International Linkages and the Changing Nature of International Business Cycles*

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Abstract

We quantify the effects of changes in international input-output linkages on the nature of business cycles. We build a multi-sector multi-country international business cycle model that matches the input-output structure within and across countries. We find that, in our 23 countries sample with manufacturing and non-manufacturing sectors, changes in the input-output linkages within and across borders between 1970 and 2007 causes a 21% drop in output volatility in a median country and a small increase in cross-country output correlations. Our decomposition attributes about 11% of the drop in output volatility to changes in international input-output linkages.

JEL classification: E32, F31.

Keywords: International business cycles, trade comovement, countercyclical markup, weak wealth effects, trade linkages.

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1 Introduction

Understanding the sources of business cycle volatilities and comovements is an important topic in macroeconomics. This paper explores the hypothesis that international linkages have an effect on business cycles. In particular, we quantify the effects of the changing international input-output linkages, including trade intensity and trade partners, on aggregate volatilities of output, consumption, investment, as well as the cross-country correlations between 1970 and 2007. To that end, we build a multi-country multi-sector real business cycle model, which extends the standard Backus, Kehoe, and Kydland (1992), to account for the sector-to-sector input-output linkages within and across countries. Furthermore, since standard international business cycle models have a hard time generating endogenous comovements across countries through international trade, which limit the extent to which international input-output linkages can affect business cycle properties, we augment the model with several features to help the model to generate substantial endogenous transmission of shocks across countries through international trade. These features include weak wealth effects in labor supply, variable capacity utilization, and endogenous countercyclical markup through firms' entry and exit. Each country is driven by independent sector-specific productivity shocks. The model is calibrated to the data for manufacturing and non-manufacturing sectors in 23 countries and a composite of the rest of the world (ROW) between 1970 and 2007. Using the World Input-Output (IO) table for these countries, we can match the model's structure completely with both the domestic and international input-output structure. We then evaluate how much aggregate volatilities and cross-country correlations can be attributed to the changes in the international input-output linkages through out the last 40 years.

The international input-output linkages can both increase and decrease output volatilities. Consider a pair of countries such as the United States and Canada. When there is a positive U.S. productivity shock, U.S. goods become more abundant, so the Canadian terms of trade appreciate. Canadian households become richer, but in our calibration with low wealth elasticity of labor supply, they do not decrease their labor supply. With higher demand for Canadian goods from the United States, more firms enter the market, increasing competition. As a result, markup declines, and firms increase their labor demand. Variable capital utilization further amplifies this increase in labor demand. In equilibrium, output in Canada also increases after a positive U.S. productivity shock.[1] In our model, foreign (U.S.) shocks can be an important source driving output fluctuations

[1] This mechanism is much weaker in a standard IRBC model, as discussed briefly in the paper.

in Canada. The more Canada trades with the United States, the more important U.S. shocks are in driving Canadian output fluctuations. This implies that on the one hand, more international linkages help Canada to diversify its own country-specific shocks. On the other hand, Canada is also hit by foreign shocks. Depending on the relative volatilities of foreign shocks and domestic shocks, the changes in the international input-output linkages may or may not reduce output fluctuations.

Since our model is matched with the entire world input-output structure, other changes such as the relative sector sizes, domestic input-output linkages, and country sizes can also affect output volatilities over time. For example, since the manufacturing sector tends to be more volatile than the non-manufacturing sector, if the size of the non-manufacturing sector relative to that of the manufacturing sector becomes larger, the standard deviation of aggregate output naturally falls, even without any changes in international linkages. When domestic input-output linkages change, such as an increase in both intermediate and final use of domestic goods, comovements between sectors within the country can increase, which can affect aggregate fluctuations. Relative country size changes can also affect output volatilities. Consider China, whose value added increases from less than 5% of total world value added in the 1970s to over 15% in the early 2000s. As China grows bigger, with the same international linkages, it can affect other countries' business cycles more substantially, leading to changes in aggregate volatilities. As all of these different channels can affect volatilities and comovements across countries, we compare the importance of these different channels with that of the international input-output linkages.

We find that changes in the entire input-output linkages both across and within countries from the 1970s to 2007 can lead to a 21% reduction in output volatilities in a median country in our sample, keeping the volatilities of the shocks constant. The reduction in consumption and investment volatilities are similar, about 21-25% in a median country. We then decompose the total effects of the entire input-output linkages into different channels. The international input-output linkages tend to reduce output volatilities by about 11% in a median country in our sample, and the relative sector size changes decreases output volatilities in a median country by a similar magnitude. The effects of the changes in relative country sizes turn out to be negligible.

The effects of changing international input-output linkages are heterogeneous across countries. While international input-output linkages decrease output volatilities about 20% in Canada between 1970 and 2007, it reduces a negligible fraction of output volatilities for the United States (less than 5%) and Italy, and even increases output volatilities in Korea. In countries such as the United States, the reduction in output volatilities over the last 40 years, or the Great Moderation, is

attributed to the changes in the relative sector sizes, rather than the international input-output linkage channel.

We note that our result does not speak to the impact of international trade such as trade costs on business cycles. In fact, the international input-output linkages in our model are changes in international trade shares in intermediate and final goods. We do not explicitly model why these trade shares change, which can be driven by several factors such as trade costs, trade policies, preferences, and demand composition. Instead, we take these changes as given, and study the the dynamics of these changes on business cycles across countries. Similarly, changes in relative sector sizes can also be explained by a number of reasons including trade costs, structural changes, and relative productivity changes. Therefore, we do not interpret that the sum of the effects of international input-output linkages and relative sector sizes on aggregate volatilities as the impact of international trade cost changes, or other fundamental reasons.

Related literature Our paper contributes to the literature studying the causes of decline in volatilities in the United States and some other countries, so called the Great Moderation, a term coined by Stock and Watson (2003). For example, Clarida, Gali, and Gertler (2000) propose better monetary policies, Justiniano and Primiceri (2008) estimate that investment-specific technology shocks explain the sharp decline in output volatilities. Jaimovich and Siu (2009) attribute part of the movement in output volatility in G7 countries to the changes in the composition of the labor force. Moro (2012) and Carvalho and Gabaix (2013) show that changes in manufacturing sector in the United States can explain the decline in output volatilities. Garin, Pries, and Sims (2017) study the relative importance of aggregate and sectoral shocks. Unlike these papers, we explore the international input-output linkage channel as a determinant of aggregate volatilities, which turns out to be substantial in many countries but not in the United States. We view our channel as complementary to other mechanisms in the literature. We also cover a larger number of countries and explore the heterogeneity effects of international input-output linkage as well as the relative sector size changes on aggregate volatilities.

Our paper relates to the literature exploring the effects of trade openness and volatilities which has mixed results. While Haddad et al. (2013) and others find that trade openness decreases volatilities, others such as Kose, Prasad, and Terrones (2003) find the opposite. Di Giovanni and Levchenko (2009) estimate that trade openness results in an increase in volatilities through sectoral volatilities with a reduction in volatilities due to comovement using an unbalanced panel data of 28

manufacturing sectors for 61 countries between 1963 and 2003. While reduced-form estimates can explore the larger panel of sectors and countries, it does not address the heterogeneous effects of trade on volatilities across countries. Furthermore, the endogeneity issue is not completely resolved in reduced-form estimates, and the total effects of trade openness on aggregate volatilities are based on specific assumptions such as no spillover across sectors within the country. We, on the other hand, use a structural model to quantify the importance of input-output linkages in driving volatilities across a number of countries, taking into account the fact that their international and domestic structures differ. The closest paper to ours is Caselli et al. (2014), who use a structural trade model and find that reduced trade costs since 1970s increase volatilities for some countries but decrease volatilities for some other countries in their sample. While their structural model is a static trade model to capture trade patterns across countries, our model is a fully dynamic business cycle model with capital accumulation and labor choices, taking into account endogenous transmission of shocks across countries, which is suitable to study business cycle properties. The endogenous transmission mechanism in our model allows for international linkages to play an important role in driving business cycles across countries. Furthermore, we can use our model to analyze the relative importance of international input-output linkage changes and sector sizes in driving business cycles, which cannot be spoken to in their model.

We are also related to the literature studying why international business cycle models fail to generate substantial comovement across countries, dubbing "trade-comovement" puzzle by Kose and Yi (2006). A recent paper by Johnson (2013) shows that the intermediate input trade, built into an international real business cycle model, does not resolve the puzzle. Since our baseline model, built on Miyamoto and Nguyen (2017), includes additional features such as variable capacity utilization and countercyclical markup, the model can generate more output correlations across countries for each bilateral country pairs.

The rest of the paper is organized as follows. Section 2 documents some features of the input-output linkages and business cycles in 23 countries between 1970 and 2007. We then describes the model used to quantify the role of international linkages in the changing nature of business cycles in Section 3. The calibration of the model is in Section 5. We analyze how international and domestic input-output linkages can affect the behavior of the aggregate economy in Section 4. The main results of the paper are presented in Section 6. We present the robustness of our results in Section 7. Section 8 concludes.

2 Data

Our data cover 23 countries and a composite ROW between 1970 and 2007. These countries are Australia, Austria, Belgium, Brazil, Canada, China, Germany, Denmark, Spain, Finland, France, UK, Greece, India, Ireland, Italy, Japan, Korea, Mexico, Netherland, Portugal, Sweden, and the United States. The national account data and the sectoral value added data for manufacturing and non-manufacturing sectors are in annual frequency from the United Nation database, while the World IO table between 1970 and 2009 are from Johnson and Noguera (2017).[2] We supplement the annual national account data by quarterly data from the OECD.

Business cycles have changed substantially in many countries over the 1970–2007 period, but the change is heterogenous across countries. We plot in Figure 1 the median 10-year rolling over standard deviations of HP-filtered output, consumption and investment in 22 countries in our samples between 1970Q1 and 2007Q4.[3] The graphs are similar if we use annual data instead. Aggregate volatilities tend to decrease over the time period. Output volatility is about 45% less volatile in the early 2000s relative to the early 1970s in the median country. Figure 1 also plots the median 10-year rolling over cross-country correlations of HP-filtered output, consumption and investment in the same sample of countries and period. The cross-country correlations declined in the 1970s, but stayed stable up until the 1990s. Nevertheless, the increase in correlations across countries beginning in the 1990s is modest.

The changes in business cycle properties are heterogeneous across countries. While for countries like the United States and Canada, output volatilities have declined up to 40% between 1970 and 2007, business cycles in Korea or Mexico do not have a clear trend: they go through both high and low volatility periods in the same time frame. Similarly, the changes in cross-country correlations are also heterogeneous. There are some tendency that countries are more correlated after 1990s, but while the increase is more substantial (from 0.05 to 0.25) for Mexico, the increase is smaller (from 0.1 to 0.2, on average) for Korea and Canada.

The input-output linkages within and across countries have also changed substantially, and heterogeneously across countries between 1970 and 2007. For example, the use of imported intermediate inputs has increased from 10% of the value added of the manufacturing sector in the United States in 1970 to over 35% in 2007. Furthermore, the importance of each sector in the economy

[2]The World Inout Output Database (WIOD) has more sectors and countries but they go back to 1995 only, and its two versions 1995–2011 and 2000–2014 are not compatible with each other.

[3]We do not have long enough quarterly data for China, so there are 22 countries. The plot is similar if we use the growth rates of output, consumption and investment.

changes over time. In many countries including the United States, the manufacturing sector as a share of total value added has declined from 24% to 14%, but this share has stayed around 20% for Mexico, and increased in Korea to 30%. In other words, these changes in the input-output linkages can potentially explain some of the heterogeneous changes in business cycles over time.

3 The Model

This section describes the model used to quantify the effects of international linkages on the changing nature of business cycles across countries. The model is an extension of Backus, Kehoe, and Kydland (1995) with several additional features. First, the model is multi-country and multi-sector, where countries trade with one another in both intermediate and final goods in each sector. This feature is to capture the input-output linkages within and across countries in the data. Second, we augment the model with variable capacity utilization, and endogenous countercyclical markup caused by firms' entry and exit. As suggested in Miyamoto and Nguyen (2017), these departures from a standard IRBC model allow the model to generate endogenous transmission of productivity shocks across countries through international linkages. We model the firms' entry and exit problem, similar to Jaimovich and Floetotto (2008), which generates endogenous variations in the number of operating firms, and consequently, markup over the business cycle. Finally, the model also includes an investment adjustment costs to avoid the strong resource shifting mechanism in the model after a foreign shock, which can cause domestic investment to fall.

There are N countries, indexed by i. We describe the setup for country i below.

3.1 Households

Households in country i, subject to a budget constraint, maximize their lifetime expected utility:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t(i), H_t(i)) \tag{1}$$

where $C_t(i)$ and $H_t(i)$ denote consumption and hours worked in country i at time t, respectively.

Households face a period by period budget constraint, as follows:

$$C_t(i) + I_t(i) + \varepsilon_t(i) E_t r_{t,t+1} B_{t+1}(i) = W_t(i) H_t(i) + R_t^k(i) K_t(i) + \varepsilon_t(i) B_t(i) - a(u_t(i)) K_t(i) \tag{2}$$

where $I_t(i)$ is the investment of country i at time t, $B_{t+1}(i)$ is the bond holding of country i,

$r_{t,t+1}$ is the interest rate that country i needs to pay, and ε_t is the real exchange rate, $K_t(i)$ is capital available at time t, $W_t(i)$ and $R_t^k(i)$ are the wage and rental rate of capital, $u_t(i)$ is the variable capital utilization rate, and $a(u_t(i))$ is the cost associated with variable capital utilization, respectively. The evolution of capital follows a standard form as follows:

$$K_{t+1}(i) = (1-\delta) K_t(i) + I_t(i) \left(1 - S\left(\frac{I_t(i)}{I_{t-1}(i)}\right)\right), \tag{3}$$

where δ is the depreciation rate, and $S(.)$ is the investment adjustment cost.

3.2 Firms

There are S sectors in each country i, each indexed by s. Each firm in country i sector s produces a tradable differentiated using capital, labor and a composite intermediate good, which is an aggregate of intermediate goods produced by other countries and sectors. The local industry in each sector s of country i has a limited number of firms, and aggregates individual firms' output into raw output $Q(i,s)$. The raw output $Q(i,s)$ is then aggregated across countries and sectors to produce final consumption, investment and intermediate goods. The details of the production in the economy are described below.

The final composite goods are aggregate of sector final composite goods. Firms producing final composite goods in country i, $F(i)$, combine sectoral final composite goods to be used for consumption and investment in country i:

$$C(i) = \left[\sum_{s=1}^{S} \left(\omega_{CF}(i,s)\right)^{\frac{1}{\gamma_F}} \underbrace{\left(f_C(i,s)\right)^{\frac{\gamma_F-1}{\gamma_F}}}_{\text{sectoral final composite good}}\right]^{\frac{\gamma_F}{\gamma_F-1}} \tag{4}$$

$$I(i) = \left[\sum_{s=1}^{S} \left(\omega_{IF}(i,s)\right)^{\frac{1}{\gamma_F}} \underbrace{\left(f_I(i,s)\right)^{\frac{\gamma_F-1}{\gamma_F}}}_{\text{sectoral final composite good}}\right]^{\frac{\gamma_F}{\gamma_F-1}} \tag{5}$$

where $\omega_{CF}(i,s)$ and $\omega_{IF}(i,s)$ are the shares of sector s in the final composite consumption and investment goods, respectively, $f(i,s)$ is the sectoral final composite goods, and γ_F is the elasticity of substitution across sectoral final composite goods. Then, the demand for final sectoral composite

is given by

$$f_C(i,s) = \left(\frac{P_{Cf}(i,s)}{P(i)}\right)^{-\gamma_F} \omega_{CF}(i,s)\, C(i), \tag{6}$$

$$f_I(i,s) = \left(\frac{P_{If}(i,s)}{P_I(i)}\right)^{-\gamma_F} \omega_{IF}(i,s)\, I(i), \tag{7}$$

where $P(i)$ is the price level of country i, and $P_f(i,s)$ is price of sector s goods in country i.

Final sectoral firms combine goods of the same sector in both domestic and foreign countries to produce a sectoral final composite good as follows:

$$\underset{\text{sectoral final composite}}{f_C(i,s)} = \left[\sum_{j=1}^{I} \left(\omega_{Cf}(i,j,s)\right)^{\frac{1}{\gamma_f}} \underbrace{\left(f(i,j,s)\right)^{\frac{\gamma_f-1}{\gamma_f}}}_{\text{shipment from country } j \text{ to } i}\right]^{\frac{\gamma_f}{\gamma_f-1}}, \tag{8}$$

where $f(i,j,s)$ is the shipment of sector s goods from country j to country i, $\omega_f(i,j,s)$ is the share of $f(i,j,s)$ in sectoral final composite goods, and ω_f is the elasticity of substitution across countries in sector s. Then the demand for the shipment of sector s goods from country j to country i is given by:

$$f(i,j,s) = \left(\frac{P_f(i,j,s)}{P_f(i,s)}\right)^{-\gamma_f} \omega_f(i,j,s)\, f(i,s), \tag{9}$$

where $P_f(i,j,s)$ is price of shipment of sector s goods from country j to country i.

Following Jaimovich and Floetotto (2008), there is a continuum of local industries of measure one, which is aggregated to a raw sectoral output in each country. This assumption means that individual firms can affect prices at the local industry prices but not in the aggregate, which simplifies the model. In particular, the raw sectoral output $Q(i,s)$ is given by:

$$\underset{\text{Raw sectoral output}}{Q(i,s)} = \left[\underbrace{\int_0^1}_{\text{local sector}} L(i,s,l)^{\frac{\gamma_Q-1}{\gamma_Q}}\, dl\right]^{\frac{\gamma_Q}{\gamma_Q-1}}, \tag{10}$$

where $L(i,s,l)$ is the output of local raw industry l in country i and sector s and γ_Q is the elasticity of substitution across different local sectors. In each local industry l of sector s in country i, there are a limited number of firms $N_f(i,s,l)$, so the local output is an aggregate of each individual firm's

output $q(i,s,l|f)$ as follows:

$$\underset{\text{local output}}{L\left(i,s,l\right)} = N_f\left(i,s,l\right)^{-\frac{1}{\gamma_L-1}}\left[\sum_{\substack{k=1\\ \text{firms}}}^{N_f} q\left(i,s,l|f\right)^{\frac{\gamma_L-1}{\gamma_L}}\right]^{\frac{\gamma_L}{\gamma_L-1}}, \tag{11}$$

where γ_L is the elasticity of substitution across firms. Entry and exit of firms in the raw sector l occurs such that the zero profit condition holds in every period in each sector. These firms combine intermediate input $M(i,s,k)$ and capital, labor to make raw sectoral output with productivity $A(i,s)$ as follows:

$$q\left(i,s,l|f\right) = A\left(i,s\right)\left[\begin{array}{c}\omega_q\left(i,s\right)^{\frac{1}{\gamma_q}}\left(K\left(i,s,l|f\right)^{\alpha}H\left(i,s,l|f\right)^{1-\alpha}\right)^{\frac{\gamma_q-1}{\gamma_q}}\\ +\left(1-\omega_q\left(i,s\right)\right)^{\frac{1}{\gamma_q}}\left(M\left(i,s,l|f\right)\right)^{\frac{\gamma_q-1}{\gamma_q}}\end{array}\right]^{\frac{\gamma_q}{\gamma_q-1}} - \phi\left(i,s\right) \tag{12}$$

where $\omega_q(i,s)$ is the share of value added in the raw output production, γ_q is the elasticity of substitution between intermediate and value added goods and $\phi(i,s)$ is the fixed cost.

The intermediate input $M(.)$ is combined in two stages. First, intermediate goods, $m(i,j,s,k)$ from different origins are combined with an elasticity of substitution ω_m to an intermediate goods of country i in sector s used in firm k, $m(i,s|f)$. Therefore, $m(i,s,k)$ is given by:

$$m\left(i,s,k\right) = \left[\sum_{\substack{j=1\\ \text{country}}}^{I}\left(\omega_m\left(i,j,s,k\right)\right)^{\frac{1}{\gamma_m}}\underset{\text{from country } j \text{ sector } k \text{ to country } i \text{ sector } s}{\left(m\left(i,j,s,k\right)\right)^{\frac{\gamma_m-1}{\gamma_m}}}\right]^{\frac{\gamma_m}{\gamma_m-1}}, \tag{13}$$

where $\omega_(i,j,s,k)$ is the share of intermediate goods from sector k in country j to sector s in country i. Second, these sectoral specific intermediate goods $m(i,s,k)$ are aggregated across sector to be used in each sector in country i, $M(i,s,k)$, as follows:

$$\underset{\text{Intermediate for sector } s \text{ in country } i}{M\left(i,s,k\right)} = \left[\sum_{\substack{k=1\\ \text{sector}}}^{S}\left(\omega_M\left(i,s,k\right)\right)^{\frac{1}{\gamma_M}}\left(m\left(i,s,k\right)\right)^{\frac{\gamma_M-1}{\gamma_M}}\right]^{\frac{\gamma_M}{\gamma_M-1}}, \tag{14}$$

where γ_M is the elasticity of substitution across different sectors and $\omega_M(i,s,k)$ is the share of the sectoral intermediate goods.

3.3 Resource Constraints and Definitions

Finally, the resource constraint in each country dictates that the output in sector s in each country i has to satisfy the following conditions:

$$\underset{\text{Raw sectoral output}}{n(i)\,Q(i,s)} = \underset{\text{for all country destination}}{\sum_{j}} \underset{\text{for sectoral composite}}{n(j)\,f(j,i,s)} + \sum_{j}\sum_{k} \underset{\text{for intermediate use}}{n(j)\,m(j,i,k,s)} \tag{15}$$

and

$$\sum_{i} n(i) B_{t+1}(i) = 0, \tag{16}$$

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

Since the model includes gross output $Q(i,s)$, we define real value added output as follows. In each sector in each country, the real value added output is equal to gross output subtracting intermediate input usage evaluated at the steady state prices, i.e.:

$$RVA(i,s) = P_{Q,ss}(i,s)\,Q(i,s) - P_{M,ss}(i,s)\,M(i,s) \tag{17}$$

The aggregate value added output in each country is the weighted sum of sectoral real value added subtracting utilization cost. Throughout the paper, we use output or VA to denote real value added output, and GO for gross output.

3.4 Productivity Process

We close the model with the description of the productivity processes. The only source of uncertainty in the model is the productivity in each sector in each country, which follows an AR(1) process with persistence $\rho(i,s)$:

$$A_t(i,s) = \rho(i,s)\,A_{t-1}(i,s) + \varepsilon_t(i,s), \tag{18}$$

where $\varepsilon(i,s)$ has a standard deviation $\sigma(i,s)$, mean 0. In the baseline model, we have no cross-country productivity correlations, or sectoral productivity correlaions.

4 Model Predictions

Before quantitatively assessing the role of changing international input-output linkages on business cycles, we discuss the mechanism in the model through which changes in input-output linkages can affect aggregate volatilities and comovement across countries in this section. To that end, we consider a two-country two-sector version of the model: the size of country 1 is $1/10^{th}$ of country 2, similar to the relative size of Canada and the United States. The two sectors correspond to the manufacturing (sector 1) and non-manufacturing sectors (sector 2). The differences between sector 1 and sector 2 are as follows: First, sector 1 is more open as its import share is larger. Second, the final demand for investment in sector 1 is 0.72, while it is around 0.75 in sector 2.[4] Third, productivity shocks in sector 1 are more volatile than in sector 2. The persistence of the productivity shocks in both sectors in both country 1 and country 2 is 0. The following analyses assume that the shocks are independent across countries and sectors.

We first show that international input-output linkages transmit shocks across countries in the model. Figure 2 plots the impulse responses of both country 1 and 2 to a positive productivity shock in sector 1 of country 2. Country 2 goes through a boom: output, consumption and investment increase substantially. The increase in output in sector 1 in country 2 is larger than sector 2 in the same country. The reason is that while sector 1 enjoys an increase in productivity, sector 2 only increases its output due to the transmission within the model: an increase in production in sector 1 leads to higher demand for sector 2's goods, which in turn generates more hours worked in sector 2, causing its output to increase. Since productivity does not change in country 1, its value added output only increases because hours and capital utilization increase in the short run. Intuitively, as productivity increases output in country 2, goods in country 2 become more abundant, causing the terms of trade for country 1 to appreciate. Since domestic goods become more valuable in country 1, more firms enter into the economy, so markups decline. Together with a higher capital utilization, firms in country 1 increases their labor demand substantially. With our calibration of the wealth effects on labor supply, households in country 1 do not decrease their labor supply while increasing consumption. In equilibrium, hours in country 1 increases, so output in country 1 comove strongly with country 2, as shown in Figure 2. Consumption increases in country 1 due to risk sharing: with the terms of trade appreciation, households are richer and can enjoy higher consumption. Similarly, investment increases in our model due to an increase in hours worked, i.e.

[4] These shares are close to the average shares in the data.

with our features, the incentives to shift investment to a more productive country are not large compared to the standard Backus, Kehoe, and Kydland (1995) model. In the Appendix Figure A1, we show that the response of country 1's output is much weaker in the plain vanilla RBC model and the models without our features.

The analyses above imply that due to international input-output linkages transmit, output fluctuations in each country are driven not only by domestic shocks, but also by foreign shocks. Therefore, changes in international input-output linkages can affect both output volatility and cross-country correlation in country 1. We plot in Figure 3a the standard deviation of output in country 1 as we vary the shares of import and export in output for sector 1. There are two important channels driving output volatility. First, as country 1 trades more with country 2, it can diversify its own domestic shocks, so the standard deviation of output falls. Second, the contribution of foreign shocks on country 1's output increases as more international linkages increase the transmission of country 2's shocks. Depending on the volatility of foreign shocks relative to that of domestic shocks, output in country 1 may fluctuate more due to the increased important of foreign shocks, which country 1 cannot diversify. In this exercise where country 1 only trade with country 2 and both countries have the same shock volatilities, as country 1 trades more with country 2, the first channel, diversification, dominates initially, and the standard deviation of output in country 1 falls. However, when its import and export shares are large, foreign shocks become important and the second channel dominates, driving up its output volatility. More generally, if foreign shocks are more volatile than domestic shocks, output can fluctuate even more than when there is no trade linkage between the two country. On the other hand, if foreign shocks are less volatile than domestic shocks, or there are many trading partners with uncorrelated shocks across trade partners, the diversification can be more important, driving down domestic output fluctuations. This example demonstrates that international input-output linkages do not always lower output volatilities. Rather, its effects on output volatilities depend on how important foreign shocks relative to domestic shocks, as well as the relative volatilities of the shock processes, the number of trading partners and the entire network. So the question on the effects of international input-output linkages is quantitative. We, therefore, calibrate the model using the World IO table and business cycle moments later to investigate this question.

Since international input-output linkages transmit shocks across countries, output correlation between country 1 and country 2 increases as there are more linkages, as plotted in Figure 3b. Intuitively, the more country 1 trades with country 2, the more foreign shocks are as the sources

of fluctuations in country 1. As a result, country 1 comove more strongly with country 2.

We note that the analyses above assume that shocks are uncorrelated across countries. If the shocks are exogenously correlated, regardless of openness or linkages, their outputs are correlated. Furthermore, exogenous correlation of shocks can reduce the diversification channel when countries are more open and interconnected. Therefore, a model with only exogenous correlations of shocks may potentially render different results from a model with endogenous transmission of shocks across countries. We explore how exogenous correlations of shocks assumption in the model changes our results in the robustness check.

Another source of variations over time in the World IO table is the relative sector sizes, which have been found in previous literature such as Carvalho and Gabaix (2013) to be important in explaining output volatility over time. We, therefore, analyze how changes in relative sector sizes may contribute to changes in aggregate volatilities and comovements in the context of our model.[5] To gain intuition, we vary the relative sizes of sector 1 and sector 2 in both countries in the two-country model. Figure 4a shows that as sector 2 becomes larger relative to sector 1, the standard deviation of output in country 1 becomes smaller. Intuitively, output in country 1 includes outputs in both sector 1 and sector 2. When sector 1 becomes relatively less important in the economy, its contribution to output falls, so output becomes less volatile. Therefore, as in Figure 4a, the decline in the size of sector 1 relative to sector 2 monotonically decreases the standard deviation of output.

In Figure 4b, the decrease in the importance of sector 1 relative to sector 2 causes the cross-country correlations of output to decline. The reason for this decline is that since the international linkages in sector 1 are more intensive than those in sector 2, sector 1's declining role in the economy reduces the transmission of shocks across countries, making the cross-country correlations smaller.

We next quantify the effects of input-output linkages on output volatility and comovements in 23 countries during the last 40 years.

5 Model Parameterization

This section describes the calibration strategy for our model. Given the data availability in our World IO table, we calibrate our model to the manufacturing and non-manufacturing sectors in 23 countries and the ROW between 1970 and 2007. We first discuss how we set parameters that are common across countries. We then explain how we set individual country's shock processes.

[5]Note that when the relative sizes of sector 1 to sector 2 decrease, holding all else constant, including the shares of imported intermediate and final goods, country 1 is less open in the aggregate.

Common parameters Table 1 summarizes the calibrated values for common parameters across countries in our baseline. The model is calibrated for annual data. The discount factor is set to be 0.96, so the implied steady state annual interest rate is about 4%. As standard in the literature, we set the labor share parameter, α, to be 0.36. The depreciation rate at the steady state is 10% a year. The parameter related to the inverse of the intertemporal elasticity of substitution, σ, is set to be 2, which is along the line of Backus, Kehoe, and Kydland (1995) and others in the international business cycle literature. The parameter related to the inverse of Frisch labor supply, ν, is set to be 1, following previous papers such as Kimball and Shapiro (2008) and Bilbiie (2009). There is a lack of consensus on the wealth elasticity of labor supply, so we set it to be 0.1, which is in the lower range in the literature.[6] We also check the robustness of the results with respect to the wealth elasticity.

There is a wide range of estimates for the elasticities of substitution across sectors and countries: the international macroeconomic literature estimates of the elasticity of substitution across countries are typically small, less than 2, e.g. Backus, Kehoe, and Kydland (1995) setting this parameter to be 1.5, while the estimates in the trade literature range from 6 to 15. In the baseline, we set the elasticities of substitution across both final and intermediate goods in different sectors and countries to be 1, i.e. $\gamma_C = \gamma_I = \gamma_f = \gamma_F = \gamma_Q = \gamma_M = \gamma_m = 1$.[7]. This implies that the composite intermediate input is Cobb-Douglas in inputs from different countries. We also set γ_q, the elasticity of substitution between value added and intermediate goods, to be 1, so the production function is Cobb-Douglas in value added and the composite intermediate input. Since these elasticities of substitution can be important for the strength of the transmission mechanism of shocks across countries, we consider other values in the robustness check.

The elasticity of substitution across firms in the raw sector, γ_L is set to be 20 and steady state markup to be 1.2 to generate the elasticity of markup about 0.12 as used in Jaimovich and Floetotto (2008). This value guarantees that the number of firms within a sector is larger than 0. Following Jaimovich and Rebelo (2009), we set the inverse of capital utilization elasticity, $\frac{\delta_u''}{\delta_u'}u$, to be 0.15. The investment adjustment cost is set to target the median relative standard deviation of investment to that of output and the autocorrelation of investment in the data between 1970 and 2007. Since the utilization elasticity, investment adjustment cost, and markup parameters can be

[6] The Greenwood, Hercowitz, and Huffman (1988) preferences correspond to the wealth elasticity of labor supply to be 0, and the standard KPR preferences corresponds to 1.

[7] Johnson (2013) also set the baseline elasticities across intermediate goods to be 1, though he chooses the elasticities across final goods to be 2.

important for the endogenous transmission mechanism of productivity shocks across countries, we examine how our results change when these parameters change in the robustness check.

Productivity process We calibrate the shock processes for each country as follows. We assume that productivity shocks are uncorrelated across countries, so that all the comovements across countries are driven by our endogenous mechanism. In order to calibrate the productivity processes, we have to set the steady state input-output shares in the model, i.e. ω's using the World IO table averaged between 1984 and 1993. The idea is that we use the midpoint of the sample, and average over 10 years to eliminate the effects of business cycles on shares. We also calibrate country and sector sizes, n_i, and the shares of intermediate and value added in gross output to match the relative gross sector output sizes across countries completely in the same time frame. Since the World IO table does not have information on the shares of both manufacturing and non-manufacturing goods used in consumption and investment separately, we set these shares to equal the average between 1995 and 2007 reported in the World Input Output Database. We then set the productivity shock persistence for both manufacturing and non-manufacturing sectors to match the median autocorrelations of output in each country. It turns out that the shock persistence is close to zero, so we set them to be 0 in both sectors, which is similar to Johnson (2013). To calibrate the standard deviations of the shocks, we target the model-implied standard deviations to be the same as the standard deviations of the value added output between 1970 and 2007 for each sector in each country.[8]

6 The Effects of Changing Input-Output Linkages on Aggregate Volatilities and Comovements

In this section, we quantify the effects of changes in the international input-output linkages on the low frequency movements in volatilities and correlations across countries. We first assess the total effects of work input-output linkages *both* across and within borders. We then decompose the total effects into the effects of international input-output linkages and compare it with the other changes including relative sector size changes.

[8]Labor productivity data for some countries are available. However, since the model includes both variable capital utilization and variable markup, we cannot use labor productivity only to back out productivity shock processes.

6.1 The Total Effects of World Input-Output Linkages

We first discuss the effects of world input output linkages over time on aggregate volatilities in 23 countries between 1970 and 2007. To that end, we assume that all the steady state shares, including the shares of intermediate and value added in production, the shares of foreign and domestic goods in final and intermediate uses, the relative sizes of the sectors and countries, vary over the last 40 years according to the World IO table, while holding the shock processes unchanged. In other words, every elements in the World IO table, as illustrated in Table 3, changes over time. To avoid the possibility that changes in the shares in the World IO table each year are driven by specific events, we set the steady state shares in each year to match the 10-year centered moving average in the data. We then solve the model and calculate the model-implied aggregate volatilities and cross-country correlations at each steady state share value.

Figure 5 plots the model-implied standard deviations of output, consumption, investment between 1970 and 2007 taken at median across countries, compared to the corresponding 10-year rolling over standard deviations in the data. The model captures the downward trend of the volatilities in output, consumption and investment in the data. Quantitatively, the changes in the world input-output linkages generate a drop in volatilities of about 21% in output, consumption and investment, over the period between 1970 and 2007, which are significant fractions of the decline in the data (40% in output, 45% in consumption and 30% in investment). The model does not generate higher frequency changes in volatilities as in the data. One reason is that we compute the theoretical standard deviations, which does not take into account small sample uncertainties.[9]

While the changes in world input-output linkages imply a decrease in aggregate volatilities in the last 40 years at median, the effects are heterogeneous across countries. Volatilities of output are predicted to decline substantially, up to 45%, in Austria, Belgium, Japan, the United States, but there is hardly any effect of these input-output linkages on Korea, Greece, India and Ireland. We plot four countries in Figure 8. The model predicts a 30% decline in output standard deviations in Canada and the United States between 1970 and 2007, while it is only about 10% decline in volatilities for Korea and Mexico. [10]

Figure 6 plots the model-implied average cross-country correlations of output between 1970 and 2007 at median across countries. The model can capture the small increase in correlations over time

[9] In the data, especially for individual countries, there are uncertainties as rolling over standard deviations do nott have many data points.

[10] Appendix Figure A2 plots the model-implied volatilities and the 10-year rolling over standard deviations in the data for all countries.

in the data. Nevertheless, the average cross-country correlations of output are lower than the data at any point in time. As shown later in the Robustness section, the plain vanilla international real business cycle model produces essentially no correlations of output across countries, even with the input-output structure, consistent with Kose and Yi (2006) and Johnson (2013). Our model can match some of the countries' average cross-country output correlations such as Korea and Mexico, as plotted in Figure 9.[11]

Overall, our quantitative exercise suggests that when the economies are driven by uncorrelated productivity shocks, changes in world input-output linkages have significant effects in most countries in our sample between 1970 and 2007: aggregate volatilities tend to decrease and there is a small increase in cross-country correlations of output in the early 2000s. Since there are several different channels within the world input-output linkages such as international input-output linkages and the relative size of sectors and countries, we next examine how much each channel may contribute to the total effects documented in this section.

6.2 The Effects of International Input-Output Linkages

To isolate the effects of changes in international input-output linkages on aggregate volatilities, we proceed as follows: Consider the two-country World IO table between the United States and Canada, illustrated in Table 3. The shares of intermediate and final goods in gross output of each sector used in the United States with origin in the United States are the domestic input-output linkages, while the shares of intermediate and final goods in gross output of each sector used in the United States with origin in Canada are the international input-output linkages. We vary the international input-output shares over time, keeping everything else constant at the initial level. We also rescale the shares of the domestic intermediate inputs and final goods in gross output to make sure that the shares of international and domestic intermediate inputs and final goods in gross output sum up to one in each sector in each country. Note that in this decomposition, the relative sector sizes and the country sizes are held constant at the World IO table in the previous year. We then solve the model for each year and calculate the model-implied moments as usual. For each year in time, we calculate the changes in standard deviations and accumulate them over the years. For example, our initial World IO table is in 1970. We calculate the standard deviation

[11] One reason for why the model does not generate as high correlations as the data is that productivity shocks increases value added directly, so foreign shocks often do not explain much of output variations, even with substantial endogenous transmission of shocks across countries. We will address this by considering demand shock in future research.

of aggregate variables in 1980 conditional on only international linkage changes by using the shares of international intermediate and final goods used in each country in 1980, keeping other shares in 1979 level, then we calculate the difference between the standard deviations of aggregate variables in 1980 and in 1979. We do this for all years and plot the cumulative changes.

Figure 7 plots the estimated effects of changing international input-output linkages on output volatilities over time together with the total effects of both domestic and international input-output linkages at median. Of the 21% drop in output volatilities caused by changes in the World IO table generates, about 11% is due to international input-output linkages at median. International input-output linkage changes have heterogeneous effects on different countries, as plotted in Figure 8.[12] While changes in international input-output linkages explain about 20% of the volatility drop in Canada between 1970 and 2007, the linkages do not explain much of the United States' drop in volatility, and only about 5% of Mexico. International input-output linkages even increase output standard deviation in Korea about 20%. A possible reason for the heterogeneous effects of international linkages on these countries is their openness to trade and trade partners. Canada is the most open country out of the four countries: Canada's export and import over output increases from about 20% up to 30% in this time frame, most of which come from manufacturing sector. Mexico is also open, but its not as much as Canada, as its export and imports ratio over output increase from 10% to 25%. The United States is more open in 2007 than in 1970, but the shares of imports and exports in output are small, so the impact of changing international input-output linkages is negligible. Korea opens up more and more over the 1970–2007 period. Nevertheless, Korea increases trading with China, and decreases trading relationship (in terms of shares) with the United States. China's shock processes are volatile, so the changing international linkages in Korea causes Korean's output standard deviation to increase.

6.3 The Effects of Relative Sector Sizes

Another factor that changes aggregate volatilities in many countries is the changing importance of sectors, so we analyze in the context of our model the quantitative importance of the changing relative sector sizes and compare it with that of the international input-output linkages. To that end, we changes the relative sizes of the manufacturing sector and non-manufacturing sector over time, holding all other fixed at the level in the previous year. In the illustrative two-country World IO table in Table 3, the ratio of gross output in sector 1, X_1, to that of sector 2, X_2, varies over

[12] All countries are plotted in Appendix Figure A3.

time, while the sum of X_1 and X_2 stays at the same level as the previous year so that the country sizes are the same as the previous year. We then solve the model for each year and calculate the model-implied moments. We calculate the changes in standard deviations in each year and accumulate them over the years.

Figure 7 plots the effects of changing relative sector sizes on output standard deviations at median. The drop in output volatilities generated by changing relative sector sizes over the entire 1970–2007 period is similar to the effects of international input-output linkages, explaining about 10% of the decline in output standard deviations. Relative sector size changes causes a larger decline in output standard deviations only in the 1990s than the international input-output linkage channel.

As suggested in Figure 8, relative sector sizes are important to explain the Great Moderation in the United States, but not for all other countries. For example, relative sector size changes explains about 10% of output volatility drop in Canada, 5% in Korea, and 1% in Mexico. In both Canada and Mexico, relative sector size changes are less important than international linkages. Why does our model imply that relative sector size changes are important for the United States? The reason is that in the data, U.S. manufacturing sector becomes much smaller over time: its share in total value added drops from 22% to 17%, and in total gross output drops from 40% to 20%. The manufacturing sector is more volatile than the non-manufacturing sector, so aggregate output volatility drops. The fact that our model contributes a significant fraction of output drop in the United States to the reduced importance of the manufacturing sector is consistent with other papers such as Carvalho and Gabaix (2013). For Canada, although the contribution of the manufacturing sector in aggregate economy also drops in Canada, it is much less compared to the United States: the shares of Canadian manufacturing sector gross output in total gross output decreases from 31% to 25% only, so the model attributes some of the drop in Canadian output standard deviation to this fact, but not as much as in the United States. Finally, in both Mexico and Korea, the shares of the manufacturing sector in gross output are fairly stable over time, so the contribution of the changes in the relative sector sizes are negligible.

In summary, our model suggests that at median, relative sector size channel is about as important as the international input-output linkages, but this result is heterogeneous across countries.

7 Robustness Check

We use several robustness check cases to understand how our results depend on the model mechanism. The results are tabulated in Table 4.

We set the elasticity of substitution across countries to be as low as 0.1. The idea is that this elasticity may generate more endogenous transmission, as suggested in the literature. We find that the contribution of international linkages to changes in volatilities is similar to the baseline. The reason is that the baseline model already generates strong endogenous transmission of shocks across countries.

We also shut down all the features in the model including investment adjustment cost, capital utilization and variable markup so that the model is close to a plain vanilla RBC model. This version of the model helps to understand how the results may be different if there is no endogenous transmission of shocks across countries. We find that the contribution of international linkages to changes in output volatilities is much smaller: the medians of bottom half and upper half of the countries are smaller than the baseline, while the contribution of relative sector sizes does not change. The reason is that with small endogenous transmission of shocks across countries in the plain vanilla RBC model, countries cannot diversify their shocks even when there are changes in input-output linkages.

The third case is when we set the standard deviation of productivity shocks in the manufacturing sector to be five times more than that in the non manufacturing sector. We would like to check if the baseline result is robust to reasonable common calibration to every country, as the measurement errors can be large when we calibrate productivity shock processes different across countries. We find that the results are similar to the baseline if we compare the medians of the bottom and upper halves of the countries.

The fourth case is when we set productivity shocks in the manufacturing sector to be the dominant shock in the economy. In this case, the diversification channel from increases as the international input-output linkages increase, so the contribution of the international linkages to the decline in output volatility increases slightly compared to the baseline. The reason is that the manufacturing sector is more open and dominant in the economy, and increased linkages can help countries to diversify their shocks. This channel is already quite large in the baseline, so the difference between this case and the baseline for the international linkages is not large. The relative sector size changes also help to reduce output volatility more significantly than the baseline. Both

channels combined help to increase the importance of the World IO table changes in explaining a decline in output volatility across countries.

The fifth case is the reverse of the fourth case: we set productivity shocks in the non manufacturing sector to be the dominant shock in the economy. Both diversification from international input-output linkages and relative sector size channels do not work as much as the baseline, so the contribution of the World IO table changes in explaining a decline in output volatility across countries is smaller than the baseline.

Finally, we allow the possibility that there are exogenous cross-country correlations of each sector's productivity. We set this correlation to be 0.2. We find that the contribution of international linkages to the decline in output variations over time to be much smaller than the baseline results. The reason, as discussed before, is that even with changes in international linkages, shocks are correlated across countries so each country cannot diversify their shocks, making the diversification channel small.

[TO BE COMPLETED]

8 Conclusion

We quantify the effects of changing international input-output linkages on aggregate volatilities and correlations across countries between 1970 and 2007. We find that while international input-output linkages lead to about 11% reduction in output volatilities at median across 23 countries in our sample in the last 40 years, its effects are heterogenous across countries. Furthermore, the changing international input-output linkage channel is less important than the changing relative sector sizes in reducing output volatilities in a number of countries including the United States, Japan, Great Britain and France. [TO BE COMPLETED]

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9 Data Appendix

9.1 World input-output table

The data are taken from Johnson and Noguera (2017). We choose 23 countries and aggregate the rest of the countries to ROW. The data span from 1970 to 2009. The original data include 4 sectors, we aggregate them into 2 sectors: manufacturing and non-manufacturing (agriculture, services, non-manufacturing industrial production).

9.2 Real aggregate data

Output, consumption, investment and real value added of manufacturing and non manufacturing sectors come from the United Nation National accounts Main aggregate database. The data are available from 1970 to 2013 for most countries: https://unstats.un.org/unsd/snaama/dnlList.asp. They have sectoral breakdown: agriculture, hunting etc., mining, manufacturing utilities, manufacturing, construction, wholesale, retail trade etc., Transport storage, other activities and total value added. All of the data are in both real and nominal terms.

We aggregate the real value added for non manufacturing sector as follows: we take a weighted sum of the growth rates of the real value added of all sectors other than manufacturing, where the weight is the share of the nominal value added of that sector in total nominal value added of non-manufacturing sectors. We then recover the time series for the non manufacturing sector for each country.

For the ROW, we aggregate all countries available data in a similar manner: the growth rate of the real value added of each sector is the weighted sum of the growth rates of the real value added of each sector in all countries available outside of the 23 countries. We then recover the time series for the real value added for each sector, then follow the same procedure to get the real value added for manufacturing and non manufacturing sectors.

For China, since we do not have data before 1970 for manufacturing, we use the share of manufacturing in total value added: $w_{manuf} = \frac{\text{Nominal Manufacturing VA}}{\text{Nominal total VA}}$ from the World Development Indicator. Then, we can get the growth rate of the real value added for manufacturing from:

$$\Rightarrow \Delta \ln RVA_{manuf} = \frac{1}{w_{manuf}} \times (\Delta \ln TotalRVA - (1 - w_{manuf}) \Delta \ln RVA_{nonmanuf})$$

then we can recover RVA_{manuf} by using 2003–2008 and backward creating the series using the

above growth rate.

Tables and Figures

Table 1: Calibrated 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
$\frac{\delta_u''}{\delta_u'}u$	0.15	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

Table 2: Second Moments

	Data	Model
Standard deviations		
Output	1.3	1.2
Consumption	1.2	1.1
Investment	3.8	3.4
Manufacturing real value added	2.6	2.6
Non-manufacturing real value added	1.4	1.4
Autocorrelation		
Output	0.32	0.33
Consumption	0.35	0.07
Investment	0.34	0.39
Manufacturing real value added	0.25	0.06
Non-manufacturing real value added	0.32	0.18

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.

Table 3: World Input-Output Table

		CA s1	CA s2	US s1	US s2	CA final	US final	GO
CA	s1	a_{11}	a_{12}	a_{13}	a_{14}	b_{11}	b_{31}	$\mathbf{X_1}$
CA	s2	a_{21}	a_{22}	a_{23}	a_{24}	b_{21}	b_{41}	$\mathbf{X_2}$
US	s1	a_{31}	a_{32}	a_{33}	a_{34}	b_{31}	b_{11}	$\mathbf{X_3}$
US	s2	a_{41}	a_{42}	a_{34}	a_{44}	b_{41}	b_{21}	$\mathbf{X_4}$
VA		V_1	V_2	V_3	V_4			
GO		X_1	X_2	X_3	X_4			

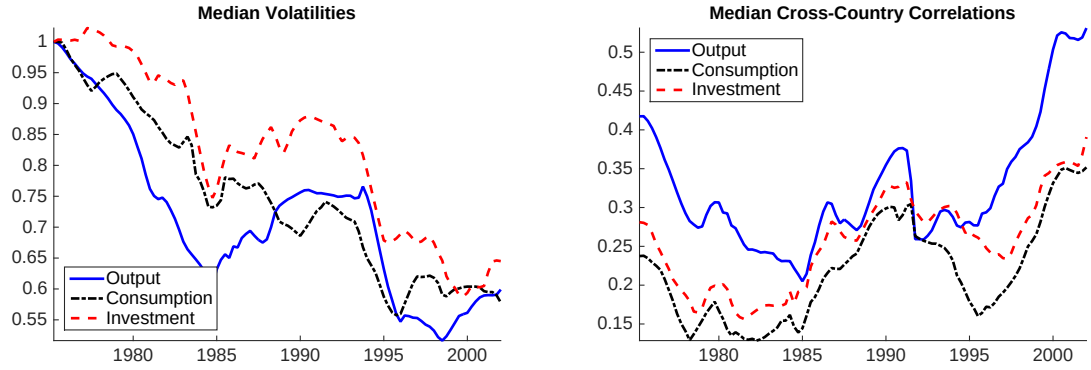
Notes: The elements in red and blue are the shares of each cell divided by gross output X in the corresponding country and sector. $s1$ and $s2$ denote sector 1 and 2, respectively. VA denotes value added, and GO denotes gross output. This table illustrate a simple two country World IO table for the United States (US) and Canada (CA).

Table 4: Robustness Check: Changes in Volatilities between the last and the first five years

Case	Variable	World IO table change			International Linkages			Relative Sector Sizes		
		Median	Bottom	Upper	Median	Bottom	Upper	Median	Bottom	Upper
Baseline	Output	-17.2	-23.9	-7.7	-8.9	-13.2	5.8	-9.1	-23.0	-5.5
	Consumption	-21.5	-32.6	-13.4	-7.4	-21.0	2.6	-11.2	-22.2	-5.4
	Investment	-19.2	-27.3	-5.7	-8.4	-13.7	5.1	-9.0	-23.4	-5.8
ES countries $\gamma = 0.1$	Output	-18.4	-24.9	-8.4	-9.2	-14.6	3.9	-9.1	-23.9	-4.8
	Consumption	-20.0	-32.7	-14.4	-8.0	-19.2	-0.3	-12.2	-22.5	-4.3
	Investment	-17.7	-26.0	-4.3	-7.6	-11.7	6.6	-8.5	-25.3	-5.8
Plain vanilla RBC model	Output	-9.3	-17.7	-4.9	2.5	-4.0	6.4	-9.0	-21.2	-5.9
	Consumption	-18.0	-29.3	-10.9	-7.8	-14.1	-5.5	-5.9	-17.3	-2.6
	Investment	-13.4	-27.2	-4.9	-0.1	-13.0	14.9	-10.5	-22.5	-7.4
std of manuf=0.05, nonmanuf=0.01	Output	-18.5	-26.9	-6.8	-3.9	-13.1	8.1	-14.6	-21.2	-6.5
	Consumption	-22.4	-29.6	-14.7	-3.0	-19.5	3.2	-17.0	-24.3	-10.0
	Investment	-18.2	-28.2	-9.4	-6.2	-12.1	6.2	-13.6	-22.8	-5.9
std of manuf=0.1, nonmanuf=0.001	Output	-24.1	-38.0	-16.2	-5.1	-15.1	6.6	-20.6	-30.3	-7.7
	Consumption	-28.5	-37.7	-20.6	-1.0	-20.7	1.9	-20.2	-29.6	-10.8
	Investment	-28.0	-41.0	-21.2	-7.1	-16.1	4.6	-20.8	-30.0	-8.4
std of manuf=0.001, nonmanuf=0.1	Output	6.7	-3.7	26.3	1.6	-4.9	19.4	4.6	1.5	7.5
	Consumption	-1.1	-7.4	21.6	-1.9	-12.9	12.4	4.6	0.8	9.7
	Investment	11.3	-0.6	33.8	6.5	-4.9	20.1	3.8	1.1	5.5
cross-country correlation of each sector=0.2	Output	-11.8	-17.0	-2.2	0.6	-8.3	13.1	-10.6	-22.7	-7.2
	Consumption	-14.3	-25.5	-7.3	2.4	-16.3	12.6	-12.9	-21.8	-8.2
	Investment	-13.0	-21.8	-1.8	-0.9	-9.8	11.8	-10.6	-22.9	-6.7

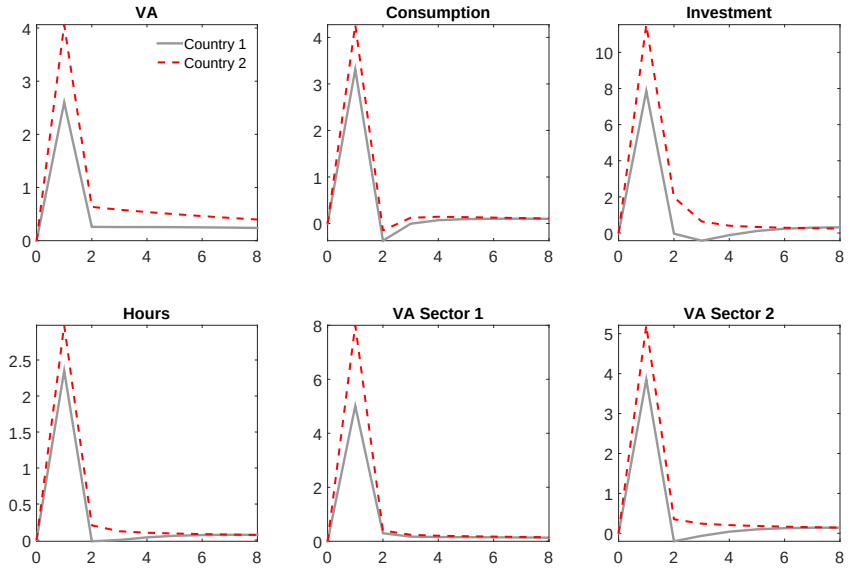
Notes: Median is the calculated as the median change in volatilities across 23 countries. Bottom and Upper are calculated as the median change in volatilities across bottom and upper half of the sample countries. The numbers are the changes in standard deviations between the average first five and last five years.

Figure 1: Median volatilities and cross-country correlations of output, consumption and investment between 1970 and 2007



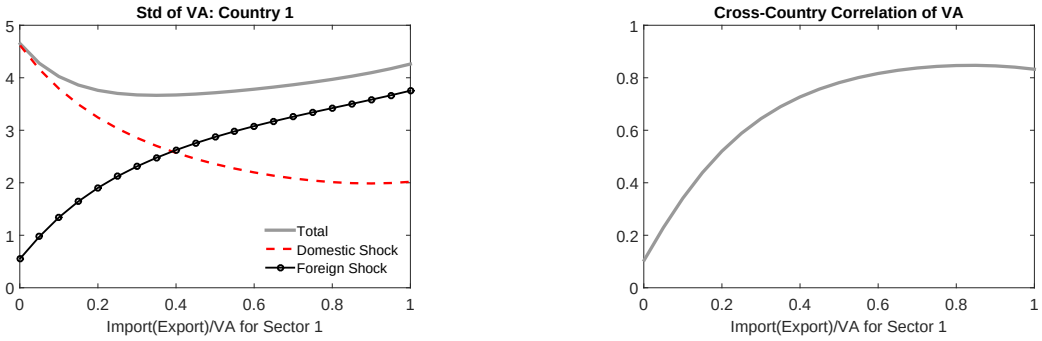
Notes: The median 10-year rolling over standard deviations of the HP-filtered of output, consumption and investment in 22 countries between 1970Q1 and 2007Q4. We normalize the standard deviations in 1975Q2 as 1 for each country, then we take median across 22 countries. For cross-country correlations, we take average bilateral cross-country correlations for each country, then take median over the sample countries.

Figure 2: Model Behavior: Transmission of shocks across countries



Notes: The impulse responses in country 1 and 2 to a positive TFP shock in country 1 sector 1 simulated in a 2-country model experiment. VA denotes value added in each country or sector.

Figure 3: Model Implication: Relationship between international linkages and output volatility and cross-country correlations

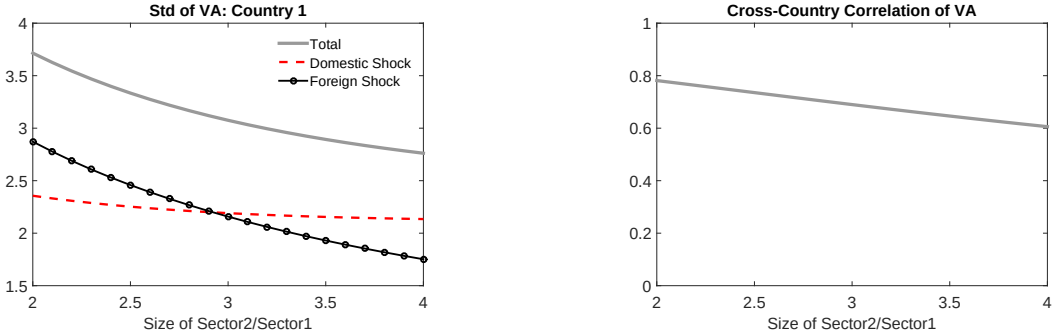


(a) Volatilities

(b) Cross-country correlations

Notes: Figure 3a plots the standard deviation of output as we vary the shares of imports and exports in sector 1 value added, when the countries are driven by all shocks (Total), only foreign shocks, and only domestic shocks in our baseline model for two countries. Figure 3b plots the cross-country correlations of output as we vary the shares of imports and exports in sector 1.

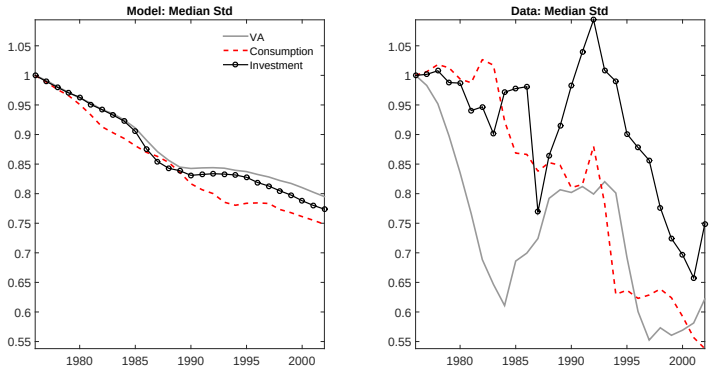
Figure 4: Model Implication: Relationship between relative sector sizes and output volatility and cross-country correlations



(a) Volatilities (b) Cross-country correlations

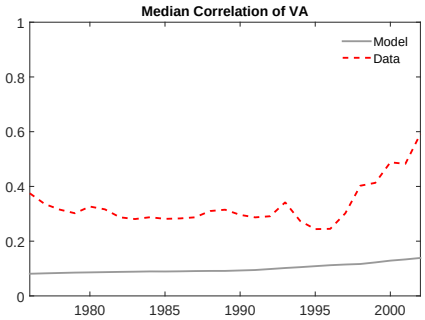
Notes: Figure 4a plots the standard deviation of output as we vary the relative sizes of sector 1 to sector 2. Figure 4b plots the cross-country correlations of output as we vary the relative sizes of the two sectors.

Figure 5: World Input-Output Changes and Output Volatilities



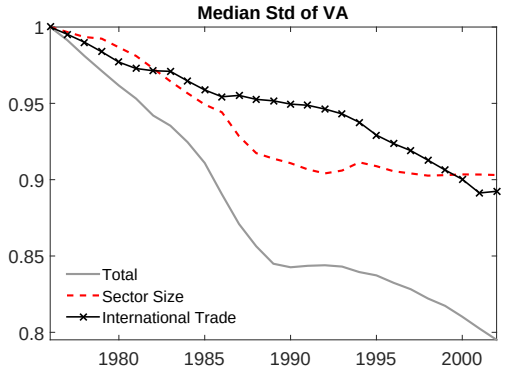
Notes: The left figure plots the standard deviations of output, consumption and investment at median as the world input-output changes from 1970 to 2007. The right figure plots the 10-year rolling over standard deviations of output, consumption and investment at median for 23 countries using annual data between 1970 and 2007.

Figure 6: World Input-Output Linkage Change on Output Correlations Across Countries



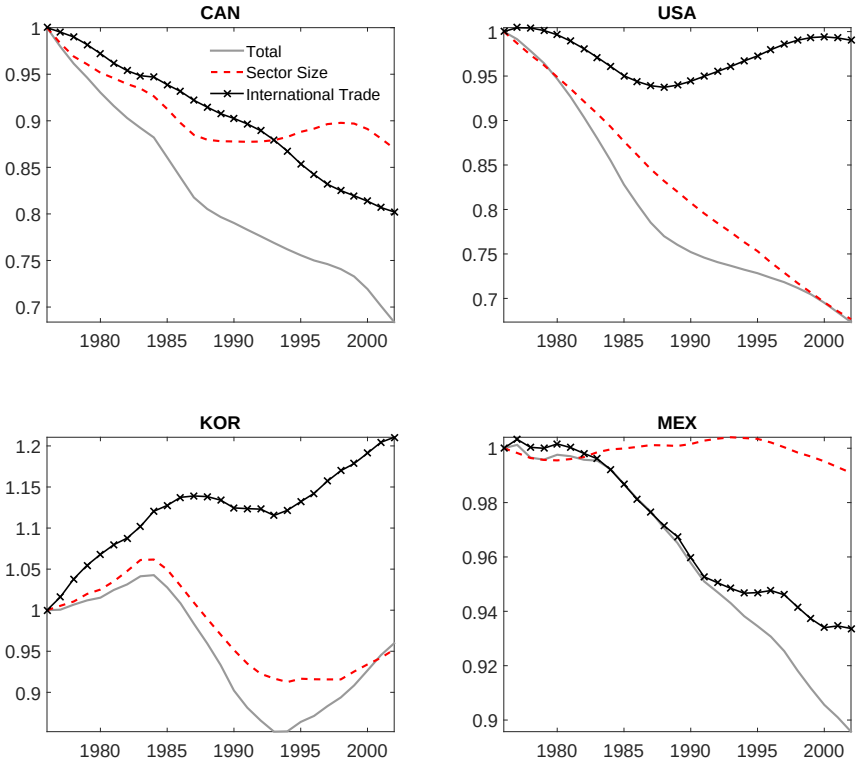
Notes: The figure plots the average cross-country correlations of output at median as the world input-output changes from 1970 to 2007 predicted by the model, along with the 10-year rolling over cross-country correlations of output at median for 23 countries using annual data between 1970 and 2007.

Figure 7: Decomposition the Effects of International Input-Output Linkage Change on Output Volatilities



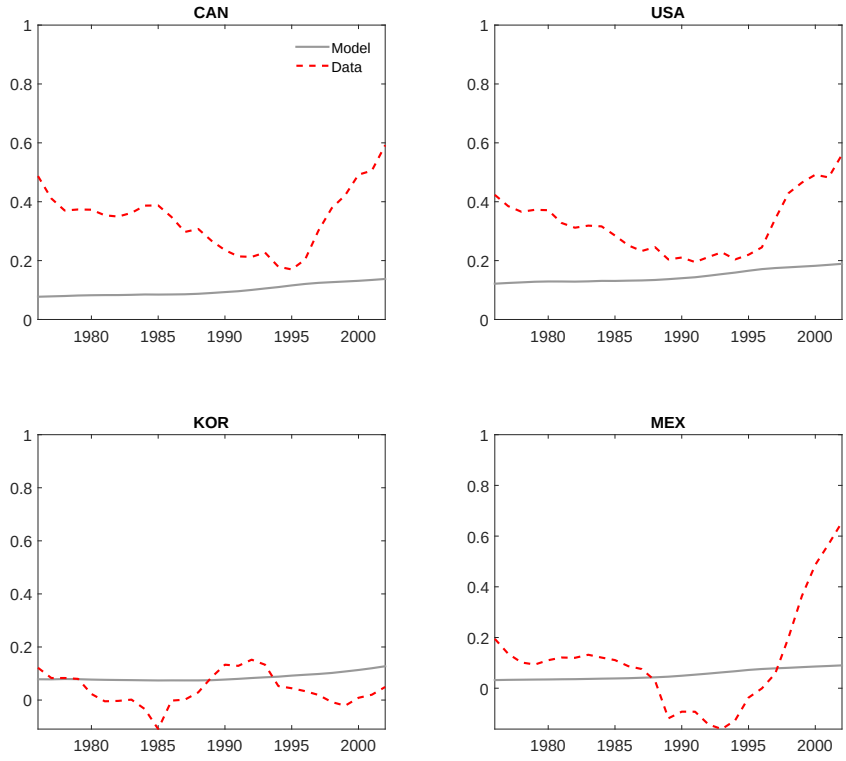
Notes: We plot the total effects of world input-output changes (Total) on standard deviation of output at median as the grey line. The black line with plus signs plots the change in the standard deviation of output at median when only the international input-output linkages change. The red dashed line plots the change in the standard deviation of output at median when only the relative sector size changes.

Figure 8: Heterogeneous Effects of International Input-Output Linkage Change on Output Volatilities



Notes: We plot the total effects of world input-output changes (Total) on standard deviation of output as the grey line. The black line with plus signs plots the change in the standard deviation of output when only the international input-output linkages change. The red dashed line plots the change in the standard deviation of output when only the relative sector size changes.

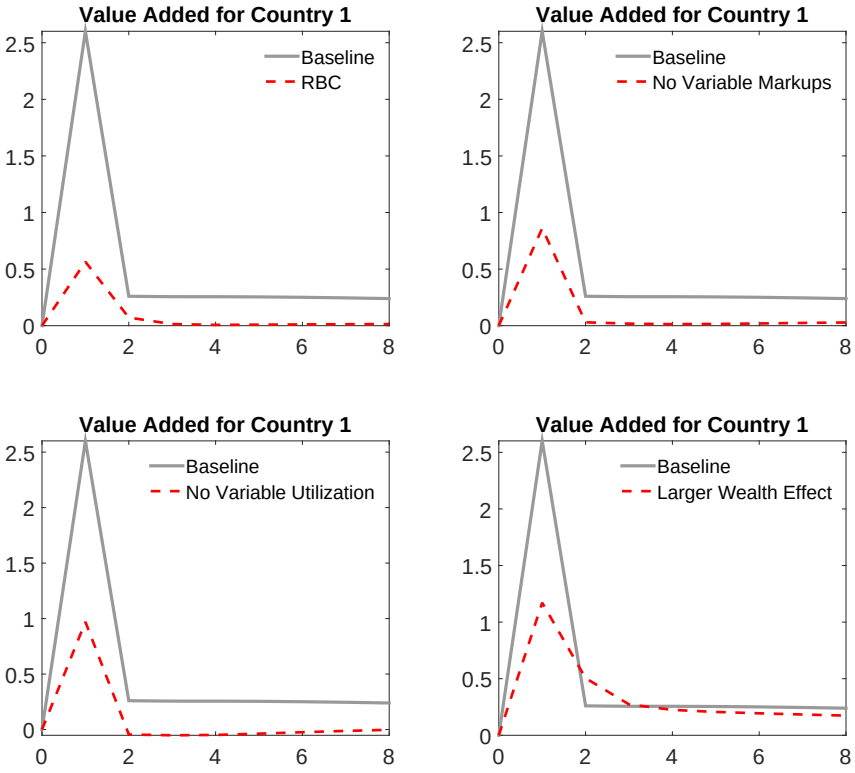
Figure 9: Heterogeneous Effects of World Input-Output Linkage Change on Output Correlations Across Countries



Notes: We plot the total effects of world input-output changes on the cross-country correlations.

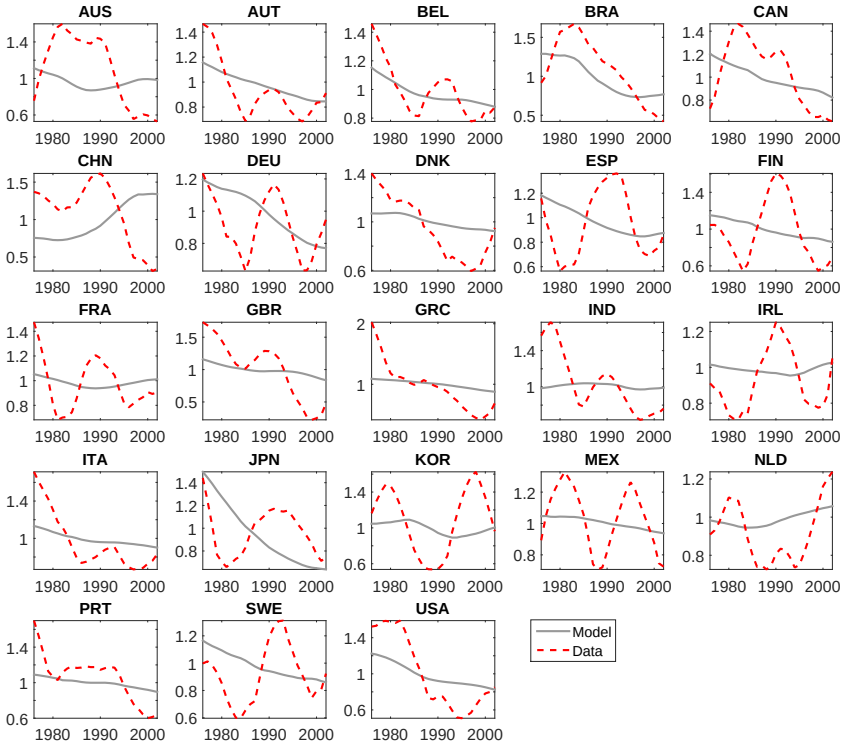
Appendix: More Tables and Figures

Figure A1: Model Behavior: Transmission of shocks across countries without our features



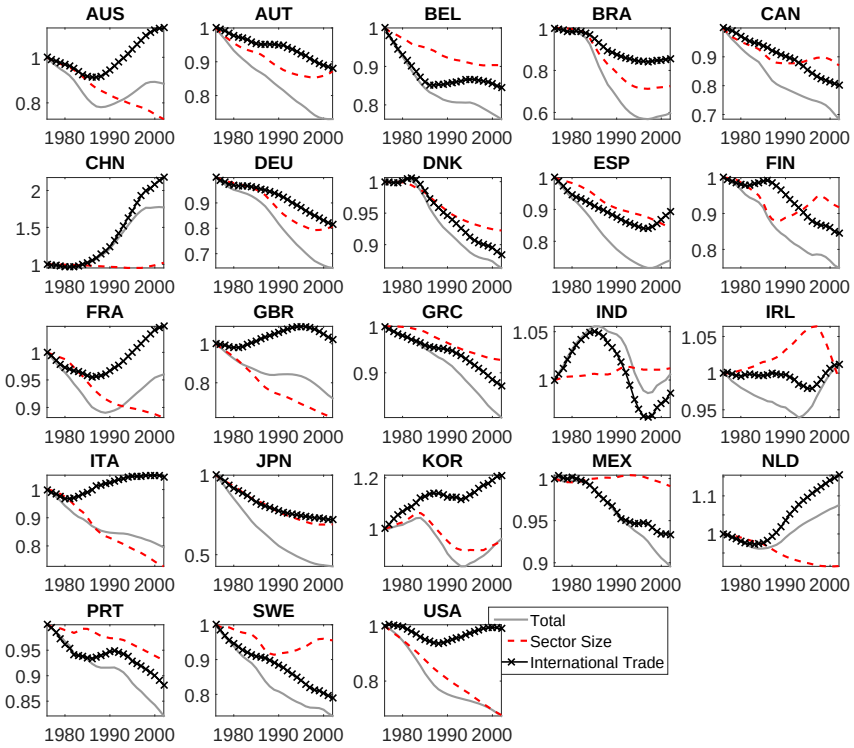
Notes: The impulse responses in country 1 and 2 to a positive TFP shock in country 1 sector 1 simulated in a 2-country model experiment. VA denotes value added in each country or sector.

Figure A2: World Input-Output Changes and Output Volatilities in All Countries



Notes: The figure plots the standard deviations of output as the world input-output changes from 1970 to 2007 for all countries, along with the 10-year rolling over standard deviations of output using annual data between 1970 and 2007.

Figure A3: Heterogeneous Effects of International Input-Output Linkage Change on Output Volatilities in All Countries



Notes: We plot the total effects of world input-output changes (Total) on standard deviation of output as the grey line. The black line with plus signs plots the change in the standard deviation of output when only the international input-output linkages change. The red dashed line plots the change in the standard deviation of output when only the relative sector size changes.