International Linkages and the Changing Nature of International Business Cycles

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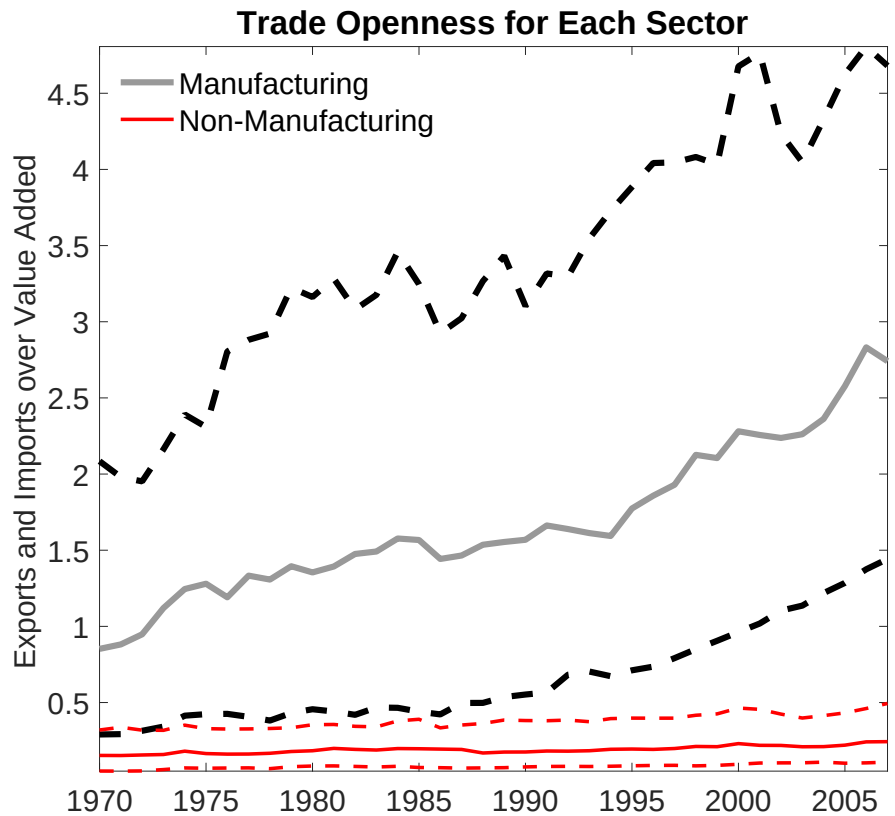
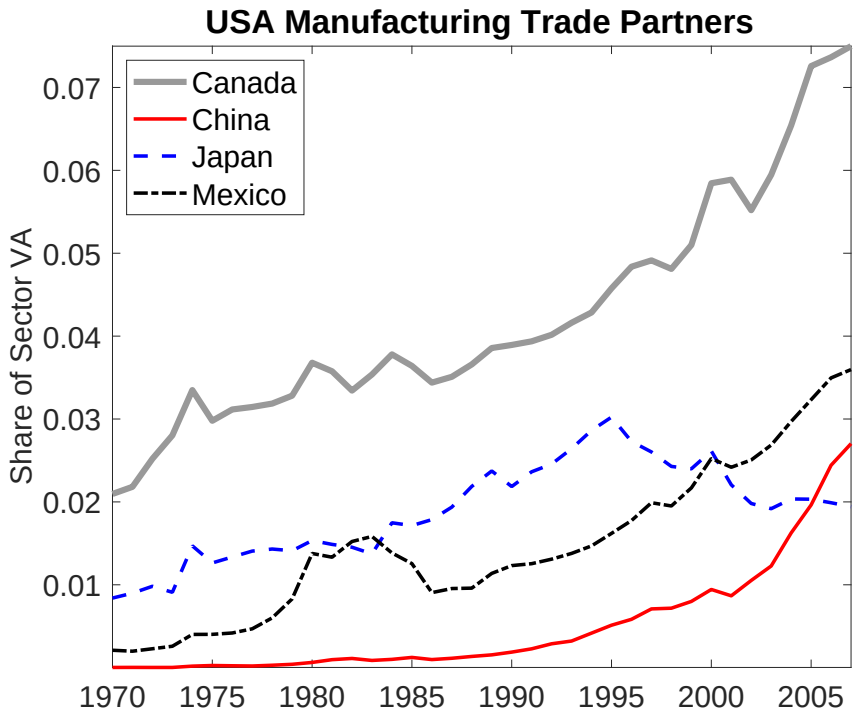
International Linkages

- 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.

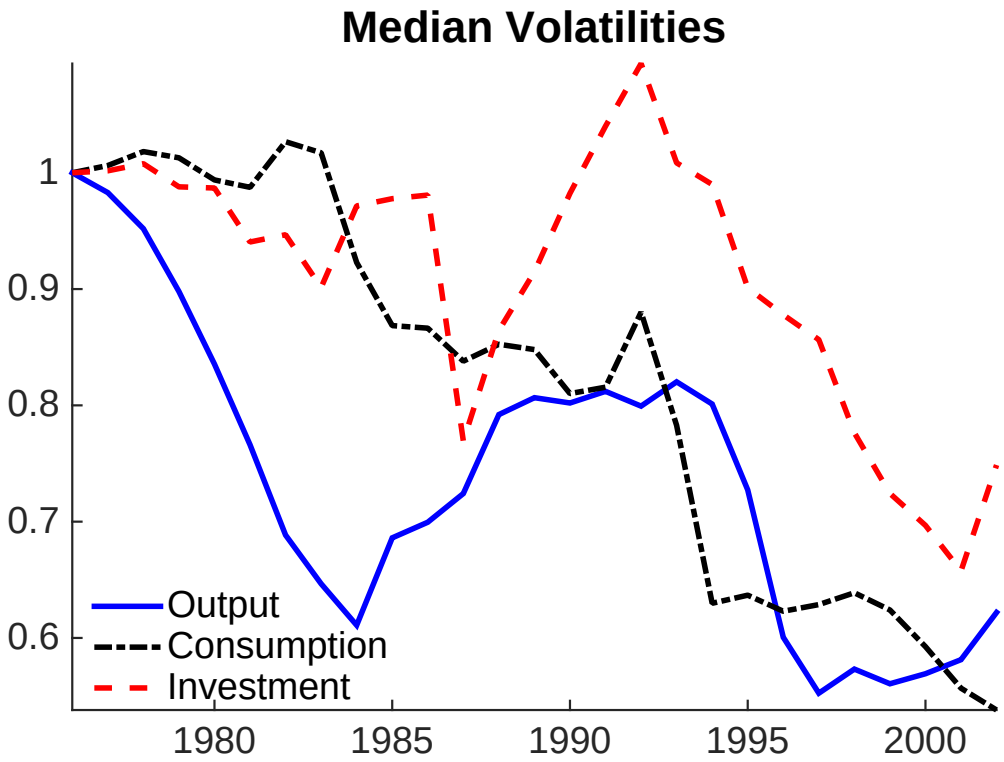


International Linkages

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



Changing Nature of Business Cycles



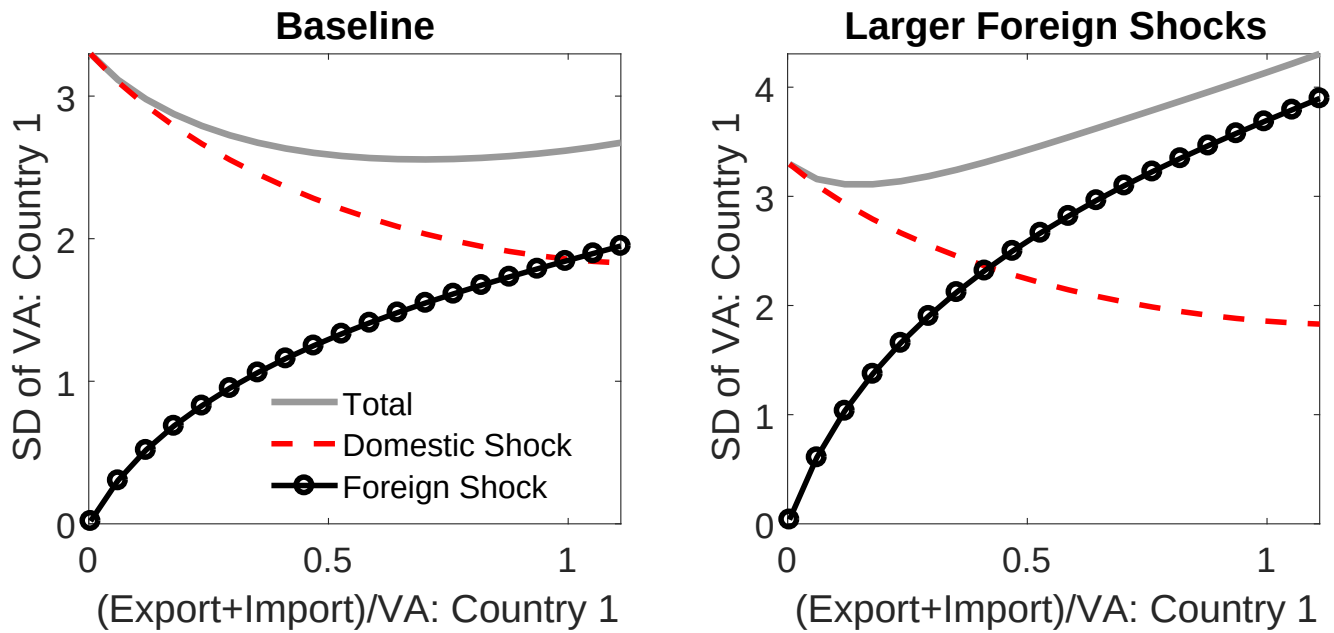
- The median 10-year rolling over standard deviations of the HP-filtered output, consumption and investment in 23 countries between 1970 and 2007.

Our Paper

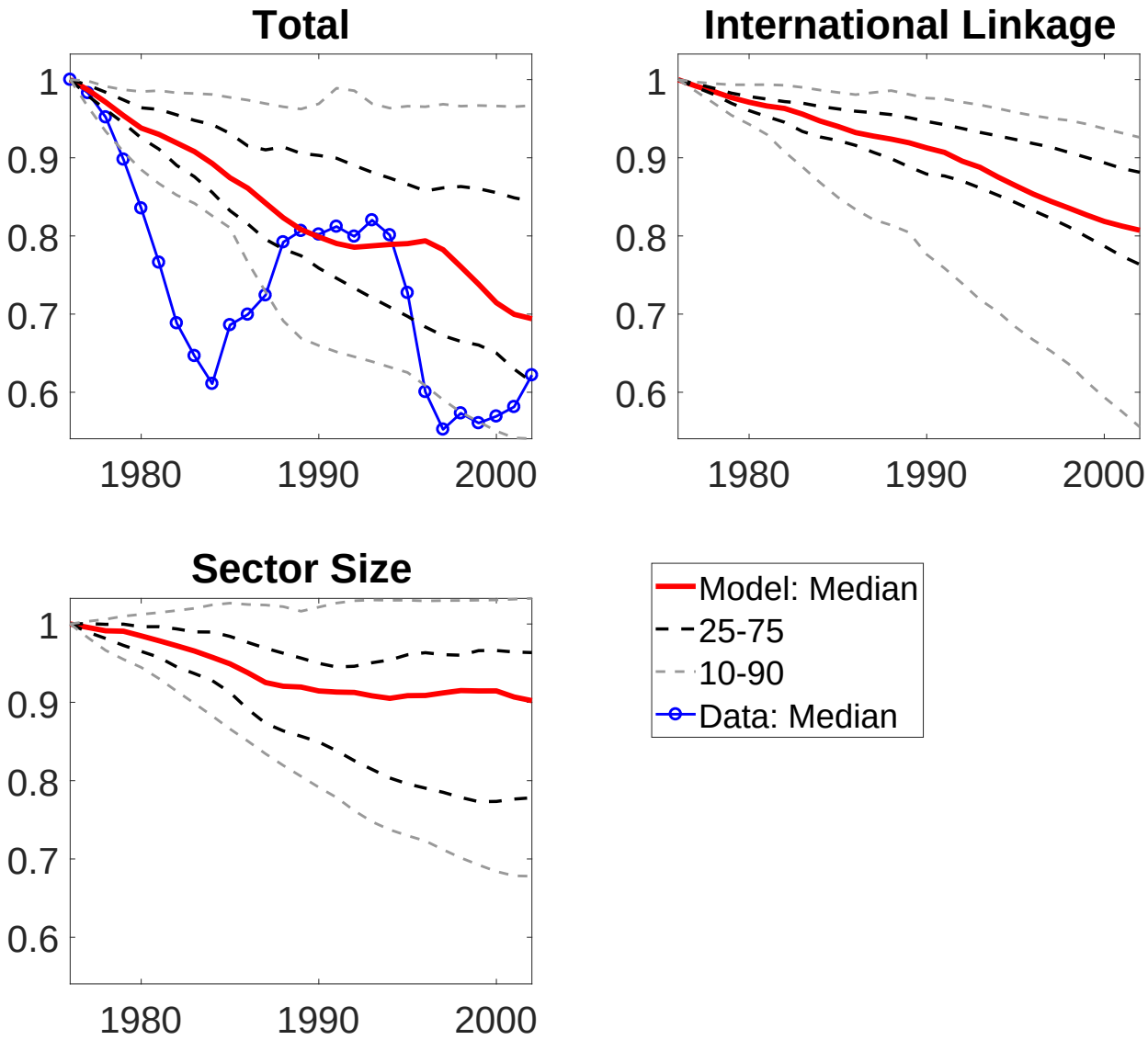
- Question: To what extent does change in international input-output linkages affect business cycles in different countries?
- Approach: Build a 24-country 2-sector augmented IRBC model
  - Match with World IO table changes from 1970–2007
  - Decompose total effects of World IO table changes into several 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

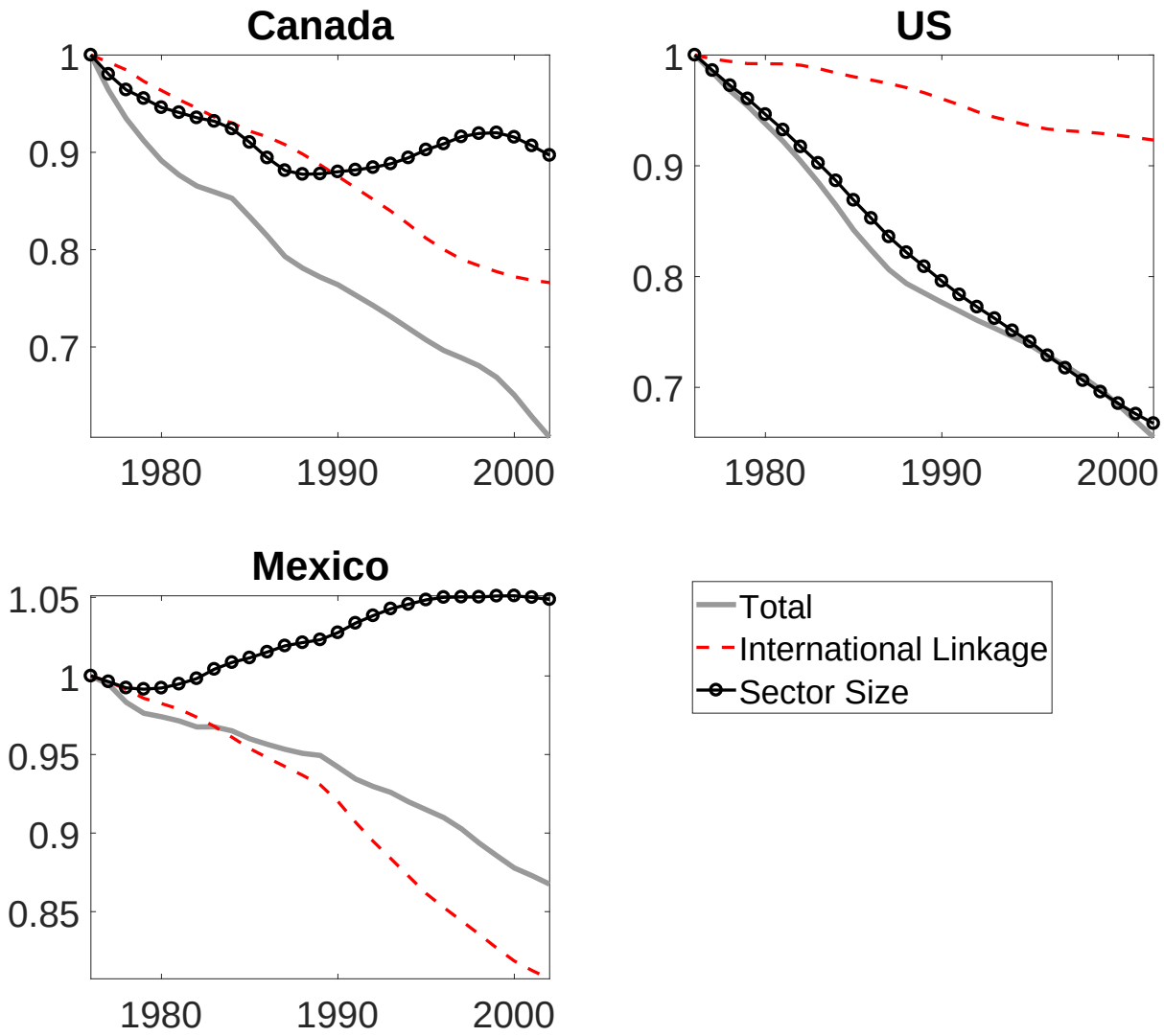


World IO changes & Changing Volatilities



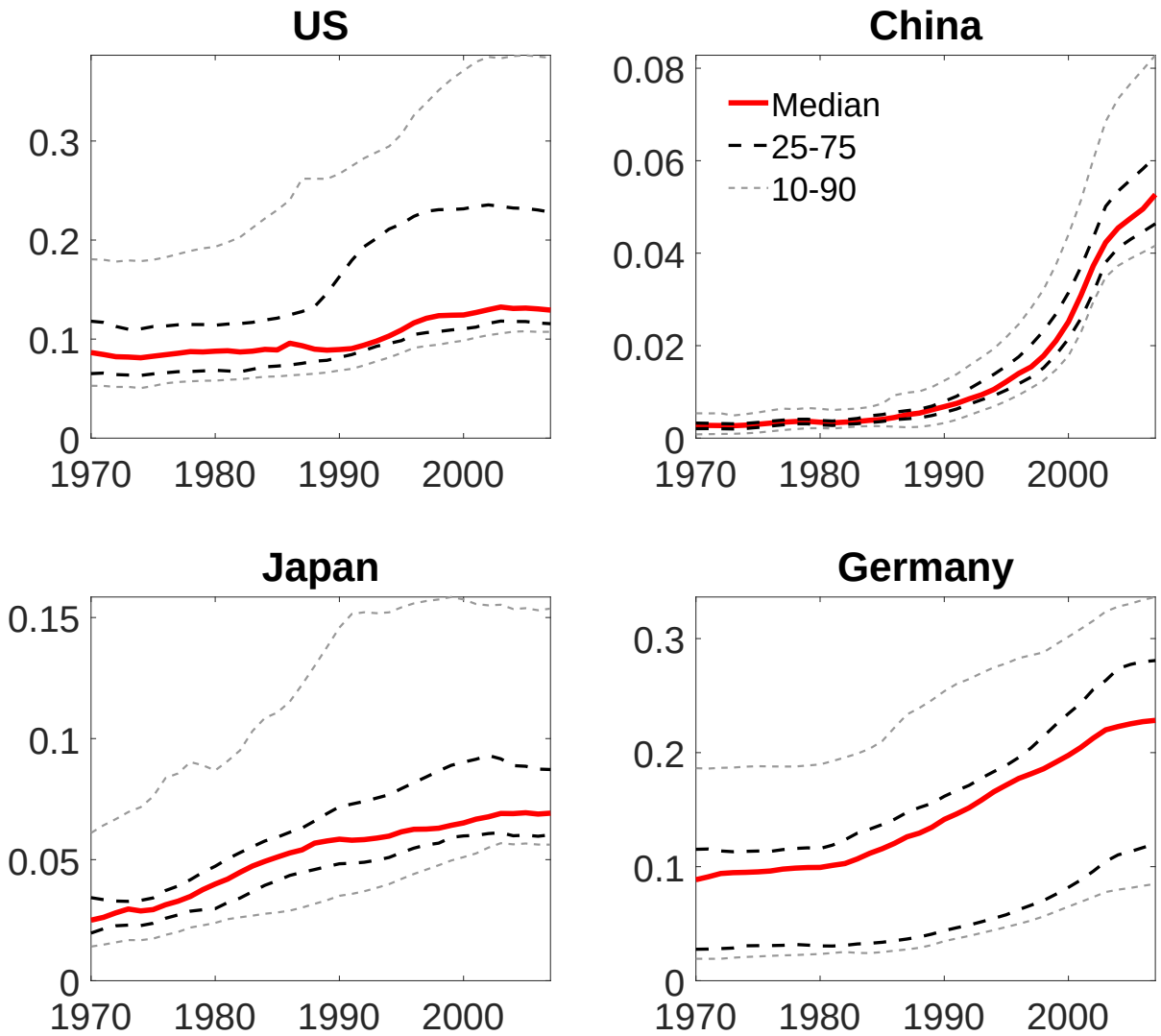
World IO changes & Changing Output Volatilities: Heterogeneity

All countries | Relative Sizes



MULTIPLIERS OVER TIME

$\omega(year)$ based on entire World IO Table change



FULL PRESENTATION

Related Literature

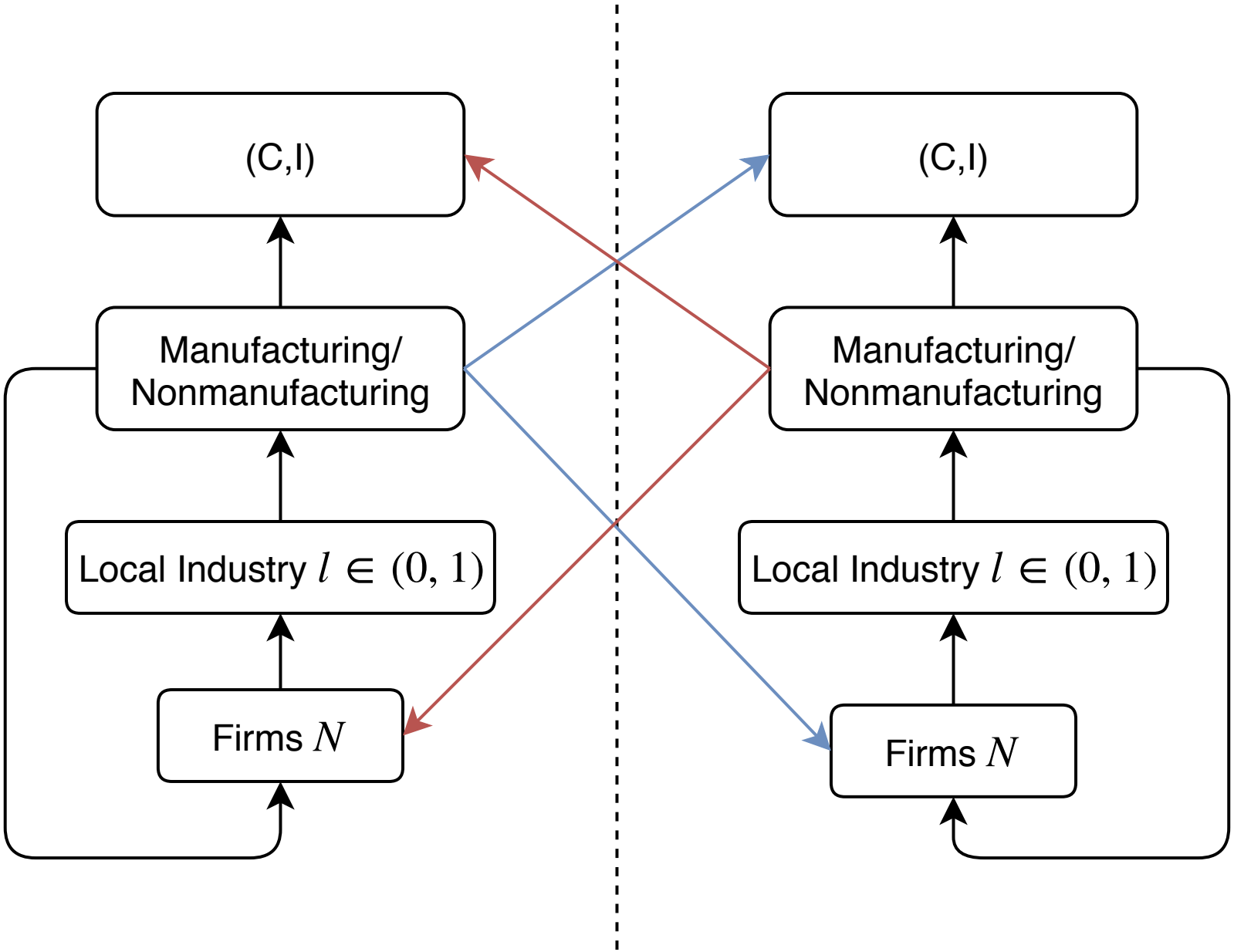
- Accounting volatility changes using network structure
  - Foerster et al. (2011), Moro (2012), Carvalho and Gabaix (2013), Atalay (2017)
- Trade, Diversification, and Volatilities
  - di Giovanni and Levchenko (2009), Caselli et al. (2017)
- International Business Cycle Comovement
  - BKK (1992), Kose and Yi (2002), Burstein et al. (2008), Johnson (2013), Davis and Huang (2011), Liao and Santacreu (2015), Nosal et al. (2015), Miyamoto and Nguyen (2017), de Soyres (2018)
- 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



Final and Intermediate Goods Production

- Final good firms produce consumption goods:

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

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

- Similar for Investment $I(i)$ and Intermediate goods $M(i)$

Raw Output Production

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 $l \in [0,1]$

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

- Raw sector output is given by:

$$Q(i,s) = \left[\int_0^1 L(i,s|l)^{\frac{\gamma_Q - 1}{\gamma_Q}} dl \right]^{\frac{\gamma_Q}{\gamma_Q - 1}}$$

Raw Output Production

- Production technology for each firm f:

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

- 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:

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

Capital accumulation:

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

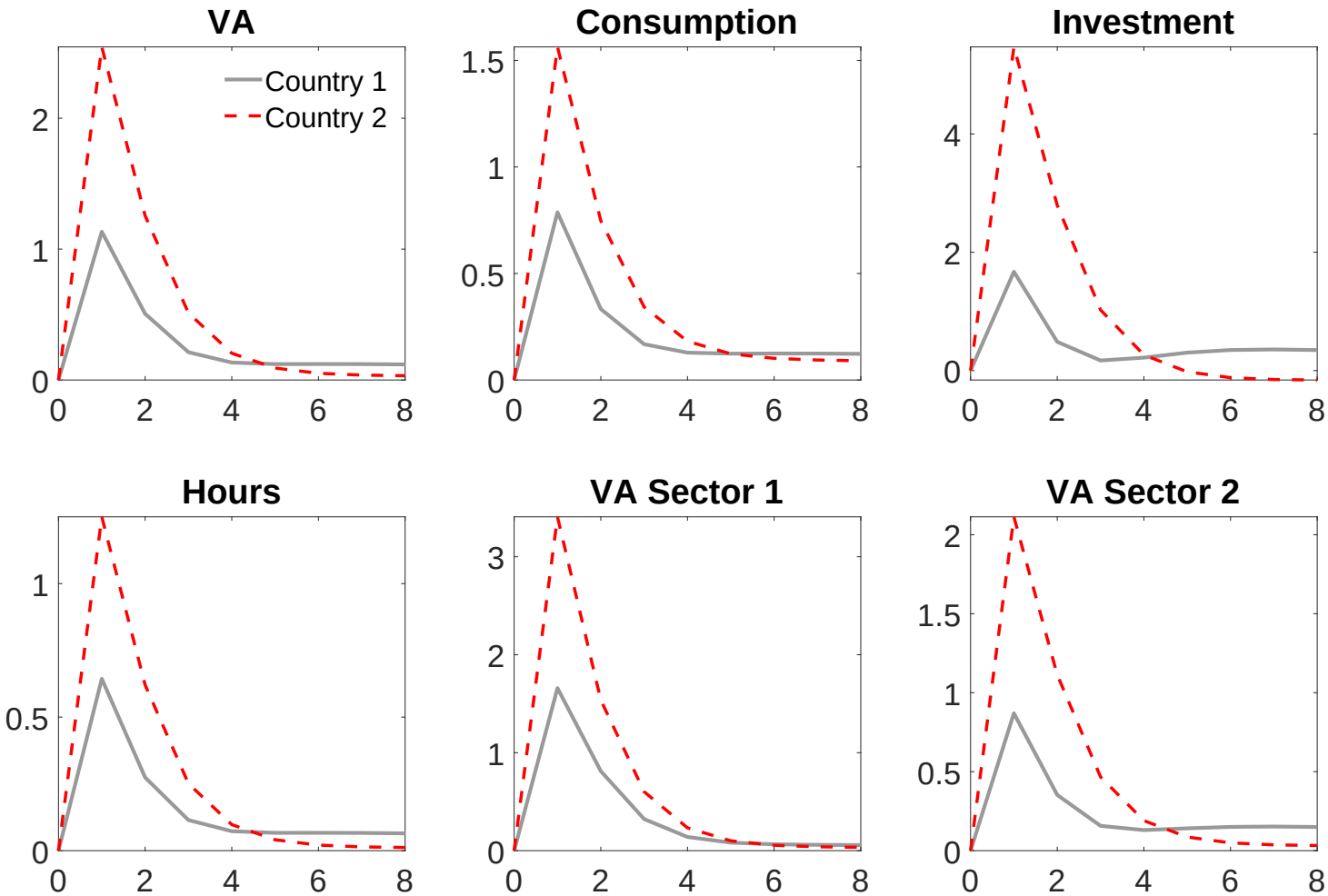
Resource Constraints

$$n(i)\,Q(i,s) = \sum_{j=1}^{I} n(j)\left[f_C\left((i,s),j\right) + f_I\left((i,s),j\right)\right] + \sum_{j=1}^{I}\sum_{k=1}^{S} n(j)\,m\left((i,s),(j,k)\right)$$

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

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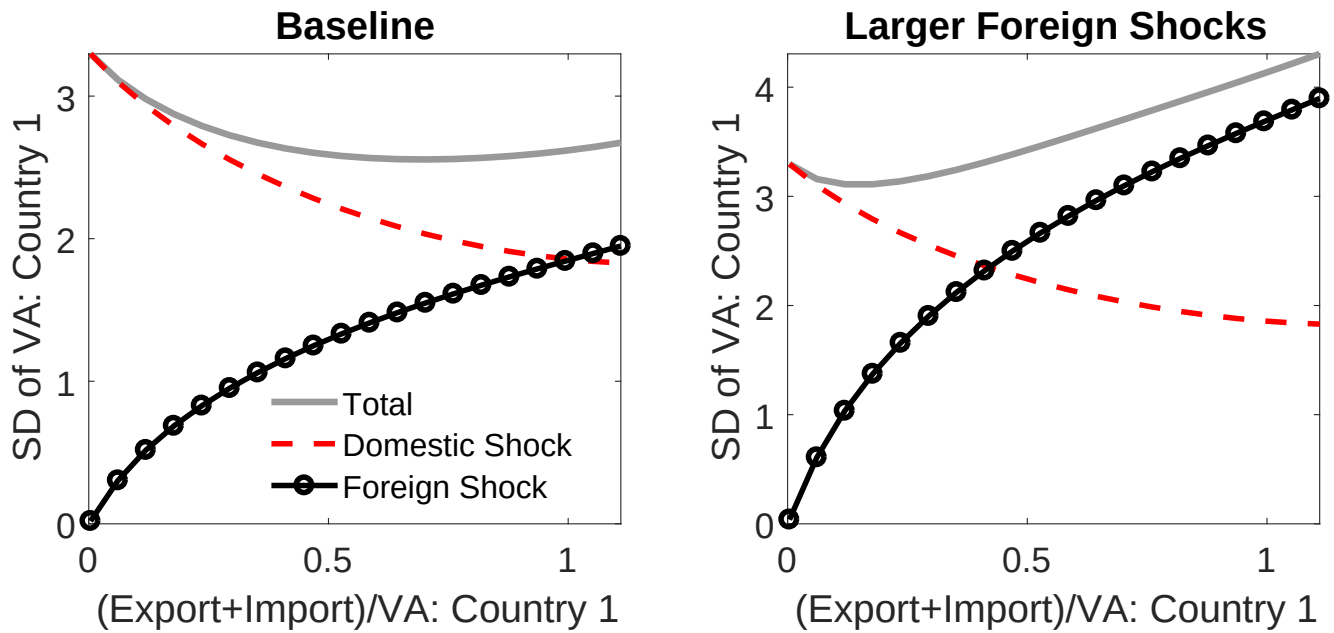
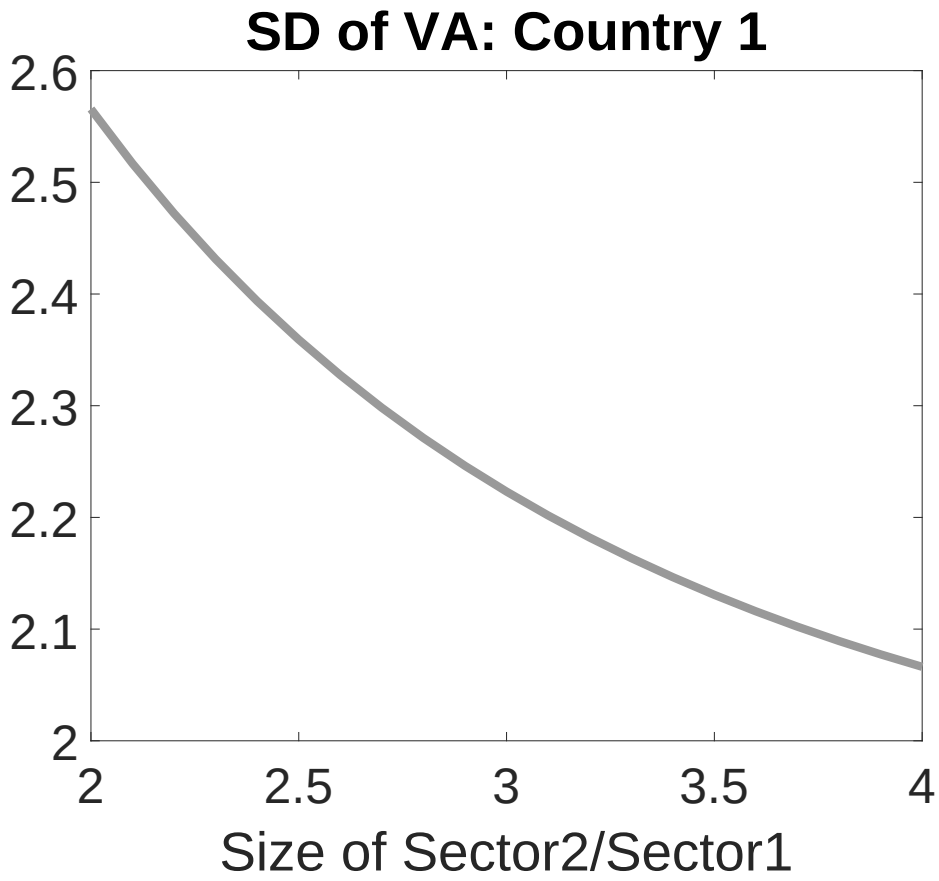


Model Mechanism: Why Volatility Stabilized

Domestic positive productivity shock

- Supply side: domestic firms try to use more intermediate inputs
  - More openness $\Rightarrow$ need foreign intermediate inputs which is not supplied more as no change in foreign productivity $\Rightarrow$ constrain production relative to closed economy case
- Demand side: foreign households/firms try to import domestic goods
  - More openness $\Rightarrow$ more dependent on foreign demand $\Rightarrow$ foreign demand does not increase much as foreign economy is not directly impacted by productivity shock $\Rightarrow$ constrain demand for domestic goods relative to closed economy case

RELATIONSHIP BETWEEN RELATIVE SECTOR SIZE AND OUTPUT VOLATILITY



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, Netherland, 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:

Parameter	Value	
β	0.96	Discount factor
α	0.36	Labor share parameter
δ	0.1	Depreciation rate
σ	2	Inverse of IES
ν	1	Inverse of Frisch labor supply
κ	0.1	Wealth effect parameter
$\frac{\delta_u''}{\delta_u'}u$	0.05	Inverse utilization elasticity
γ_F	1	ES between sectoral goods
γ_f	1	ES between home and foreign goods
ϵ_{markup}	0.12	Elasticity of markup
s	0.1	Investment adjustment cost
ρ_A	0	Shock persistence

CALIBRATION

Calibrate productivity shock standard deviations

- Let ω be the vector of steady state parameters that include all share and size parameters in IO table
- Calibrate ω: 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

	Data	Model
Standard deviations		
Output	1.3	1.5
Consumption	1.2	1.0
Investment	3.8	3.3
Manufacturing real value added	2.7	2.7
Non-manufacturing real value added	1.4	1.4
Autocorrelation		
Output	0.32	0.26
Consumption	0.35	0.23
Investment	0.39	0.47
Manufacturing real value added	0.25	0.12
Non-manufacturing real value added	0.32	0.3

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

		CA s1	CA s2	US s1	US s2	CA final	US final	GO
CA	s1	M_{11}	M_{12}	M_{13}	M_{14}	F_{11}	F_{12}	Q_1
CA	s2	M_{21}	M_{22}	M_{23}	M_{24}	F_{21}	F_{22}	Q_2
US	s1	M_{31}	M_{32}	M_{33}	M_{34}	F_{31}	F_{32}	Q_3
US	s2	M_{41}	M_{42}	M_{43}	M_{44}	F_{41}	F_{42}	Q_4
VA		V_1	V_2	V_3	V_4			
GO		Q_1	Q_2	Q_3	Q_4			

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 $\omega(year)$ to be the steady state for each year
- Calibrate $\omega(year)$ 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 $\widetilde{WIOT}$ at each year T
  - Use information in both T and $T-1$
  - In $\widetilde{WIOT}$, *only* international dimension changes based on WIOT at T
- Calibrate $\omega(year)$ using $\widetilde{WIOT}$ and solve model
  - Actual WIOT 1990 $\rightarrow \omega(1990) \rightarrow \sigma^{Y}_{1990}$
  - Hypothetical $\widetilde{WIOT}$ 1991 $\rightarrow \omega(1991) \rightarrow \widetilde{\sigma}^{Y}_{1991}$
  - $\widetilde{\sigma}^{Y}_{1991} - \sigma^{Y}_{1990}$ is the effect of international linkage changes between 1990 and 1991
- Accumulate the effects over time

EXPERIMENT 2: INTERNATIONAL LINKAGES

Construction of $\widetilde{WIOT}$

		CA s1	CA s2	US s1	US s2	CA final	US final	GO
CA	s1	m_{11}	m_{12}	m_{13}	m_{14}	f_{11}	f_{12}	Q_1
CA	s2	m_{21}	m_{22}	m_{23}	m_{24}	f_{21}	f_{22}	Q_2
US	s1	m_{31}	m_{32}	m_{33}	m_{34}	f_{31}	f_{32}	Q_3
US	s2	m_{41}	m_{42}	m_{43}	m_{44}	f_{41}	f_{42}	Q_4
VA		v_1	v_2	v_3	v_4			
GO		Q_1	Q_2	Q_3	Q_4			

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

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

- Accumulate the effects over time

EXPERIMENT 3: RELATIVE SECTORAL SIZE

Construction of $\widetilde{WIOT}$

		CA s1	CA s2	US s1	US s2	CA final	US final	GO
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VA		v_1	v_2	v_3	v_4			
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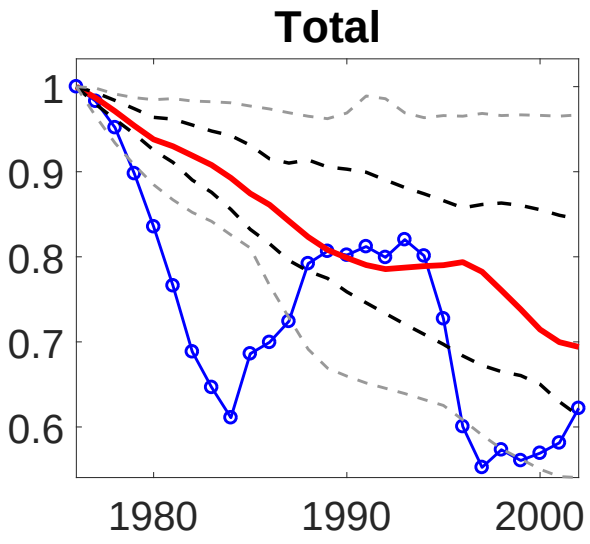
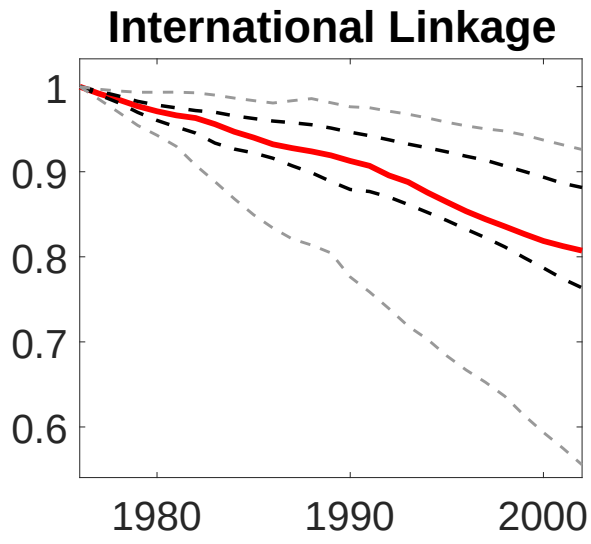
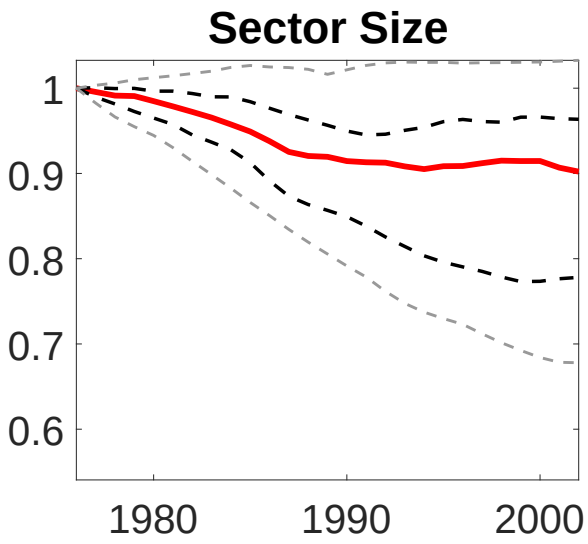
where technical coefficients $m_{ij} = \frac{M_{ij}}{Q_j}$ and $f_{ij} = \frac{F_{ij}}{Q_i}$ and $v_i = \frac{V_i}{Q_i}$

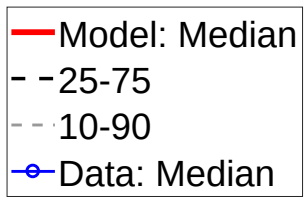
- Change Q_1 / Q_2
- Calculate $F = GO - M$, keep f_{11} / f_{21}

World IO changes & Changing Volatilities



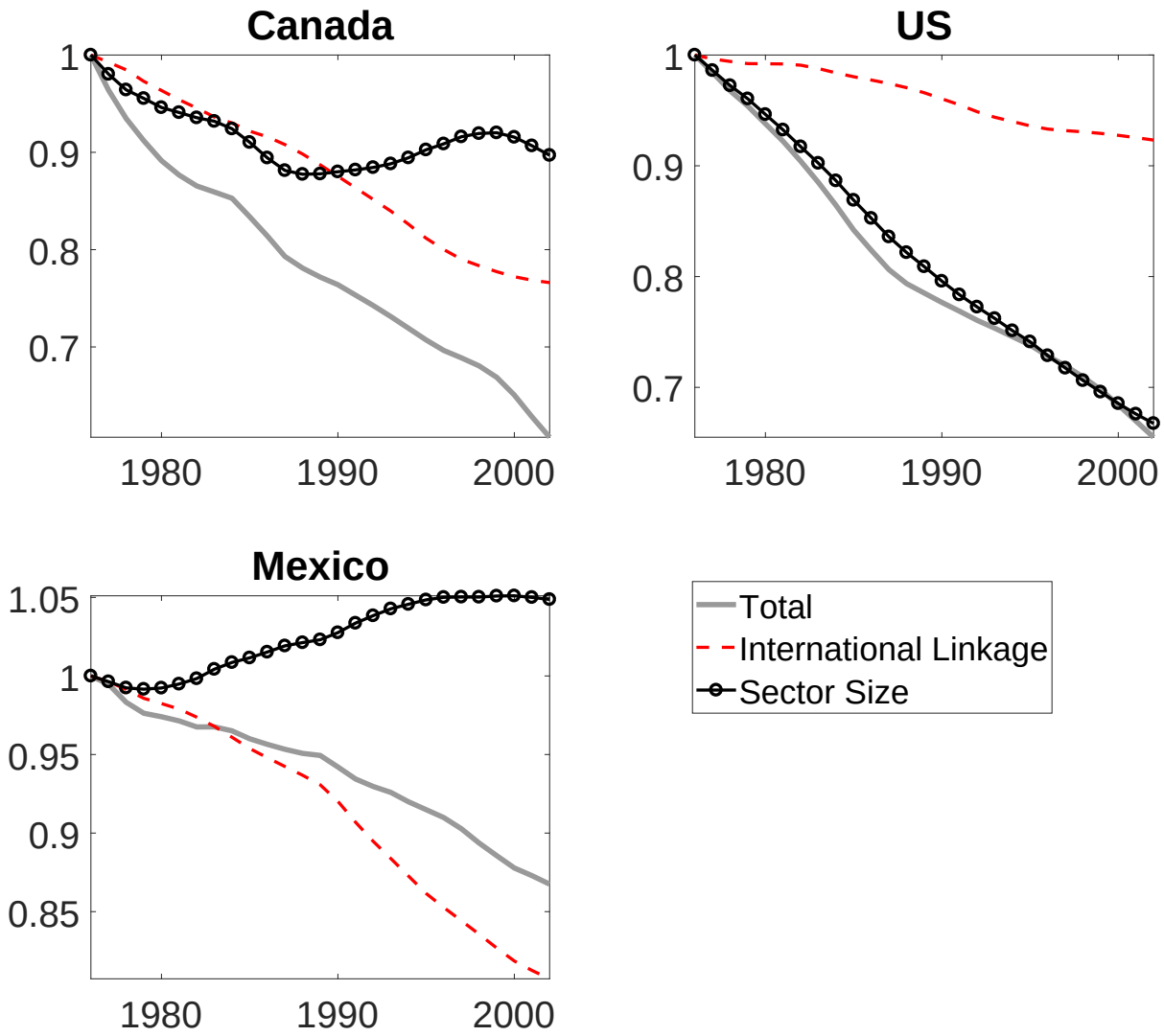




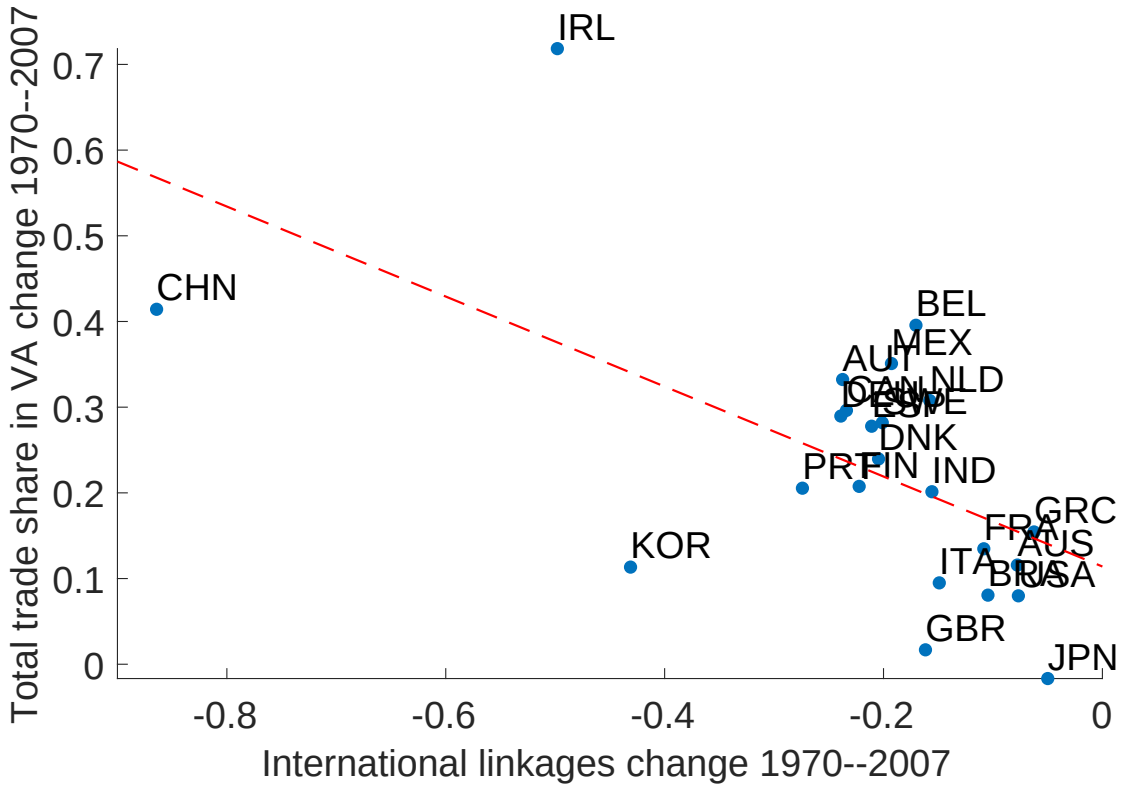


World IO changes & Changing Output Volatilities: Heterogeneity

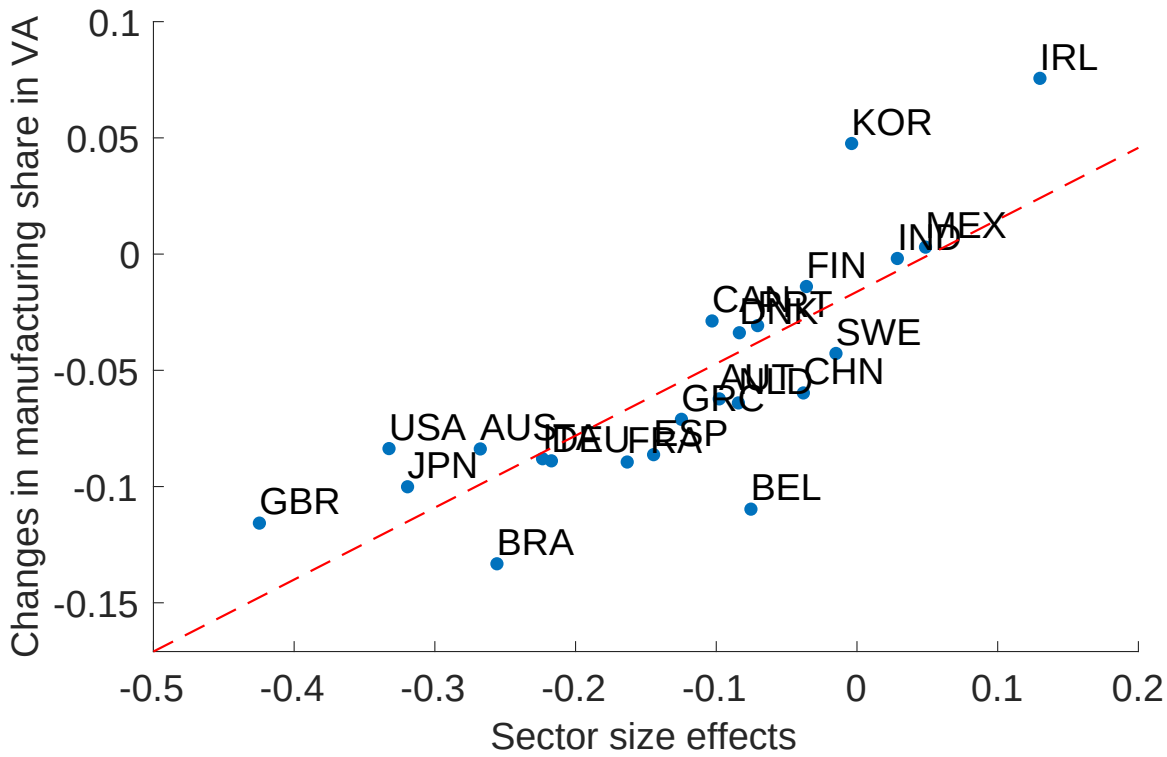
All countries | Relative Sizes



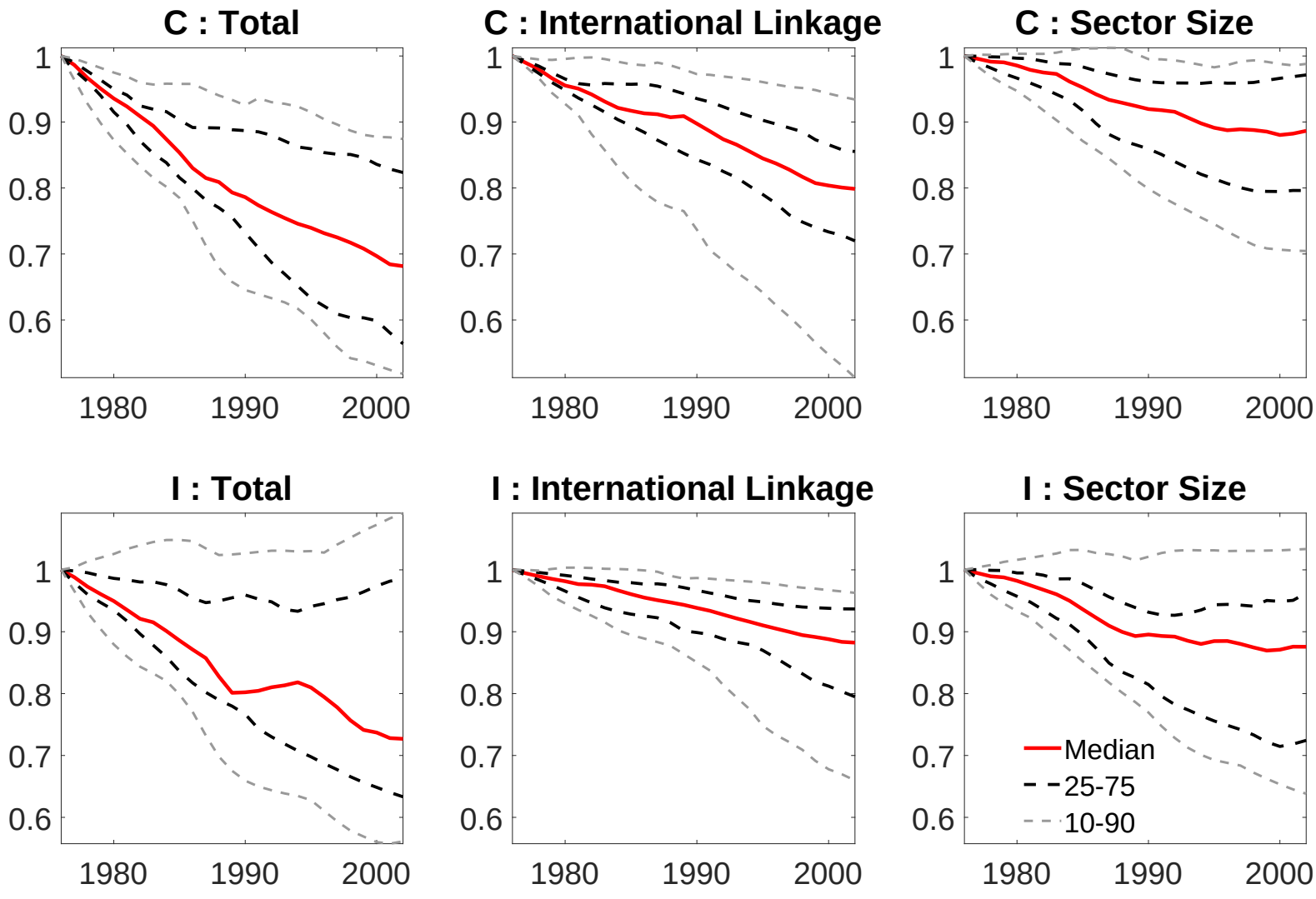
International Linkage Changes' Effects on Volatility



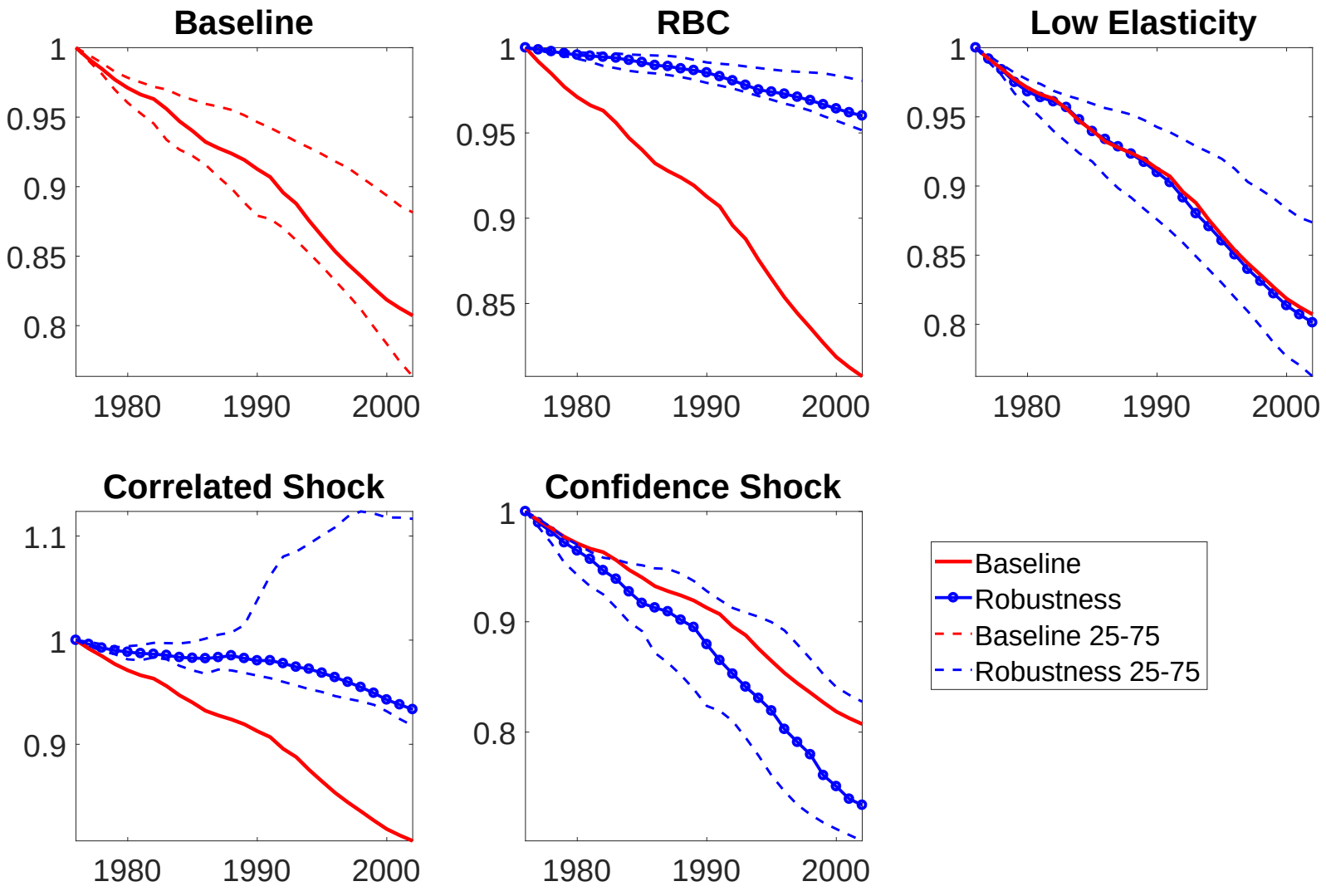
Relative Sector Size Changes' Effects on Volatility



Other Variables



Inspecting Mechanism



Potential Risk: Cross-Country Value Added Multipliers

- 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

Potential Risk: Cross-Country Value Added Multipliers

- Define Cross-country value added multipliers

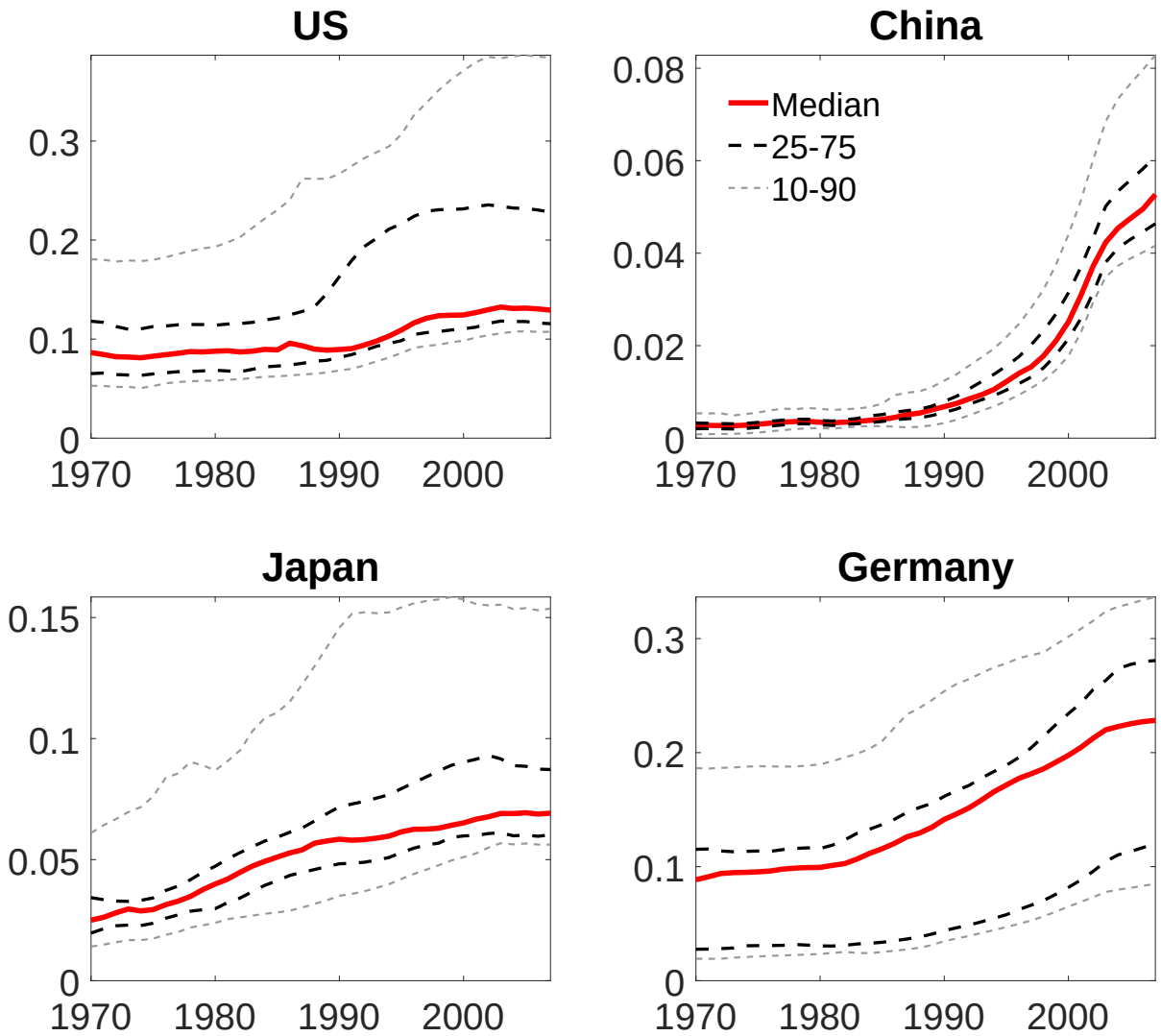
$$M_{US}^{H} = \frac{\sum_{h=1}^{H} \frac{\partial VA_{X,h}}{\partial A_{US,1}}}{\sum_{h=1}^{H} \frac{\partial VA_{US,h}}{\partial A_{US,1}}} \tag{1}$$

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

$\omega(year)$ based on entire World IO Table change



Conclusion

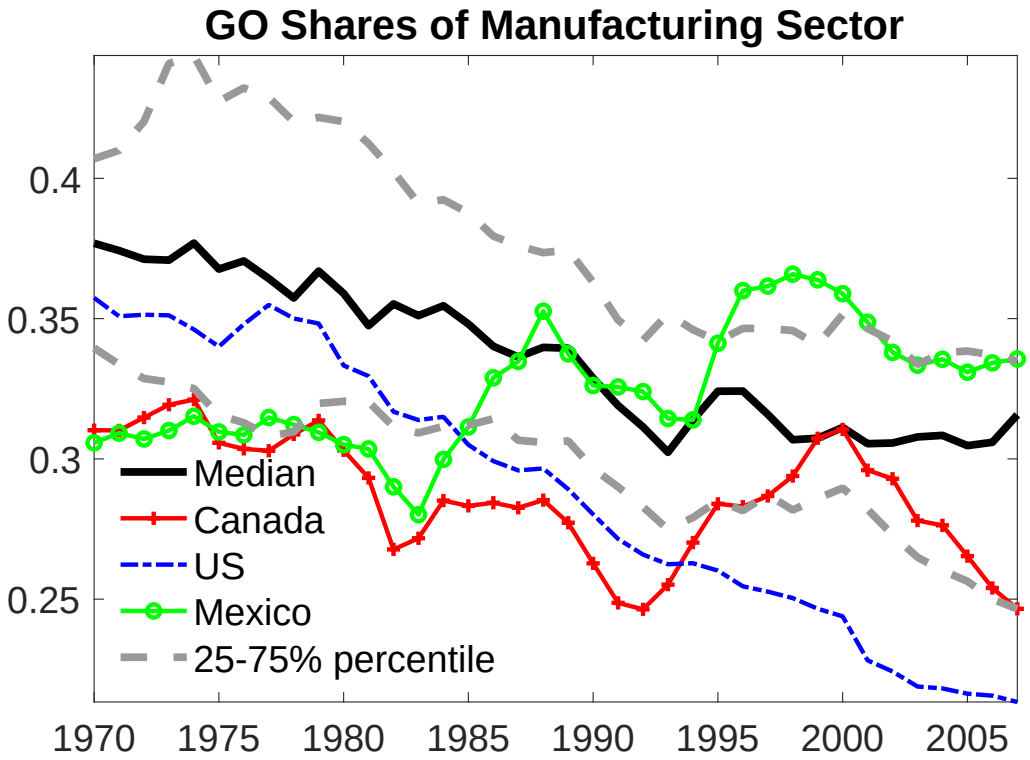
- Our model implies that international linkages explain a sizable change in aggregate volatilities
  - Magnitude depends on the mechanism and transmission channels

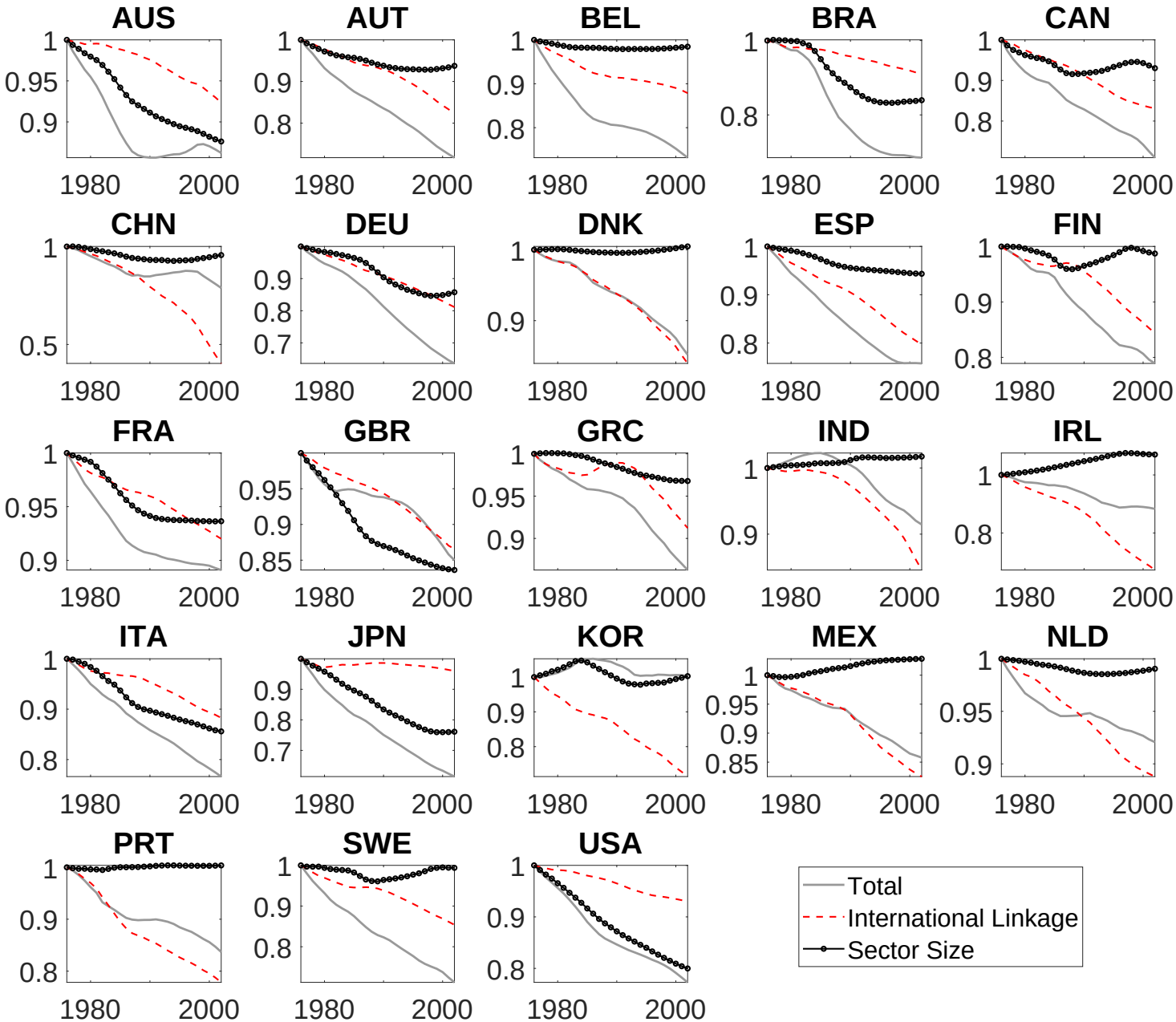
- Increase in potential risk of global recession

EXTRA SLIDES

Relative Sector Sizes

Back

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