightarrow \omega(1990) \rightarrow \sigma^Y_{1990}$
  - Mean of WIOT 1986-1996 $\rightarrow \omega(1991) \rightarrow \sigma^Y_{1991}$
  - Mean of WIOT 1987-1997 $\rightarrow \omega(1992) \rightarrow \sigma^Y_{1992}$
  - $\sigma^Y_{1992} - \sigma^Y_{1990}$ is the effect of World IO changes between 1990 and 1992
**Decomposition**

- Total effects include several changes such as changes in
  1. international input-output linkages
  2. relative sector sizes
  3. relative country sizes
  4. domestic input-output linkages
  5. value added shares in production

- Goal is to isolate the effects of these changes.

- Focus on (1) and (2)
**Experiment 2: International Linkages**

**Goal:** Isolate changes due to openness from others such as sectoral compositions of inputs and sector sizes

- Construct hypothetical $\tilde{WIOT}$ at each year $T$
  - Use information in both $T$ and $T - 1$
  - In $\tilde{WIOT}$, only international dimension changes based on WIOT at $T$

- Calibrate $\omega(\text{year})$ using $\tilde{WIOT}$ and solve model
  - Actual WIOT 1990 $\rightarrow \omega(1990) \rightarrow \sigma^Y_{1990}$
  - Hypothetical $\tilde{WIOT}$ 1991 $\rightarrow \omega(1991) \rightarrow \tilde{\sigma}^Y_{1991}$
  - $\tilde{\sigma}^Y_{1991} - \sigma^Y_{1990}$ is the effect of international linkage changes between 1990 and 1991

- Accumulate the effects over time
**EXPERIMENT 2: INTERNATIONAL LINKAGES**

Construction of \( \text{WIOT} \)

<table>
<thead>
<tr>
<th></th>
<th>CA s1</th>
<th>CA s2</th>
<th>US s1</th>
<th>US s2</th>
<th>CA final</th>
<th>US final</th>
<th>GO</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>( m_{11} )</td>
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<td>( m_{13} )</td>
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<td>( f_{11} )</td>
<td>( f_{12} )</td>
<td>( Q_1 )</td>
</tr>
<tr>
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<td>( m_{21} )</td>
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<td>( f_{42} )</td>
<td>( Q_4 )</td>
</tr>
<tr>
<td>VA</td>
<td>( v_1 )</td>
<td>( v_2 )</td>
<td>( v_3 )</td>
<td>( v_4 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GO</td>
<td>( Q_1 )</td>
<td>( Q_2 )</td>
<td>( Q_3 )</td>
<td>( Q_4 )</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

where technical coefficients \( m_{ij} = \frac{M_{ij}}{Q_j} \) and \( f_{ij} = \frac{F_{ij}}{Q_i} \) and \( v_i = \frac{V_i}{Q_i} \)

- Keep shares of VA in GO
- Keep \( m_{11} + m_{31} \)
- Change \( m_{11}/m_{31} \), recover \( M \)'s
- Calculate \( F = GO - M \), change \( f_{11}/f_{21} \)
**Experiment 3: Relative Sectoral Size**

**Goal:** Isolate changes due to sector size from others such as sectoral compositions of inputs, country sizes

- Construct hypothetical $\tilde{WIOT}$ at each year $T$
  - Use information in both $T$ and $T-1$
  - In $\tilde{WIOT}$, only relative sector sizes based on WIOT at $T$

- Calibrate $\omega(\text{year})$ using $\tilde{WIOT}$ and solve model
  - Actual WIOT 1990 $\rightarrow \omega(1990) \rightarrow \sigma_{1990}^Y$
  - Hypothetical $\tilde{WIOT}$ 1991 $\rightarrow \omega(1991) \rightarrow \tilde{\sigma}_{1991}^Y$
  - $\tilde{\sigma}_{1991}^Y - \sigma_{1990}^Y$ is the effect of international linkage changes between 1990 and 1991

- Accumulate the effects over time
## Experiment 3: Relative Sectoral Size

<table>
<thead>
<tr>
<th>Construction of WIOT</th>
<th>CA</th>
<th>CA</th>
<th>US</th>
<th>US</th>
<th>CA</th>
<th>US</th>
<th>GO</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>s1</td>
<td>s2</td>
<td>s1</td>
<td>s2</td>
<td>final</td>
<td>final</td>
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</tr>
<tr>
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<td></td>
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</tr>
</tbody>
</table>

where technical coefficients $m_{ij} = \frac{M_{ij}}{Q_j}$ and $f_{ij} = \frac{F_{ij}}{Q_i}$ and $v_i = \frac{V_i}{Q_i}$

- Change $Q_1 / Q_2$
- Calculate $F = GO - M$, keep $f_{11} / f_{21}$
World IO Changes & Changing Volatilities

Total

International Linkage

Sector Size

Model: Median

25-75

10-90

Data: Median
**World IO changes & Changing Output Volatilities: Heterogeneity**

All countries

<table>
<thead>
<tr>
<th></th>
<th>Relative Sizes</th>
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<tbody>
<tr>
<td>1980</td>
<td>1990</td>
</tr>
<tr>
<td>Canada</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td></td>
</tr>
</tbody>
</table>

- **Canada**
  - Total
  - International Linkage
  - Sector Size

- **US**
  - Total
  - International Linkage
  - Sector Size

- **Mexico**
  - Total
  - International Linkage
  - Sector Size
INTERNATIONAL LINKAGE CHANGES’ EFFECTS ON VOLATILITY
Relative Sector Size Changes’ Effects on Volatility
**OTHER VARIABLES**

![Graphs showing the changes in other variables from 1980 to 2000.](image)

- **C : Total**
- **C : International Linkage**
- **C : Sector Size**
- **I : Total**
- **I : International Linkage**
- **I : Sector Size**

With lines indicating median and 25-75% and 10-90% confidence intervals.
INSPECTING MECHANISM

Baseline

RBC

Low Elasticity

Correlated Shock

Confidence Shock

Baseline
Robustness
Baseline 25-75
Robustness 25-75
How much do shocks in one country affect other countries over time?
- Our model can predict foreign shocks can be more important over time

Model provides decomposition but depends on calibrated fixed standard deviations of shocks
- Decomposition exercise is about the long run
- A rare large shock in foreign country as in Great Recession can increase observed volatility with more linkages
  - Even when theoretical long run volatility declines
- We next isolate the effects of a unit GDP shock in one country to other countries over time
Define Cross-country value added multipliers

\[
M_{US}^H = \frac{\sum_{h=1}^{H} \frac{\partial VA_{X,h}}{\partial A_{US,1}}}{\sum_{h=1}^{H} \frac{\partial VA_{US,h}}{\partial A_{US,1}}}
\]

(1)

with X as other countries in the sample

- Over H years, if US output goes up by 1%, Country X’s output goes up by \( M \)%
- Account for only degree of transmission of shocks across countries over time
**Multipliers Over Time**

$\omega(\text{year})$ based on entire World IO Table change
Our model implies that international linkages explain a sizable change in aggregate volatilities

- Magnitude depends on the mechanism and transmission channels

- Increase in potential risk of global recession
EXTRA SLIDES
Relative Sector Sizes

GO Shares of Manufacturing Sector

0.25 0.3 0.35 0.4

- Median
- Canada
- US
- Mexico
- 25-75% percentile