Putting the Parts Together: Trade, Vertical Linkages, and Business Cycle Comovement*

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Abstract

Countries that trade more with each other exhibit higher business cycle correlation. This paper examines the mechanisms underlying this relationship using a large cross-country industry-level panel dataset of manufacturing production and trade. We show that sector pairs that experience more bilateral trade exhibit stronger comovement. Vertical linkages in production are an important explanation behind this effect: bilateral international trade increases comovement significantly more in cross-border industry pairs that use each other as intermediate inputs. Our estimates imply that these vertical production linkages account for some 30% of the total impact of bilateral trade on the business cycle correlation.

JEL Classifications: F15, F4

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1 Introduction

By almost any measure, the world economy exhibits ever stronger international linkages. International trade tripled as a share of world GDP since 1960 (World Trade Organization 2007). This increase is due to both a reduction in barriers and a change in the production structure. Goods trade has become more vertical, as intermediates account for an increasing share of total trade (Hummels, Ishii and Yi 2001, Yi 2003).

As economic globalization proceeds apace, what can we say about its effects on international business cycles? The seminal paper by Frankel and Rose (1998) established what has become a well-known empirical regularity: country pairs that trade more with each other experience higher business cycle correlation. While the finding has been confirmed by a series of subsequent studies (Clark and van Wincoop 2001, Baxter and Kouparitsas 2005, Calderon, Chong and Stein 2007), the mechanisms underlying this relationship are still not well understood. Empirically, the key unanswered question is whether the Frankel-Rose result is truly about trade's role in the transmission of shocks, or it is instead driven by omitted variables: common shocks that happen to be stronger for countries that trade more with each other (Imbs 2004). This question is especially important because standard international business cycle models of transmission have difficulty in matching the Frankel and Rose empirical results, leading to a "trade-comovement puzzle" (Kose and Yi 2006). In light of the rapidly changing nature of global trade, understanding these mechanisms is becoming increasingly relevant for economic policy.[1]

This paper uses industry-level data on production and trade to examine the importance of various channels through which international trade affects the aggregate comovement. To carry out the empirical analysis, we combine sectoral output data from the UNIDO database for 55 developed and developing countries during the period 1970–99 with the bilateral sectoral trade series from the World Trade Database (Feenstra et al. 2005). The

[1] For instance, Tesar (2006) analyzes business cycle synchronization of the EU accession countries in a model of cross-border production sharing, and argues that whether trade increases business cycle comovement between Western and Eastern Europe depends crucially on the nature of international trade between the countries in those regions.

use of sector-level data has two key advantages. First, the four-dimensional dataset indexed by exporter, importer, and sector-pair permits the inclusion of a rich set of fixed effects in order to control for many possible unobservables and resolve most of the omitted variables and simultaneity concerns in estimation. In particular, country-pair and sector-pair effects can control for aggregate common shocks that plague the interpretation of results based on cross-country data, and provide much more robust evidence on transmission of shocks.

Second, using sector-level data we investigate whether vertical production linkages across industries can help explain the impact of international trade on comovement. To measure the extent of vertical linkages, we use Input-Output matrices to gauge the intensity with which individual sectors use each other as intermediate inputs in production. We then condition the impact of bilateral trade on the strength of Input-Output linkages between each pair of sectors. This provides additional evidence of transmission, by focusing on a particular identifiable channel: the use of intermediate inputs in production.

Our main results can be summarized as follows. First, the Frankel-Rose effect is present at the sector level: sector pairs that experience more bilateral trade exhibit stronger comovement. Second, a given increase in bilateral trade leads to higher comovement in sector pairs that use each other heavily as intermediate inputs. That is, bilateral trade is more important in generating comovement in sectors characterized by greater vertical production linkages. Having established these two results, we then quantify the relative importance of the various channels for aggregate comovement. We write the aggregate correlation as a function of sector-pair level correlations, and carry out the usual thought experiment of increasing bilateral trade between two countries. In order to investigate the relative importance of vertical linkages in generating aggregate comovement, we break down the change in correlation between each individual sector pair into the component that is due to the Input-Output linkages and the remaining main effect. It turns out that vertical linkages explain 32% of the overall impact of bilateral trade on aggregate comovement in the full sample of both developed and developing countries.

By breaking down the overall effect into sector-pair level components, we can also evaluate the importance of intra-industry trade in generating increased comovement between trading partners highlighted in recent studies (see, e.g., Fidrmuc 2004, Koo and Gruben 2006, Calderon et al. 2007). Our methodology lets us decompose the aggregate impact into the part coming from intra-industry comovement (which we call the Within-Sector component), and the inter-industry comovement (the Cross-Sector component). The results are surprising. The Within-Sector component accounts for only 18% of the impact of bilateral trade on aggregate business cycle correlation. By contrast, the Cross-Sector component accounts for the remaining 82% of the total effect. What is the intuition for this result? It turns out that the same increase in bilateral trade changes the correlation within a sector by four to five times as much as the correlation across sectors. At first glance, such a difference bodes well for the finding that intra-industry trade is particularly important in generating aggregate comovement. However, a typical sector is quite small in our sample relative to the aggregate. As a result, the impact of a within-sector increase in correlation on the aggregate is moderated by its average small size. Correspondingly, the increase in the correlation of a particular sector with the rest of the economy is that much more important for the same reason: since an average sector is small, its complement is quite large.

Finally, we explore whether the role of trade and vertical linkages differs across subsets of countries. To do this, we split the sample into OECD–OECD country pairs (henceforth North-North), non-OECD–non-OECD (South-South), and OECD–non-OECD (North-South) country pairs, and carry out the estimation and aggregation exercises on each individual subsample. It turns out that the overall relationship between bilateral trade and comovement is far stronger in the North-North group than the other subsamples, confirming the findings of Calderon et al. (2007). We estimate that the same increase in bilateral trade changes business cycle comovement 4-17 times more in the North-North sample compared to the others. By contrast, vertical linkages are relatively more important for North-South trade. While vertical linkages are responsible for 17% of the overall impact of trade in the North-North sample, and for 4% in the South-South sample, they account for 73% of the total among the North-South country pairs.

This paper is part of a growing literature on the role of trade in business cycle transmission. Fidrmuc (2004), Koo and Gruben (2006), and Calderon et al. (2007) find that intra-industry trade, as measured by the Grubel-Lloyd index, accounts for most of the Frankel-Rose effect. Imbs (2004) shows that in addition to bilateral trade, similarity in sectoral structure and financial linkages are also important. By contrast, Baxter and Kouparitsas (2005) find sectoral similarity does not have a robustly significant effect on cross-country output correlations. Our paper is the first to examine both comovement and vertical linkages at the industry level, providing a richer picture of the underlying effects and transmission mechanisms. In particular, the vertical linkage results point to the key role of industrial structure in transmitting shocks via trade. Moreover, our estimates reveal that vertical linkages are especially important within sectors. Thus, our paper arguably provides a bridge between the results of Imbs (2004) and Baxter and Kouparitsas (2005), by highlighting the interaction between countries' trade and the similarity of their industrial structure in explaining business cycle synchronization. Finally, the evidence on vertical linkages in this paper complements recent DSGE analyses (Kose and Yi 2001, Kose and Yi 2006, Burstein, Kurz and Tesar 2008, Huang and Liu 2007, Arkolakis and Ramanarayanan 2008) that model these effects.[2]

The rest of the paper is organized as follows. Section 2 describes the empirical strategy and data. Section 3 presents the regression results, while Section 4 describes the quantitative impact of the various channels on aggregate comovement. Section 5 concludes.

[2]Using data on U.S. multinationals, Burstein et al. (2008) find that trade between affiliates – the measure of production sharing used in that paper – is robustly correlated to bilateral comovement of manufacturing GDP at the country level.

2 Empirical Strategy and Data

2.1 Sector-Level and Aggregate Comovement

Let there be two economies, c and d, each comprised of $\mathcal{I}$ sectors indexed by i and j. The aggregate growth in the two countries, y^c and y^d, can be written as:

$$y^c = \sum_{i=1}^{\mathcal{I}} s_i^c y_i^c$$

and

$$y^d = \sum_{j=1}^{\mathcal{I}} s_j^d y_j^d,$$

where y_i^c is the growth rate of sector i in country c, and s_i^c is the share of sector i in the aggregate output of country c. The business cycle covariance between these two countries is then equal to:

$$\mathrm{Cov}\left(y^c, y^d\right) = \mathrm{Cov}\left(\sum_{i=1}^{\mathcal{I}} s_i^c y_i^c, \sum_{j=1}^{\mathcal{I}} s_j^d y_j^d\right) = \sum_{i=1}^{\mathcal{I}} \sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \mathrm{Cov}\left(y_i^c, y_j^d\right). \tag{1}$$

Since all of the empirical work in this literature is carried out on correlations, and because, conceptually, correlations are pure measures of comovement, we take one extra step and rewrite the identity in terms of correlations:

$$\rho^{cd} = \frac{1}{\sigma^c \sigma^d} \sum_{i=1}^{\mathcal{I}} \sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d \rho_{ij}^{cd}. \tag{2}$$

In this expression, σ^c and σ^d are the standard deviations of aggregate growth in the two countries, while σ_i^c and σ_j^d are the standard deviations of the growth rates in individual sectors i and j in countries c and d respectively.

Until now, the literature has examined the left-hand side of this identity, the correlation of countries' aggregate growth ρ^{cd}. Using sector-level data, this paper instead examines the impact of sector-level trade on the correlation between individual sectors in the two economies, ρ_{ij}^{cd}. As we show in the paper, this allows us to develop a much richer picture of the mechanics of trade's impact on aggregate comovement.

In particular, we estimate the following specification, using comovement and trade data for each sector-pair:

$$\rho_{ij}^{cd} = \alpha + \beta_1 \text{Trade}_{ij}^{cd} + \mathbf{u} + \varepsilon_{ij}^{cd}. \tag{3}$$

In the benchmark estimations, the left-hand side variables are correlations computed on 30 years of annual data, helping reduce the measurement error. Trade_{ij}^{cd} is one of four possible trade intensity measures, constructed as described in Section 2.4.

All specifications include various configurations of fixed effects $\mathbf{u}$. The observations are recorded at the exporter×sector×importer×sector level, rendering possible the use of a variety of fixed effects. The baseline specifications control for importer, exporter, and sector effects. These capture the average effect of country characteristics on comovement across trading partners and sectors, such as macro policies, country-level aggregate volatility, country size and population, and the level of income. Sector effects capture any inherent characteristics of sectors, including, but not limited to, overall volatility, tradability, capital, skilled and unskilled labor intensity, R&D intensity, tangibility, reliance on external finance, liquidity needs, or institutional intensity. We also estimate the model with exporter×sector and importer×sector effects. These control for the average comovement properties of each sector within each country across trading partners, for instance tariffs and non-tariff barriers. Finally, we also control for country-pair and sector-pair effects. The country-pair effects capture the average linkages for each country pair, such as bilateral distance, total bilateral trade and financial integration, common exchange rate regimes, monetary and fiscal policy synchronization, and sectoral similarity, among others. Sector-pair effects absorb the average comovement for a particular pair of sectors in the data. Note that when we use country-pair effects, the coefficient on trade is identified purely from the variation in bilateral trade volumes *within each country pair across industry pairs*.[3]

[3] Equation (3) is estimated on the full sample, ignoring the possibility of coefficient heterogeneity across pairs of sectors. As an alternative, an earlier version of the paper estimated a random coefficient model that allows for coefficient heterogeneity. Results were practically identical to the OLS estimates presented below (if anything the average slope coefficient is slightly larger in the random coefficient model). We therefore present OLS estimates in this version of the paper, both for expositional simplicity and because we are ultimately interested in the average impact of trade among all sector pairs.

Some papers in the literature focus on the impact of intra-industry trade in particular on the aggregate comovement. A typical finding is that intra-industry trade, captured by the aggregate Grubel-Lloyd index for each country pair, is solely responsible for the result that trade between two countries increases comovement. In order to isolate the impact of intra-industry trade, we estimate a variant of equation (3) that allows the coefficient on the trade variable to differ when it occurs within the industry:

$$\rho_{ij}^{cd} = \alpha + \beta_1 \text{Trade}_{ij}^{cd} + \beta_2 \mathbf{1}\left[i = j\right] \text{Trade}_{ij}^{cd} + \mathbf{u} + \varepsilon_{ij}^{cd}, \tag{4}$$

where $\mathbf{1}\left[\cdot\right]$ is the indicator function. That is, the coefficient on trade can be different for observations in which $i = j$.

2.2 Vertical Linkages and Transmission of Shocks

We then investigate further the nature of transmission of shocks at the sector level. We would like to understand whether vertical production linkages help explain the positive elasticity of the output correlation – within and across sectors – with respect to trade in a sector. The explanation behind this link relies on the vertical nature of the production chain. Here, a positive shock (either demand or supply) to a sector in one country increases that sector's demand for intermediate goods in production, and thus stimulates output of intermediates in the partner country (Kose and Yi 2001, Burstein et al. 2008, Huang and Liu 2007).[4]

We exploit information from the Input-Output (I-O) matrices about the extent to which sectors use each other as intermediates in production. Our hypothesis is that the positive link between trade and comovement will be stronger in sector pairs that use each other as intermediates in production. To establish this effect, we estimate the following specification:

$$\rho_{ij}^{cd} = \alpha + \beta_1 \text{Trade}_{ij}^{cd} + \gamma_1 \left(\text{IO}_{ij} \text{Exports}_i^{cd} + \text{IO}_{ji} \text{Exports}_j^{dc}\right) + \mathbf{u} + \varepsilon_{ij}^{cd}, \tag{5}$$

where IO_{ij} is the (i, j)th cell of the I-O matrix. It captures the value of intermediate inputs from sector i required to produce one dollar of final output of good j. It is interacted with

[4] See Ramanarayanan (2009) for illustrative evidence that at sector level, comovement of output between the U.S. and Canada is increasing in the amount of intermediate input trade.

the trade variable Exports_i^{cd}, which is the value of exports in sector i from country c to country d. That is, exports of good i from country c to country d will increase comovement by more with sectors j that use i heavily as an intermediate. Correspondingly, IO_{ji} is the value of intermediate j required to produce one dollar of final good i. Therefore, comovement between sector i in country c and sector j in country d will be more affected by exports of j from d to c, Exports_j^{dc}, whenever i uses j intensively as an intermediate (IO_{ji} is high). Note that we constrain the coefficient (γ_1) to be the same regardless of the direction of trade. This is because indices c and d are completely interchangeable, so there is no economic or technological reason why the coefficients on $\text{IO}_{ij}\text{Exports}_i^{cd}$ and $\text{IO}_{ji}\text{Exports}_j^{dc}$ should be different. In addition, the coefficient magnitudes in the unconstrained regressions were quite similar, and the F-tests could not reject equality in most specifications.

Once again, to focus attention on intra-industry trade, the final specification allows the coefficients to be different when trade is intra-industry:

$$\begin{aligned}\rho_{ij}^{cd} = \alpha + \beta_1 \text{Trade}_{ij}^{cd} + \gamma_1 \left(\text{IO}_{ij}^{cd}\text{Exports}_i^{cd} + \text{IO}_{ji}\text{Exports}_j^{dc}\right) + \beta_2 \mathbf{1}\left[i=j\right] \text{Trade}_{ij}^{cd} \\ + \gamma_2 \mathbf{1}\left[i=j\right] \left(\text{IO}_{ij}\text{Exports}_i^{cd} + \text{IO}_{ji}\text{Exports}_j^{dc}\right) + \mathbf{u} + \varepsilon_{ij}^{cd}.\end{aligned} \quad (6)$$

2.3 Identification and Interpretation

What is the role of international trade in the transmission of business cycles? Theoretically and quantitatively, the challenge has been to find frameworks and/or parameter values that are consistent with the observed correlations in the data. Empirically, the debate is whether the Frankel-Rose result is truly about trade's role in the transmission of shocks, or it is instead driven by omitted variables: common shocks that happen to be stronger for countries that trade more with each other.

The theoretical and quantitative literature focuses on transmission.[5] In the canonical framework of Backus, Kehoe and Kydland (1995, henceforth BKK), that features one homogeneous good produced by both countries, international trade *lowers* business cycle correlation between countries. In fact, in the baseline BKK model, the output correlation is

[5]Indeed, one does not need a model to rationalize the trade-business cycle link by appealing to exogenous common shocks hitting countries that trade with each other.

negative, even when productivity shocks are positively correlated. The intuition for this is clear: when goods are substitutable, a positive shock in one country leads to more output in that country, but less output in the trading partner, as resources are shifted to the more productive location.

Kose and Yi (2006) model the Frankel-Rose relationship directly. Their main finding is that the qualitative relationship between trade intensity and business cycle correlation can be reproduced in the standard BKK setup with three countries. However, the model does not perform well quantitatively: the trade-comovement relationship is roughly 10 times weaker in the model than it appears to be in the data.

These authors then demonstrate two ways of improving the match of the model to the data. First, if they assume that trade impacts the correlation of true TFP directly, the model can in fact replicate the magnitudes in the data very well. This approach is quite unsatisfying because it is assumed exogenously rather than modeled in a production framework, and thus circumvents any economic mechanism at work. At the same time, it also speaks to the transmission vs. common shocks debate in the empirical literature: if trade is correlated with common productivity shocks, then the Frankel-Rose estimates themselves may not be informative about the role of trade in transmission as we discuss below.

Second, Kose and Yi (2006) find that the positive relationship between trade and comovement becomes much stronger under lower elasticity of substitution between domestic and foreign goods. When this elasticity is 0.9 – goods from the different countries are complements – instead of the baseline 1.5, the quantitative performance of the model in matching the data improves dramatically.

The elasticity of substitution is thus the key parameter underlying the trade-comovement relationship in quantitative models. Unfortunately, in the canonical BKK model with aggregate demand linkages, it is difficult to understand what the low elasticity of substitution – indeed, complementarity – between products coming from different countries really represents. After all, available estimates of the elasticity of substitution in consumption based on disaggregated data yield values that are far higher, typically in the range of 3 to 10 (Broda and Weinstein 2006).

This is why the notion of vertical linkages in production is so important. Indeed, while consumption elasticities tend to be high, it is reasonable to believe that elasticities in production are low. That is, inputs in production are somehow "essential," in the sense that a negative shock to one input has the potential to severely reduce the ultimate final output. The complementarity view of the production process is influential, most notably associated with Kremer (1993), and recently revived by Jones (2007 and 2008). This is the approach taken by Burstein et al. (2008). These authors model a vertical production structure in which intermediate inputs from the different countries are strong complements, and demonstrate that this assumption can generate both higher levels of output correlations, and a stronger relationship between trade intensity and those correlations.[6]

On the empirical side, ever since Frankel and Rose's original contribution the debate has been about whether transmission or common shocks are responsible for business cycle comovement across countries. Taken at face value, the Frankel and Rose result is about transmission: by emphasizing the role of trade linkages, the authors in effect argue that shocks in one country – be it to demand or productivity – propagate to another country through trade. Indeed, as detailed above, transmission is at the heart of the theoretical and quantitative literature on international business cycles.

A competing hypothesis is that countries comove simply because their shocks are correlated. An influential proponent of the common shock view is Imbs (2004). This paper argues that country pairs with a similar production structure exhibit greater business cycle synchronization because individual industries are subject to common shocks. Therefore countries

[6]Ambler, Cardia and Zimmerman (2002) and Arkolakis and Ramanarayanan (2008) also build a models with two stages and vertical production linkages across countries, and show that quantitatively, adding a second production stage does not help match either the observed levels of GDP correlations across countries, or the observed positive relationship between trade intensity and those correlations, at least with the canonical BKK elasticity of 1.5. These results are further confirmation that simply assuming two production stages may not be enough; a low elasticity is indeed important for the quantitative performance of these models. Arkolakis and Ramanarayanan (2008)'s quantitative exercise stands in stark contrast with our empirical results, and suggests that another quantitative framework, or at least a much lower elasticity of substitution, is needed to match the data.

that have a similar industrial mix will be more synchronized.[7] In the most stark form, the common shock view has no role for international trade: if industries are truly hit by common global technology or demand shocks, comovement will occur even in the complete absence of trade (and therefore transmission).

What is troubling about this debate is that with country-level data, it is very difficult to sort out the relative importance of the transmission and common shock channels, or indeed estimate either one of them reliably. For instance, the positive relationship between overall bilateral trade and comovement (Frankel and Rose 1998), or between intra-industry trade and comovement (Fidrmuc 2004, Koo and Gruben 2006, Calderon et al. 2007) is not conclusive evidence of transmission, since it could be driven by the omitted common shocks. Countries that are close to each other have high levels of bilateral trade, but their production structure could also be more similar, or monetary policy more coordinated. In this case bilateral trade could be a proxy for greater common shocks rather than transmission. Until now, the strategy adopted in the literature to deal with this estimation problem has been to run a horse race between the two types explanatory variables and see which is a more robust determinant of comovement (Imbs 2004, Baxter and Kouparitsas 2005).

This paper proposes a different approach. Estimation at the industry level allows us to sweep out many of the potential common shock explanations, and focus on results that are driven by transmission. In particular, inclusion of country-pair effects eliminates any impact of common shocks that occur at country-pair level, such as similarity in industrial structure, aggregate demand, currency unions or any other type of monetary policy coordination, among many others. In addition, the inclusion of sector (indeed, sector-pair) effects allows us to control for the impact of common global sectoral shocks that are an integral part of the Imbs (2004) explanation of comovement. In order for common shocks to drive our results, they would have to be correlated with trade at sector-pair level: a large amount of trade in Machinery in the U.K. and Textiles in the U.S. would have to be a proxy for the prevalence

[7] This is not the only mechanism through which common shocks can be rationalized. Monetary policy coordination would be another example.

of common demand and/or technology shocks in that pair of sectors, after controlling for the aggregate characteristics of the U.S.-U.K. country pair and the Machinery-Textiles sector pair. It is clear that at the level of individual sector pairs, this omitted variables problem is much less likely to arise.

In addition, the use of I-O matrices to condition the impact of trade on comovement makes it possible to focus even more squarely on transmission by specifying a particular channel: the trade in intermediate inputs. It is quite difficult to imagine a scenario in which bilateral trade at sector-pair level interacted with the I-O linkages is a proxy for a common shock.[8]

Our empirical results are thus relevant to the theoretical and quantitative literature in two respects. First, we demonstrate that transmission, rather than simply exogenous common shocks, does matter. Second, we show that vertical linkages are an important part of the explanation. Thus, modeling efforts that focus on the production structure rather than aggregate demand linkages are likely to be most fruitful. Clearly, for the vertical linkage explanation to have traction, the inputs must be sufficiently essential for the production of the final output that a negative shock to the imported intermediate input leads to a decrease in final output rather than an increase. In that sense, our results offer indirect support for the notion that inputs are essential in production (Kremer 1993, Jones 2007, Jones 2008, Burstein et al. 2008).[9]

At the same time, it is important to emphasize that our results cannot be readily mapped back into quantitative models. Partly, this is because the results in the existing quantitative literature are mostly negative, in the sense that the calibrated models featuring the various plausible mechanisms match neither the level of observed output correlations, nor the elastic-

[8]The strategy of interacting bilateral sector trade with the Input-Output matrix can be interpreted as a difference-in-differences model in the spirit of Rajan and Zingales (1998). The identifying assumption is that if trade is to matter for the transmission of shocks, it will matter systematically more in sectors technologically characterized by greater Input-Output linkages. Though we do not emphasize it in the empirical analysis, under this interpretation our estimates can be seen as evidence of the causal impact of trade on comovement.

[9]Unfortunately, greater progress on the issue of complementarities in the production process is currently not possible due to lack of sufficiently detailed production elasticity measures. Nonetheless, below we report a set of preliminary checks using the available elasticity measures that yield sensible conclusions.

ity of those correlations with respect to bilateral trade. Thus, there is no natural dominant theory to which our results can be benchmarked. More importantly, the novel findings in our paper are about variation across sectors rather than aggregate variables. Thus, in order to explore our results in a theoretical setting, a model must feature many sectors and a realistic Input-Output structure. While such efforts have been undertaken in closed economy settings (Long and Plosser 1983, Horvath 1998, Horvath 2000, Carvalho 2008), open economy versions of these frameworks have not to our knowledge been developed. This type of modeling exercise thus remains a fruitful avenue for future research.

2.4 Data and Summary Statistics

Data on sectoral production come from the UNIDO Industrial Statistics Database. We use the version that reports data according to the 3-digit ISIC Revision 2 classification for the period 1963-2003 in the best cases. There are 28 manufacturing sectors, plus the information on total manufacturing. We dropped observations that did not conform to the standard 3-digit ISIC classification, or took on implausible values, such as a growth rate of more than 100% year to year.[10] The resulting dataset is a panel of 55 countries. Though it is unbalanced, the country, sector, and year coverage is reasonably complete in this sample. We calculate correlations of the growth rates of real output in a sector, computed using sector-specific deflators.[11] We then combine information on sectoral production with bilateral sectoral trade flows from the World Trade Database (Feenstra et al. 2005). This database contains trade flows between some 150 countries, accounting for 98% of world trade. Trade flows are reported using the 4-digit SITC Revision 2 classification. We convert the trade flows from SITC to ISIC classification and merge them with the production data. The final sample is for the period 1970–99, giving us three full decades.

[10]The latter is meant to take out erroneous observations, such those arising from sector re-classifications. It results in the removal of less than 1% of yearly observations, and does not affect the results. The coarse level of aggregation into 28 sectors (e.g. Food Products, Apparel, and Electrical Machinery) makes it highly unlikely that a sector experiences a genuine takeoff of doubling production from year to year.

[11]A previous version of the paper carried out the analysis using instead the OECD production data from the STAN database. The results were virtually the same as those obtained with the OECD–OECD subsample of the UNIDO database used here, and we do not report them to conserve space.

We employ four indicators of bilateral trade intensity. Following Frankel and Rose (1998), our measures differ from one another in the scale variable used to normalize the bilateral trade volume. In particular, the first two measures normalize bilateral sectoral trade with output, either at the aggregate or sector level:

$$\text{Trade}_{ij}^{cd} = \log\left(\frac{1}{T}\sum_t \frac{X_{i,t}^{cd} + X_{j,t}^{dc}}{Y_t^c + Y_t^d}\right) \qquad \text{(Measure I)}$$

$$\text{Trade}_{ij}^{cd} = \log\left(\frac{1}{T}\sum_t \frac{X_{i,t}^{cd} + X_{j,t}^{dc}}{Y_{i,t}^c + Y_{i,t}^d}\right) \qquad \text{(Measure II)}$$

where $X_{i,t}^{cd}$ represents the value of exports in sector i from country c to country d, Y_t^c is the GDP of country c and $Y_{i,t}^c$ is the output of sector i in country c in period t.

The two alternative intensity measures normalize bilateral sector-level trade volumes by the overall trade in the two countries:

$$\text{Trade}_{ij}^{cd} = \log\left(\frac{1}{T}\sum_t \frac{X_{i,t}^{cd} + X_{j,t}^{dc}}{(X_t^c + M_t^c) + (X_t^d + M_t^d)}\right) \qquad \text{(Measure III)}$$

$$\text{Trade}_{ij}^{cd} = \log\left(\frac{1}{T}\sum_t \frac{X_{i,t}^{cd} + X_{j,t}^{dc}}{(X_{i,t}^c + M_{i,t}^c) + (X_{i,t}^d + M_{i,t}^d)}\right) \qquad \text{(Measure IV)}$$

where $X_{i,t}^c$ ($M_{i,t}^c$) is the total exports (imports) of sector i of country c, and X_t^c is the total manufacturing exports of country c. In all of our regressions, the intensity measures are averaged over the sample period and their natural logs are used in estimation. In addition, we carried out estimation using the levels of these measures, and the results were robust (see Appendix B).[12]

Appendix Table A1 reports the list of countries in our sample, the average correlation of manufacturing output between the country and other ones in the sample, and the average of the total manufacturing trade relative to GDP over the sample period. For ease of comparison, we break down the countries into the OECD and non-OECD subsamples. The differences between countries in the business cycle comovement and trade openness are pronounced. The most correlated countries tend to be in Western Europe (Italy, France,

[12] The Exports_i^{cd} measures used in specifications (5) and (6) are straightforward modifications of Measures I through IV that use only unidirectional trade, e.g. $\text{Exports}_i^{cd} = \log\left(\frac{1}{T}\sum_t \frac{X_{i,t}^{cd}}{Y_t^c + Y_t^d}\right)$.

Spain), while many of the poorest countries in the sample have an average correlation close to zero or even mildly negative. The share of manufacturing trade in GDP ranges from 8% in India to 190% in Singapore. Appendix Table A2 reports the average correlations in the North-North, South-South, and North-South subsamples. OECD countries are on average considerably more correlated with the other OECD countries (average correlation of 0.397) than non-OECD countries (average of 0.091), while the South-South sample is the least correlated (average 0.065).

Appendix Table A3 presents the list of sectors used in the analysis and some descriptive statistics, such as the average correlation of output growth of each sector between country pairs, and the average of the total trade of each sector of a country to its GDP. The average within-sector bilateral correlation, at 0.090, is some 25% lower than that of total manufacturing output in the full sample. However, there are also differences in correlations across sectors. For example, the average bilateral correlation of the Paper and Products sector is around 0.228 while the correlation for the Tobacco sector is almost zero. The average cross-sector correlation is 0.068, somewhat lower than the within-sector correlation. There are also large differences in the degree of openness across sectors.

A potential issue in this analysis is that we consider the manufacturing sector only, whereas previous work studied correlations of overall GDP's. We check whether our results are informative about the overall business cycle correlations in two ways. First, Figure 1 reports the scatterplot of bilateral GDP correlations against bilateral total manufacturing correlations in our sample. The relationship is positive, with the correlation coefficient of 0.41 and Spearman rank correlation of 0.39. Second, Appendix Table A4 reports the canonical Frankel-Rose regression with GDP correlations on the left-hand side along with a specification that uses manufacturing correlations instead. The two give very similar results, in both the coefficient magnitudes and the R^2's. It is clear that by focusing on manufacturing only, we will not reach results that are misleading for the overall economy. Figure 2 reports the scatterplot of bilateral correlations of the total manufacturing output against the four measures of trade openness. As had been found in the large majority of the literature, there is a strong positive association between these variables.

The I-O matrices come from the U.S. Bureau of Economic Analysis. We use the 1997 Benchmark version, and build a Direct Requirements Table at the 3-digit ISIC Revision 2 level from the detailed Make and Use tables and a concordance between the NAICS and the ISIC classifications. As defined by the BEA, the (i, j)th cell in the Direct Requirements Table gives the amount of a commodity in row i required to produce one dollar of final output in column j. From the Direct Requirements Table, we then construct the Total Requirements Table in the standard way.[13] The Total Requirements Table records both the direct requirement – how much Textiles are needed to make one dollar's worth of Apparel – as well as the indirect requirements – if it takes Electrical Machinery to make Textiles, and Textiles in turn are used by Apparel, then the Apparel sector in effect uses Electrical Machinery as an input indirectly. By construction, no cell in the Total Requirements Table can take on values greater than 1. This is the table we use in estimation.[14]

Figure 3 presents a contour plot of the I-O matrix. Darker colors indicate higher values in the cells of the matrix. Two prominent features stand out. First, the diagonal elements are often the most important. That is, at this level of aggregation, the most important input in a given industry tends to be that industry itself. In our estimation, we will attempt to take this into account. Second, outside of the diagonal the matrix tends to be rather sparse, but there is a great deal of variation in the extent to which industries use output of other sectors as intermediates. To get a sense of the magnitudes involved, Appendix Table A3 presents for each sector the "vertical intensity," which is the diagonal element of the Total Requirements Table. It is clear that sectors differ a great deal in the extent to which they

[13] Let D be the Direct Requirements Table. The Total Requirements Table is then given by: $T = D\left[I - D\right]^{-1}$, where I is the identity matrix.

[14] Two points are worth noting about the use of the Total Requirements Table. First, this table records the overall use of intermediate products, rather than of imported intermediates only. Conceptually, we would like to capture the technological requirements of industries, whereas the imports-only I-O table confounds technological requirements with trade policy variation and comparative advantage. It is therefore preferable to use the overall Total Requirements Table. Second, an alternative approach would be to use the Direct Requirements Table. This would be preferable, for instance, if at the business cycle frequencies trade did not affect the indirect input usage due to inventories or lags in production. We carried out the analysis using the Direct Requirements Table, and the results were virtually the same.

use themselves as intermediates, with vertical intensity ranging from 0.012 in Miscellaneous petroleum and coal products to 0.606 in Non-ferrous metals. Its mean value across sectors is 0.165. We also present what we call "upstream intensity," which is the sum of the columns in the I-O matrix (excluding the diagonal term). Upstream intensity captures the total amount of intermediates from other sectors required to produce one dollar of output in each sector. We can see that there is a great deal of variation in this variable as well. It ranges from 0.060 in Petroleum refineries to 0.709 in Footwear, with a mean of 0.393. Note that in our estimation we will of course exploit variation in the I-O matrix cell-by-cell.

The I-O matrix we use in baseline estimation reflects the input use patterns in the United States. Therefore our approach, akin to Rajan and Zingales (1998), is to treat IO_{ij} as a technological characteristic of each sector pair, and apply it across countries uniformly. How restrictive is this assumption? Fortunately, we can check this using the GTAP4 database, which contains information on I-O matrices for many countries. We do not use it in the baseline estimations because it contains information on only 17 distinct manufacturing sectors. However, we can use it to check whether the I-O matrices look radically different among the countries in the sample. It turns out that the I-O matrices are quite similar across countries. For instance, the correlation of the diagonal elements of the I-O matrix (vertical intensity) between the U.S. and the U.K. is 0.91. Taking vertical intensities of the 19 developed countries in the GTAP4 database, the first principal component explains 40% of the variation, suggesting that the diagonals of the I-O matrices are quite similar across countries. The same could be said for the upstream intensity, as defined above. The correlation between sector-level upstream intensity between the U.S. and the U.K., for instance, is 0.75, and the first principal component explains 60% of the variation in upstream intensity across the countries in the sample. We estimated all specifications using the average of the I-O matrices across the countries in the sample, and the results were robust.[15]

Finally, we highlight two other features of this I-O matrix: i) the level of aggregation,

[15]It is also important to note that the I-O matrix contains information only on intermediate input usage, but not capital or labor, the two factors of production likely to vary the most across countries.

and ii) the lack of variation over time. Clearly, I-O matrices can be obtained at a much more disaggregated level. However, in this empirical analysis we are constrained by the availability of production data: industry-level output is not available at a more finely disaggregated level for a sufficiently long time period and large enough sample of countries. Regarding the lack of variation over time, it is likely that the relatively coarse level of aggregation is helpful in this regard. Though the finely classified inputs might change over time, the broad production process is relatively more stable. For example, the Apparel industry may over time switch from Cotton to Synthetic Textiles. However, the overall amount of Textiles used by the Apparel sector is unlikely to undergo major changes.

3 Results

Table 1 presents the results of estimating equation (3). There are four panels, one for each measure of trade linkages. Column (1) reports the simple OLS regression without any fixed effects. Column (2) adds country and sector effects, while column (3) includes country×sector effects. Finally, column (4) is estimated using country-pair and sector-pair effects. For ease of reading the tables and to reduce the number of decimal points, the regression coefficients and standard errors reported throughout are multiplied by 1000 (equivalently, all of the regressors are multiplied by 1/1000 prior to estimation.

There is a positive relationship between the strength of bilateral sectoral trade linkages and sector-level comovement. Although the trade intensity coefficients tend to become less significant with the inclusion of more stringent fixed effects, they are significant at the 1% level in all cases. It is notable that the magnitude of the coefficient is roughly ten times lower than in the aggregate Frankel-Rose specifications. The two specifications are not directly comparable, however, as they capture distinct economic phenomena. In addition, we show below that the estimated sector-level coefficient magnitudes are in fact fully consistent with the estimated aggregate impact.

As we described above, some of the recent literature focuses on the role of intra-industry trade in particular. To isolate whether trade has a special role for within-sector correlations, we estimate equation (4), in which the coefficient on the trade variable is allowed to be different for observations with $i = j$. That is, bilateral trade is allowed to affect the correlation of Textiles in the U.S. with Textiles in the U.K. differently than the correlation of Textiles in the U.S. with Apparel (or Machinery) in the U.K.. Table 2 presents the results. The structure of this table is similar to the previous one, with columns 1 through 4 differing in the configuration of fixed effects they use. It is clear that the coefficient on the within-sector trade is about 4-5 times the size of the coefficient on cross-sector trade, and always significantly different at the 1% level. There is indeed something about the within-sector transmission of shocks through trade. In estimating the next specification, we attempt to understand the sources of this difference, while in the calculation of aggregate impact, we assess its quantitative importance for the aggregate comovement.

3.1 Vertical Production Linkages, Trade, and Comovement

Next, we estimate the role of vertical production linkages in explaining comovement within sector pairs. Table 3 presents the results of estimating equation (5). Once again, there are four panels that use different measures of trade intensity. Column (1) reports the simple OLS regression without any fixed effects. Column (2) adds country and sector effects, while column (3) includes country$\times$sector effects. Finally, column (4) is estimated using country-pair and sector-pair effects.

There is a highly statistically significant relationship between trade intensity interacted with I-O linkages and cross-sector comovement in all specifications. The positive coefficient implies that sector pairs that use each other heavily as intermediates experience a higher elasticity of comovement with respect to bilateral trade intensity. Note also that the main effect of trade is remains highly significant. That is, vertical linkages are a significant determinant of comovement as well as of the role of trade in increasing comovement. But they are clearly not the whole story. Section 4 calculates how much of trade's impact on aggregate comovement can be explained by vertical linkages.

Finally, Table 4 reports estimation results for equation (6). These establish whether the impact of I-O linkages is different for within-sector comovement compared to cross-sector comovement. This might be especially important in light of our earlier observation that the diagonal elements of the I-O matrix tend to be much larger than the off-diagonal elements. The four panels and configurations of fixed effects are the same as in the previous table. The results here are somewhat ambiguous. Though the within-sector coefficient is still significantly greater than the cross-sector coefficient, the inclusion of I-O linkages reduces this difference in half. That is, once the intermediate input linkages are taken into account – and these tend to be more important with within-sector observations – the elasticity of comovement with respect to trade becomes much more similar for intra- and inter-industry observations.

Our empirical strategy rests in part on the variation in the I-O coefficients across sector pairs. However, another important characteristic of sector pairs that should affect the trade-comovement relationship is the elasticity of substitution between goods in consumption or inputs in production. As discussed in detail in section 2.3, in sector pairs with higher elasticity of substitution, greater trade will raise comovement by less (indeed, it may even make it negative). In Table 5 we examine this possibility, using two types of elasticities. The first comes from Luong (2008), which to our knowledge is the only study that estimates, for each sector, the elasticity of substitution among intermediate inputs in that sector. The second is the elasticity of substitution in consumption among varieties within an individual sector, from Broda and Weinstein (2006, henceforth BW).[16]

The four panels in Table 5 use the four measures of trade openness. Each specification

[16] We must emphasize that neither of these are exactly what we need. What would be required to control for the complementarity/substitutability issue fully is to have information on the elasticity of substitution between every pair of sectors (in production or consumption). Then, we could condition the impact of trade on the correlation between a pair of sectors on the elasticity of substitution between those two sectors. Unfortunately, pair-wise elasticities do not exist. Luong's estimates impose the same elasticity of substitution on all intermediate inputs in each sector. Thus, in the Apparel industry, for instance, inputs of Textiles have the same elasticity of substitution as inputs of Machinery. As such, we cannot exploit variation within a final output sector across intermediate input sectors. BW compute elasticities in consumption among varieties in a sector. Thus, the BW elasticity for Apparel will reflect the substitution between different varieties of Apparel, rather than substitution between Apparel and Textiles, or Apparel and Machinery. Thus, in a sector-pair-level regression, the BW elasticities are even less appropriate than Luong's, because unlike Luong's, they do not have any cross-sector content.

is estimated controlling for country-pair and sector-pair effects. Column 1 reports the specification in which sector-level trade is interacted with the Luong elasticity, while column 2 interacts trade with the BW elasticity.[17] We can see that neither the main effect of bilateral trade, nor the interaction of the trade variable with the I-O linkage is affected by the inclusion of the elasticity of substitution as an additional control. Intriguingly, for all the shortcomings of these elasticity measures, the sign of the coefficients goes in the direction predicted by theory: greater trade increases comovement by *less* in sectors with *higher* elasticities of substitution.

Another aspect of our empirical strategy that deserves attention is the decision to use the log of bilateral trade rather than the level in estimation. The reason we chose the log specification as our baseline is that the trade ratios in levels are extremely skewed, and thus a tiny share of the top values of the trade ratios affect the estimated coefficient a great deal. Appendix B discussed the levels vs. logs issue in details, and reports the full set of estimates using levels rather than logs. All of the main results are robust to estimation in levels. To further assess robustness of these results, Appendix Table A5 repeats the analysis above for correlations computed on HP-filtered data rather than on growth rates. It is evident from these tables that the results are by and large the same when using HP-filtered data.

4 The Impact of Sector-Level Trade on Aggregate Comovement

The preceding section estimates the impact of bilateral sectoral trade on sector-level comovement, focusing in particular on two aspects of this relationship: intra-industry trade and intermediate input linkages. In this section, we use these estimates to quantify the relative importance of each of these on aggregate comovement.

The identity in equation (2) relates the correlation of aggregate output growth ρ^{cd} between two countries c and d to the correlations ρ_{ij}^{cd} between each pair of individual sectors i and

[17] Since the elasticity of substitution varies at the sector level only, the main effect is absorbed by sector-pair effects.

j in those two countries. A change in these bilateral sector-pair correlations leads to the change in the aggregate correlation equal to:

$$\Delta\rho^{cd} = \frac{1}{\sigma^c\sigma^d}\sum_{i=1}^{\mathcal{I}}\sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d \Delta\rho_{ij}^{cd}. \tag{7}$$

As we note in Section 2, σ^c and σ^d are the standard deviations of the aggregate manufacturing growth in countries c and d; σ_i^c and σ_j^d are the standard deviations of the growth rate of individual sectors in each economy; and s_i^c and s_j^d are the shares of sectors i and j in aggregate output of countries c and d, respectively. Since aggregate correlation is simply additive in all of the bilateral sector-pair correlations, this expression is an exact one rather than an approximation.

The empirical analysis above estimates the impact of bilateral trade on ρ_{ij}^{cd}. Thus, we can compute the change in the aggregate volatility brought about by a symmetric increase in bilateral trade between these two countries. According to the estimates of the baseline equation (3),

$$\Delta\rho_{ij} = \beta_1 \times \Delta\text{Trade}_{ij}^{cd}. \tag{8}$$

The value of $\Delta\text{Trade}_{ij}^{cd}$ corresponds to moving from the 25$^{\text{th}}$ to the 75$^{\text{th}}$ percentile in the distribution of bilateral trade intensity in the sample. This is equivalent to going from the level of bilateral manufacturing trade as a share of GDP of 0.004% (Bolivia-Mexico) to 0.07% (U.S.-Indonesia). The thought experiment is a symmetric rise in bilateral trade in all sectors for a given country pair. Thus, the exercise is meant to capture mainly the consequences of cross-sectional variation in bilateral trade intensity between countries, and maps most precisely to the existing literature, which examines aggregate trade and correlations. Note that since the trade variables are taken in logs, we are evaluating the impact of an identical proportional increase in trade in all sectors, rather than an absolute increase.

Plugging $\Delta\rho_{ij}$ from equation (8) in place of $\Delta\rho_{ij}^{cd}$ in equation (7) yields the corresponding change in the aggregate correlation between each country pair, $\Delta\rho^{cd}$. Note that this comparative static is carried out under two assumptions. The first is that the change in bilateral trade we consider here does not affect sector-level and aggregate volatilities (σ_i^c's and σ^c's).

This assumption may not be innocuous if, for example, bilateral trade for a given country-pair also represents a large share of total trade for one or both countries. If the change in bilateral trade is large enough to substantially affect the overall trade openness, di Giovanni and Levchenko (2007) show that it will affect both industry-level and aggregate volatility. However, in our sample of countries it is rarely the case that bilateral trade between any pair of countries accounts for a substantial share of the country's overall trade. In addition, the regression models include various combinations of country and sector-level fixed effects that absorb the trade-volatility relationship at the country level. The second assumption is that bilateral trade does not affect the similarity of the two countries' industrial structure (i.e. the $s_i^c s_j^d$ terms). A previous version of the paper estimated this effect and found it to be quantitatively tiny, so we do not treat it here. The result that the impact of bilateral trade on sectoral similarity is small has also been reported by Imbs (2004). Though these two channels do not appear to be quantitatively important, they must be kept in mind when interpreting our comparative statics. To be precise, the results below report the impact of bilateral trade on aggregate comovement *due exclusively to changes in sector-pair level comovement.*

We report the mean value of $\Delta\rho^{cd}$ across all of the country pairs in our data in the first row of Table 6. Note that this calculation gives different values across country pairs because we use actual values of s_i^c, s_j^d, σ_i^c, σ_j^d, σ^c, and σ^d for each country and sector in this calculation. The standard deviations of aggregate and sector-level growth rates are computed over the entire sample period, 1970–99, and the shares of sectors in total output are averages over the same period. On average in this sample, the standard deviation of aggregate manufacturing output is $\bar{\sigma}^c = \bar{\sigma}^d = 0.0518$, while the average standard deviation of a sector is $\bar{\sigma}_i^c = \bar{\sigma}_j^d = 0.1208$. The mean share of an individual sector in total manufacturing is $\bar{s}_i^c = \bar{s}_j^d = 0.034$. Since this calculation uses an estimated coefficient β_1, the table reports the mean of the standard error of this estimate in parentheses. Not surprisingly, because β_1 is highly statistically significant, the change in the aggregate correlation implied by our estimates is highly significant as well.

Our calculation implies that in response to moving from a 25th to the 75th percentile in bilateral trade openness, aggregate correlation increases by 0.031, which is equivalent to 0.14 standard deviations of aggregate correlations found in the sample. How does the total effect we obtain by adding up the changes in individual sector-pair correlations compare to the change in comovement obtained from the aggregate Frankel-Rose regression for the manufacturing sector? Using the estimates in column (1) of Appendix Table A4, we calculate that the same change in bilateral trade when applied to these estimates results in an increase in bilateral correlation of 0.046. This implies that our procedure captures about two-thirds of the magnitude implied by the aggregate relationship. Note that there is no inherent reason that these two sets of estimates should match perfectly, as the sector-pair-level estimation uses a much more stringent array of fixed effects than is possible in the canonical Frankel-Rose regression.

The more interesting results concern the relative importance of within- and cross-sector trade in the total estimated impact of trade reported above. To that end, we use the coefficient estimates in equation (4) to break down the change in correlation depending on whether trade occurs in the same sector or not:

$$\begin{aligned} \Delta\rho_{ij} &= \beta_1 \times \Delta\text{Trade}_{ij}^{cd} \\ \Delta\rho_{ii} &= (\beta_1 + \beta_2) \times \Delta\text{Trade}_{ij}^{cd}. \end{aligned} \tag{9}$$

Combining these expressions with equation (7), we decompose the overall effect of trade openness on comovement into the Within-Sector component and the Cross-Sector component:

$$\Delta\rho^{cd} = \underbrace{\frac{1}{\sigma^c\sigma^d}\sum_{i=1}^{\mathcal{I}} s_i^c s_i^d \sigma_i^c \sigma_i^d \Delta\rho_{ii}}_{\text{Within-Sector Component}} + \underbrace{\frac{1}{\sigma^c\sigma^d}\sum_{i=1}^{\mathcal{I}}\sum_{j\neq i}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d \Delta\rho_{ij}}_{\text{Cross-Sector Component}} \tag{10}$$

The second row of Table 6 reports the results. The Within-Sector component contributes only about 0.006 to increased aggregate correlation, accounting for about 18% of the total estimated effect. The Cross-Sector component contributes the remaining 82%. These results are that much more striking because the estimated coefficient on within sector trade, $(\beta_1 + \beta_2)$, is four to five times the magnitude of the cross-sector trade, β_1. Nonetheless, the

Within-Sector trade accounts for only a small minority of the total impact. This goes against the conclusions of aggregate-level studies such as Koo and Gruben (2006), or Calderon et al. (2007) that argue for the importance of intra-industry trade for aggregate comovement. If intra-industry trade matters, we demonstrate that it is not because it increases comovement within the same sectors. What is the intuition for this result? Our estimates show that bilateral trade between two countries increases comovement both within sectors and across sectors. However, a typical individual sector is quite small relative to the economy. As we report above, the typical share of an individual sector in total output is less than 4%. Thus, there is limited scope for the increased correlation between, say, the Textile sector in the U.S. and the Textile sector in the U.K. to raise aggregate comovement. However, we also find that more trade in Textiles raises the correlation between Textiles in the U.S. and every other sector in the U.K. Since the sum of all other sectors except Textiles is quite large, the cross-sector correlation has much greater potential to increase aggregate comovement.[18]

We now move on to the role of vertical production linkages and bilateral trade in generating comovement between countries. Using our estimates of equation (5), a given change in trade openness produces the following change in sector-pair correlation:

$$\Delta\rho_{ij} = \beta_1 \times \Delta\mathrm{Trade}_{ij}^{cd} + \gamma_1 \times (\mathrm{IO}_{ij} + \mathrm{IO}_{ji}) \times \Delta\mathrm{Trade}_{ij}^{cd}. \tag{11}$$

Note that in this case, even though we apply the same change in trade openness, $\Delta\mathrm{Trade}_{ij}^{cd}$, to each sector pair ij, the actual resulting change in correlation will be different across sector pairs, due to input-output linkages IO_{ij} and IO_{ji}. With this in mind, we decompose the total estimated effect of trade on aggregate comovement into what we call the Main Effect and

[18] One might be concerned that the reason we get a small impact of intra-industry comovement on the aggregate is that we study a change in trade that is the same for within- and cross-sector pairs, while in the data most trade could be intra-industry. In our exercise, it is actually not possible to consider a change in intra-industry trade that would be different from a change in cross-industry trade. This is because an increase in sector i exports from country c to country d changes Trade_{ii}^{cd}, but also Trade_{ij}^{cd} for every other sector j. Economically, this means that we must allow for – and estimate – the impact of an increase in exports in sector i not only on the within-sector correlation ρ_{ii}, but also the cross-sector correlation ρ_{ij} for every j.

the Vertical Linkage Effect:

$$\Delta\rho^{cd} = \underbrace{\frac{1}{\sigma^c\sigma^d}\sum_{i=1}^{\mathcal{I}}\sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d \beta_1 \Delta\text{Trade}_{ij}^{cd}}_{\text{Main Effect}} + \underbrace{\frac{1}{\sigma^c\sigma^d}\sum_{i=1}^{\mathcal{I}}\sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d \left(\text{IO}_{ij} + \text{IO}_{ji}\right)\gamma_1 \Delta\text{Trade}_{ij}^{cd}}_{\text{Vertical Linkage Effect}} \tag{12}$$

The results are reported in the first row of Table 7. The estimates of equation (5) imply that the change in bilateral trade we are considering raises aggregate comovement by about 0.035, which is slightly larger than 0.031 obtained from estimates of equation (3). Applying the reported average standard errors, it turns out that this difference is not statistically significant, however. More interestingly, our estimates show that the Vertical Linkage Effect accounts for 32% of the total impact of increased bilateral trade on aggregate comovement, with the remaining 68% due to the Main Effect.

Finally, we can break down both the Main and the Vertical Linkage Effects into the Within- and the Cross-Sector components using our estimates of equation (6). The last row of Table 7 reports the results. What is remarkable is how different is the behavior of the two effects in Within- and Cross-Sector observations. Above, we found that the Within-Sector component accounts for 18% of the total impact of trade on aggregate volatility. By contrast, the Within-Sector component accounts for 34% of the Vertical Linkage Effect (0.003 out of 0.009). Not surprisingly, since the diagonal elements of the I-O matrix tend to be large, there is more scope for vertical transmission of shocks through within-industry trade. Indeed, in this set of estimates, just the Within-Sector component of the Vertical Linkage Effect on its own accounts for 9% of the total increase in comovement, accounting for half of the 18% implied by equation (4). Nonetheless, the lion share of the total impact (63%) is accounted by the Cross-Sector, Main Effect.

4.1 Heterogeneity Across Country Pairs

Tables 6 and 7 report the mean impacts of trade openness on aggregate volatility in our sample of country pairs. But the change in aggregate correlation is calculated for each country pair, and depends on country-pair characteristics. What can we say about the variation in the estimated impact across countries? In the remainder of this section we explore this question in two ways.

First, Figure 4 reports the histogram of estimated impacts of bilateral trade on aggregate comovement. There is significant variation across country pairs, with the change in correlation ranging from 0.012 to 0.075. Half of the observations are fairly close to the mean impact of 0.031 reported in Table 6: the 25th percentile impact is 0.024, and the 75th percentile 0.036. What can we say about the relative importance of the vertical transmission channel in this sample? It turns out that among country pairs in our sample, the share of the overall impact due to the vertical transmission channel ranges from 18 to 46% (the mean, reported above, is 32%). The 25th to 75th range is much narrower, however, from 30 to 34%. Thus, the relative importance of the vertical transmission channel does not appear to vary that much across country pairs.

The discussion above reveals the variation in the estimated impact of trade as it depends on country characteristics. However, it uses the same full-sample coefficient estimates for each country pair. Thus, it ignores the possibility that the impact of international trade itself differs across country samples. To check for this, we re-estimated the specifications in this paper on three subsamples: North-North, in which both trading partners are OECD countries; South-South, in which both partners are non-OECD countries, and finally North-South. Table 8 reports the results of estimating equations (3) through (6) comparing the three subsamples side-by-side. We only report the specifications that use our preferred configuration of fixed effects: country-pair and sector-pair. The impact of international trade, as well as the relative importance of the vertical transmission channel differ a great deal between subsamples. These estimates reveal that both are primarily a phenomenon relevant to the North-North trade. Table 9 summarizes the aggregate impact of an identical change in bilateral trade in the three subsamples. For comparability, we consider an identical increase in bilateral trade in the three subsamples, which is the same as in the calculations above. The results are striking. Moving from the 25th to the 75th percentile in bilateral trade openness raises business cycle correlation by 0.114 in the North-North sample, a number that is more than three times larger than the full sample estimate. By contrast, trade leads to an increase in correlation of 0.028 in the South-South sample, and a tiny 0.007 in the North-South sample. The relative importance of vertical linkages is very different as well. For North-North trade, vertical linkages are responsible for only 17% of the total impact, well below the 32% full sample figure. For South-South trade, this channel is even less important, accounting for just 4% of the total. By contrast, vertical linkages account for 73% of the total impact of trade in the North-South sample.

To summarize, the picture that emerges from this analysis is a nuanced one. On the one hand, the overall impact of trade is far larger in the North-North group of countries than elsewhere. On the other hand, vertical linkages are relatively less important there, compared to the North-South trade.

5 Conclusion

This paper studies the mechanisms behind a well-known empirical regularity: country pairs that trade more with each other experience higher business cycle comovement. We start by estimating the impact of trade on comovement not just for each pair of countries, but for each pair of sectors within each pair of countries. It turns out that bilateral trade increases comovement at sector level as well. Next, we investigate the possible transmission channels behind this result. We exploit the information contained in Input-Output tables on the extent to which sectors use others as intermediate inputs, to demonstrate the importance of the vertical transmission channel. The robust finding is that sector pairs that use each other as intermediates exhibit significantly higher elasticity of comovement with respect to trade.

We then go on to quantify the relative importance of the various channels through which trade generates aggregate comovement. Though previous literature identified intra-industry trade as especially important in propagating shocks across countries, we find that the increase in within-sector correlation due to trade accounts for only about 18% of the overall impact, the rest being due to transmission across sectors. When it comes to vertical linkages, we find that they account for 32% of the impact of bilateral trade on aggregate comovement.

How should we interpret these results? On the one hand, the evidence on vertical linkages accords well with the recent quantitative studies that model transmission of shocks through production chains (Burstein et al. 2008, Huang and Liu 2007). On the other hand, we find that some 70% of the overall estimated impact is still "unexplained" by vertical linkages. Developing a theoretical and quantitative framework that can be used to fit the industry-level facts uncovered in this paper presents a fruitful direction for future research.

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Table 1. Impact of Trade on Comovement at the Sector-Level: Pooled Estimates

	I. Trade/GDP				*II. Trade/Output*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	6.64**	3.06**	2.70**	1.47**	5.79**	2.52**	2.20**	0.91**
	(0.06)	(0.08)	(0.08)	(0.09)	(0.06)	(0.07)	(0.07)	(0.09)
Observations	653,588	653,588	653,588	653,588	650,341	650,341	650,341	650,341
R_o^2	0.021	0.114	0.250	0.173	0.016	0.114	0.251	0.173
R_w^2	–	0.0024	0.0016	0.0004	–	0.0020	0.0014	0.0002
	III. Trade/Total Trade				*IV. Trade/Sector Total Trade*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	7.56**	3.19**	2.84**	1.51**	8.08**	3.13**	2.90**	1.29**
	(0.06)	(0.08)	(0.08)	(0.09)	(0.06)	(0.08)	(0.08)	(0.10)
Observations	655,011	655,011	655,011	655,011	655,011	655,011	655,011	655,011
R_o^2	0.027	0.114	0.250	0.173	0.027	0.114	0.250	0.173
R_w^2	–	0.0027	0.0019	0.0004	–	0.0024	0.0020	0.0002
$\mu_{c1} + \mu_{c2} + \mu_i + \mu_j$	no	yes	no	no	no	yes	no	no
$\mu_{c1} \times \mu_i + \mu_{c2} \times \mu_j$	no	no	yes	no	no	no	yes	no
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	no	no	no	yes	no	no	no	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. R_o^2 is the overall R^2 and R_w^2 is the within-R^2 associated with the regressor of interest. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Table 2. Impact of Trade on Comovement at the Sector-Level: Within- and Cross-Sector Estimates

	I. Trade/GDP				*II. Trade/Output*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	6.52**	2.97**	2.59**	1.35**	5.69**	2.43**	2.10**	0.81**
	(0.06)	(0.10)	(0.09)	(0.09)	(0.06)	(0.07)	(0.08)	(0.09)
Trade×Same Sector	2.95**	3.02**	3.12**	3.66**	2.75**	2.74**	2.90**	2.98**
	(0.31)	(0.29)	(0.26)	(0.30)	(0.32)	(0.29)	(0.27)	(0.29)
Same Sector	100.57**	101.69**	104.19**	–	70.30**	68.64**	71.07**	–
	(8.57)	(7.81)	(7.10)	–	(5.82)	(5.25)	(4.75)	–
Observations	653,588	653,588	653,588	653,588	650,341	650,341	650,341	650,341
R^2_o	0.022	0.115	0.251	0.173	0.017	0.115	0.251	0.173
R^2_w	–	0.0030	0.0023	0.0006	–	0.0025	0.0021	0.0003
	III. Trade/Total Trade				*IV. Trade/Sector Total Trade*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	7.44**	3.09**	2.72**	1.39**	7.94**	3.01**	2.77**	1.15**
	(0.06)	(0.08)	(0.08)	(0.10)	(0.06)	(0.08)	(0.08)	(0.10)
Trade×Same Sector	3.09**	3.23**	3.31**	3.93**	4.20**	3.80**	3.93**	3.95**
	(0.32)	(0.29)	(0.26)	(0.31)	(0.35)	(0.32)	(0.29)	(0.32)
Same Sector	93.02**	95.58**	97.22**	–	87.14**	79.04**	80.70**	–
	(7.53)	(6.85)	(6.16)	–	(5.64)	(5.10)	(4.57)	–
Observations	655,011	655,011	655,011	655,011	655,011	655,011	655,011	655,011
R^2_o	0.028	0.115	0.251	0.173	0.027	0.115	0.251	0.173
R^2_w	–	0.0034	0.0026	0.0007	–	0.0031	0.0027	0.0005
$\mu_{c1} + \mu_{c2} + \mu_i + \mu_j$	no	yes	no	no	no	yes	no	no
$\mu_{c1} \times \mu_i + \mu_{c2} \times \mu_j$	no	no	yes	no	no	no	yes	no
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	no	no	no	yes	no	no	no	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. R^2_o is the overall R^2 and R^2_w is the within-R^2 associated with the regressors of interest. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Table 3. Impact of Trade on Comovement at the Sector-Level: Vertical Linkage Estimates

	I. Trade/GDP				*II. Trade/Output*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	6.23**	2.73**	2.38**	1.11**	5.45**	2.22**	1.91**	0.62**
	(0.06)	(0.08)	(0.09)	(0.10)	(0.06)	(0.07)	(0.08)	(0.09)
Trade×IO	14.62**	15.88**	15.35**	17.50**	15.47**	14.46**	13.61**	14.77**
	(1.15)	(1.07)	(1.00)	(1.06)	(1.15)	(1.07)	(0.99)	(1.05)
Input-Output	257.45**	252.13**	244.85**	–	218.90**	172.87**	165.20**	–
	(14.95)	(13.79)	(12.79)	–	(10.25)	(9.39)	(8.64)	–
Observations	653,588	653,588	653,588	653,588	650,341	650,341	650,341	650,341
R_o^2	0.022	0.115	0.251	0.173	0.017	0.115	0.251	0.173
R_w^2	–	0.0030	0.0023	0.0006	–	0.0025	0.0021	0.0003
	III. Trade/Total Trade				*IV. Trade/Sector Total Trade*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	7.14**	2.82**	2.50**	1.12**	7.70**	2.70**	2.52**	0.87**
	(0.06)	(0.08)	(0.09)	(0.10)	(0.07)	(0.08)	(0.09)	(0.11)
Trade×IO	15.53**	17.27**	15.93**	19.12**	18.89**	20.24**	18.38**	19.62**
	(1.16)	(1.08)	(1.00)	(1.07)	(1.21)	(1.13)	(1.05)	(1.10)
Input-Output	238.14**	238.14**	223.10**	–	240.32**	204.28**	189.77**	–
	(12.97)	(11.97)	(11.02)	–	(9.76)	(8.95)	(8.24)	–
Observations	655,011	655,011	655,011	655,011	655,011	655,011	655,011	655,011
R_o^2	0.028	0.115	0.251	0.173	0.029	0.115	0.251	0.173
R_w^2	–	0.0038	0.0030	0.0009	–	0.0035	0.0032	0.0008
$\mu_{c1} + \mu_{c2} + \mu_i + \mu_j$	no	yes	no	no	no	yes	no	no
$\mu_{c1} \times \mu_i + \mu_{c2} \times \mu_j$	no	no	yes	no	no	no	yes	no
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	no	no	no	yes	no	no	no	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. R_o^2 is the overall R^2 and R_w^2 is the within-R^2 associated with the regressors of interest. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Table 4. Impact of Trade on Comovement at the Sector-Level: Vertical Linkages, Within- and Cross-Sector Estimates

	I. Trade/GDP				*II. Trade/Output*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	6.22**	2.68**	2.34**	1.09**	5.39**	2.17**	1.87**	0.60**
	(0.06)	(0.08)	(0.09)	(0.10)	(0.06)	(0.08)	(0.08)	(0.09)
Trade×Same Sector	0.72	1.47**	1.61**	1.87**	1.07*	1.48**	1.80**	1.59**
	(0.49)	(0.46)	(0.42)	(0.48)	(0.48)	(0.45)	(0.41)	(0.46)
Trade×IO	13.85**	18.24**	16.59**	17.01**	18.41**	17.22**	15.17**	15.02**
	(1.73)	(1.65)	(1.58)	(1.62)	(1.71)	(1.63)	(1.55)	(1.58)
Trade×Same Sector×IO	-0.76	-7.56**	-6.25*	-5.32*	-7.96**	-8.50**	-7.62**	-5.63*
	(2.83)	(2.63)	(2.41)	(2.66)	(2.82)	(2.61)	(2.39)	(2.60)
Same Sector×IO	-100.01**	-147.00**	-130.26**	–	-167.77**	-120.69**	-112.44**	–
	(37.38)	(34.36)	(31.22)	–	(24.94)	(22.85)	(20.62)	–
Same Sector	36.31**	59.37**	63.11**	–	29.36**	43.59**	48.95**	–
	(13.68)	(12.66)	(11.57)	–	(8.75)	(8.06)	(7.31)	–
Input-Output	291.95**	293.00**	271.44**	–	303.27**	210.03**	191.79**	–
	(22.37)	(21.21)	(20.08)	–	(15.29)	(14.54)	(13.60)	–
Observations	653,588	653,588	653,588	653,588	650,341	650,341	650,341	650,341
R_o^2	0.023	0.115	0.251	0.173	0.019	0.115	0.252	0.174
R_w^2	–	0.0036	0.0029	0.0009	–	0.0030	0.0026	0.0005
	III. Trade/Total Trade				*IV. Trade/Sector Total Trade*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	7.12**	2.77**	2.45**	1.09**	7.68**	2.64**	2.47**	0.84**
	(0.06)	(0.08)	(0.09)	(0.10)	(0.07)	(0.08)	(0.09)	(0.11)
Trade×Same Sector	0.82	1.57**	1.87**	2.01**	2.60**	2.04**	2.51**	2.00**
	(0.49)	(0.46)	(0.42)	(0.49)	(0.55)	(0.51)	(0.46)	(0.50)
Trade×IO	15.03**	20.11**	17.36**	19.16**	18.13**	22.97**	19.18**	19.99**
	(1.74)	(1.66)	(1.58)	(1.63)	(1.81)	(1.73)	(1.64)	(1.67)
Trade×Same Sector×IO	-1.37	-8.62**	-7.37**	-6.64*	-7.62*	-11.03**	-9.54**	-7.17**
	(2.85)	(2.65)	(2.41)	(2.69)	(3.03)	(2.82)	(2.56)	(2.75)
Same Sector×IO	-105.32**	-144.88**	-131.50**	–	-162.09**	-126.87**	-114.57**	–
	(32.55)	(29.90)	(26.91)	–	(24.22)	(22.22)	(19.98)	–
Same Sector	37.61*	56.78**	63.59**	–	47.18**	47.65**	54.50**	–
	(12.05)	(11.15)	(10.04)	–	(8.67)	(7.98)	(7.16)	–
Input-Output	275.20**	279.50**	249.28**	–	300.51**	236.30**	207.01**	–
	(19.36)	(18.34)	(17.22)	–	(14.63)	(13.87)	(12.96)	–
Observations	655,011	655,011	655,011	655,011	655,011	655,011	655,011	655,011
R_o^2	0.028	0.115	0.251	0.173	0.029	0.115	0.251	0.173
R_w^2	–	0.0039	0.0032	0.0010	–	0.0037	0.0033	0.0008
$\mu_{c1} + \mu_{c2} + \mu_i + \mu_j$	no	yes	no	no	no	yes	no	no
$\mu_{c1} \times \mu_i + \mu_{c2} \times \mu_j$	no	no	yes	no	no	no	yes	no
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	no	no	no	yes	no	no	no	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. R_o^2 is the overall R^2 and R_w^2 is the within-R^2 associated with the regressors of interest. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Table 5. Impact of Trade on Comovement at the Sector-Level: Vertical Linkages and Elasticities of Substitution Estimates

	I. Trade/GDP		*II. Trade/Output*	
	(1)	(2)	(1)	(2)
Trade	4.92**	2.15**	3.17**	1.50**
	(0.38)	(0.12)	(0.37)	(0.11)
Trade×IO	15.24**	17.30**	12.66**	14.63**
	(1.09)	(1.07)	(1.07)	(1.05)
Trade×(Production Elasticity)	-2.25**	–	-1.56**	–
	(0.22)	–	(0.21)	–
Trade×(Consumption Elasticity)	–	-0.17**	–	-0.14**
	–	(0.01)	–	(0.01)
Observations	541,386	653,588	539,597	650,341
R_o^2	0.195	0.174	0.195	0.174
R_w^2	0.0010	0.0013	0.0005	0.0008
	III. Trade/Total Trade		*IV. Trade/Sector Total Trade*	
	(1)	(2)	(1)	(2)
Trade	4.94**	2.43**	4.69**	2.21**
	(0.38)	(0.12)	(0.40)	(0.13)
Trade×IO	16.83**	18.89**	17.30**	19.35**
	(1.09)	(1.08)	(1.12)	(1.10)
Trade×(Production Elasticity)	-2.26**	–	-2.33**	–
	(0.22)	–	(0.23)	–
Trade×(Consumption Elasticity)	–	-0.21**	–	-0.22**
	–	(0.01)	–	(0.01)
Observations	542,604	655,011	542,604	655,011
R_o^2	0.195	0.174	0.195	0.174
R_w^2	0.0011	0.0016	0.0009	0.0015
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	yes	yes	yes	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. R_o^2 is the overall R^2 and R_w^2 is the within-R^2 associated with the regressors of interest. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. Production Elasticity taken from Luong (2008), and Consumption Elasticity taken from Broda and Weinstein (2006). μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Table 6. Impact of Trade on Aggregate Comovement: Baseline and Within vs. Cross-Sector Estimates

Specification	Total Effect	Cross-Sector Component	Within-Sector Component
Baseline: Pooled			
$\Delta\rho^{cd}$	0.031	–	–
	(0.002)	–	–
Separate Within- and Cross-Sector Coefficients			
$\Delta\rho^{cd}$	0.033	0.0268	0.0060
	(0.002)	(0.0019)	(0.0004)
Share of Total		**0.82**	**0.18**

Notes: Calculations based on specification (4), Panel I of Tables 1 and 2, respectively. The independent variable is Trade/GDP, and country-pair and sector-pair fixed effects are included. The first row corresponds to the cross-country average impact given by equation (7), while the second row corresponds to the average given by equation (10). Robust standard errors are in parentheses.

Table 7. Impact of Trade on Aggregate Comovement: Main Effect vs. Vertical Linkage Estimates

Specification	Total Effect	Main Effect		Vertical Linkage Effect	
Baseline: Pooled					
$\Delta\rho^{cd}$	0.035	0.023		0.011	
	(0.002)	(0.002)		(0.001)	
Share of Total		**0.68**		**0.32**	
		Within-Sector Component	Cross-Sector Component	Within-Sector Component	Cross-Sector Component
Separate Within- and Cross-Sector Coefficients					
$\Delta\rho^{cd}$	0.035	0.0035	0.0217	0.0032	0.0061
	(0.002)	(0.0006)	(0.0019)	(0.0006)	(0.0006)
Share of Total		**0.10**	**0.63**	**0.09**	**0.18**

Notes: Calculations based on specification (4), Panel I of Tables 3 and 4, respectively. The independent variable is Trade/GDP, and country-pair and sector-pair fixed effects are included. The first row corresponds to the cross-country average impact given by equation (12), while the second row breaks down the average impact into within- and cross-sector components. Robust standard errors are in parentheses.

Table 8. Impact of Trade on Comovement for Country-Pair Subsamples: All Specifications

	Specification I			*Specification II*		
	OECD/ OECD	non-OECD/ non-OECD	OECD/ non-OECD	OECD/ OECD	non-OECD/ non-OECD	OECD/ non-OECD
	(1)	(2)	(3)	(1)	(2)	(3)
Trade	5.69**	1.23**	0.23**	5.49**	1.21**	0.17**
	(0.27)	(0.20)	(0.12)	(0.27)	(0.20)	(0.12)
Trade×Same Sector	–	–	–	6.07**	0.48**	2.07**
	–	–	–	(0.76)	(0.65)	(0.43)
Observations	141,188	144,883	367,517	141,188	144,883	367,517
R^2_o	0.251	0.132	0.130	0.252	0.132	0.130
R^2_w	0.0032	0.0003	1.10E-05	0.0037	0.0003	0.0001
	Specification III			*Specification IV*		
	OECD/ OECD	non-OECD/ non-OECD	OECD/ non-OECD	OECD/ OECD	non-OECD/ non-OECD	OECD/ non-OECD
	(1)	(2)	(3)	(1)	(2)	(3)
Trade	5.17**	1.19**	0.08	5.15**	1.17**	0.11
	(0.28)	(0.20)	(0.12)	(0.28)	(0.20)	(0.12)
Trade×Same Sector	–	–	–	2.01+	0.81	0.81
	–	–	–	(1.12)	(1.10)	(0.69)
Trade×IO	33.75**	1.5922	7.66**	31.80**	2.39	4.39*
	(2.88)	(2.20)	(1.45)	(5.00)	(3.34)	(2.13)
Trade×Same Sector×IO	–	–	–	-3.63	-3.88	3.13
	–	–	–	(6.99)	(5.68)	(3.67)
Observations	141,188	144,883	367,517	141,188	144,883	367,517
R^2_o	0.252	0.132	0.130	0.252	0.132	0.130
R^2_w	0.0042	0.0003	0.0001	0.0042	0.0003	0.0001
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	yes	yes	yes	yes	yes	yes

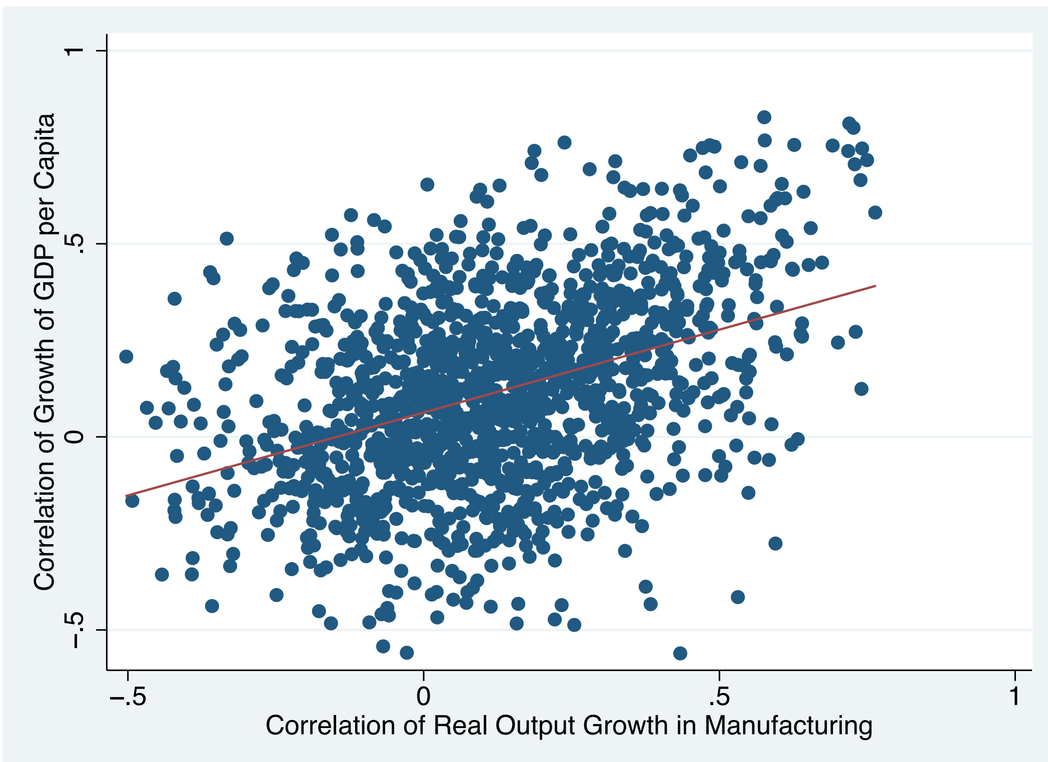
Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. R^2_o is the overall R^2 and R^2_w is the within-R^2 associated with the regressors of interest. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. In all specifications, the trade variable is normalized by GDP. All specifications include country-pair and sector-pair fixed effects. Variable definitions and sources are described in detail in the text.

Table 9. Impact of Trade on Aggregate Comovement for Subsamples: Main Effect vs. Vertical Linkage Estimates

	Total Effect	Main Effect	Vertical Linkage Effect
	OECD/OECD		
$\Delta\rho^{cd}$	0.114	0.095	0.019
	(0.005)	(0.005)	(0.002)
Share of Total		**0.83**	**0.17**
	non-OECD/non-OECD		
$\Delta\rho^{cd}$	0.028	0.026	0.001
	(0.004)	(0.004)	(0.002)
Share of Total		**0.96**	**0.04**
	OECD/non-OECD		
$\Delta\rho^{cd}$	0.007	0.002	0.005
	(0.003)	(0.003)	(0.001)
Share of Total		**0.27**	**0.73**

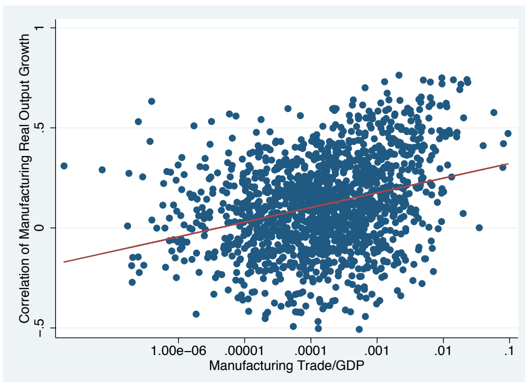
Notes: Calculations based on Specification III of Table 8. The independent variable is Trade/GDP, and country and sector-pair fixed effects are included. The row corresponds to the cross-country average impact given by equation (12). Robust standard errors are in parentheses.

Figure 1. Correlation of Real GDP Growth vs. Correlation of Real Manufacturing Output Growth

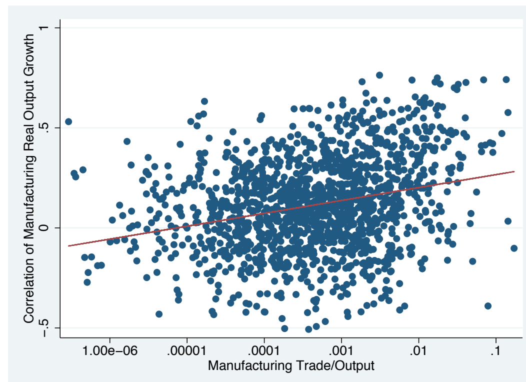


Notes: The x-axis variable is the correlation of manufacturing real output growth between country pairs. The y-axis is the correlation of real GDP growth computed using data from the WDI. In total, there are 1496 country pairs.

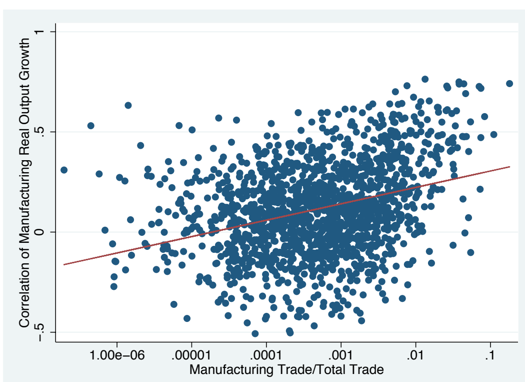
Figure 2. Correlation of Real Manufacturing Output Growth vs. Trade Ratios



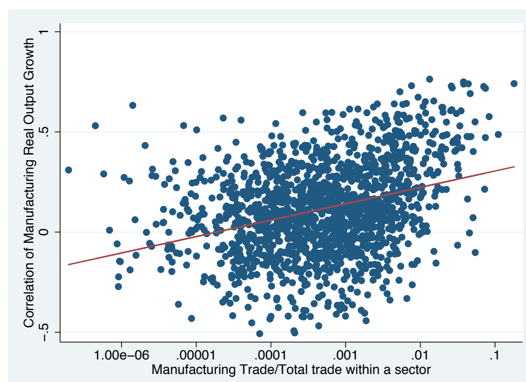
(a)



(b)



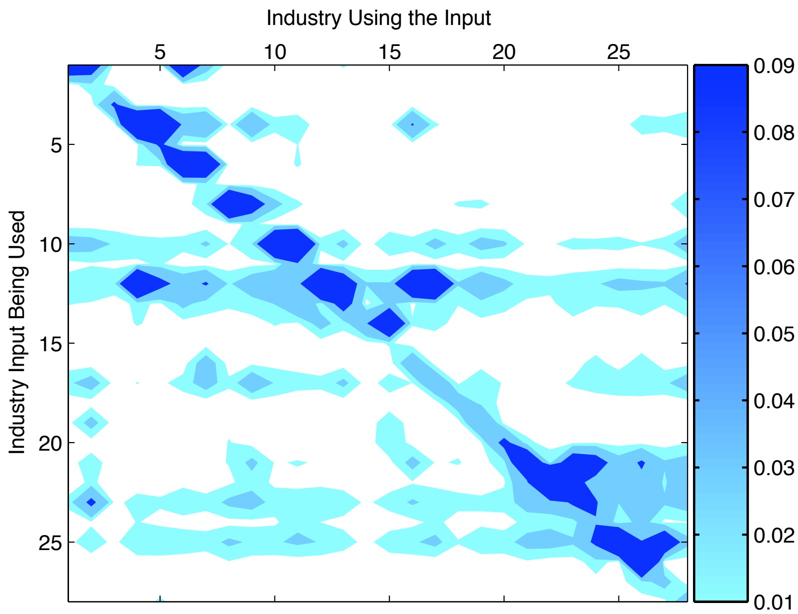
(c)



(d)

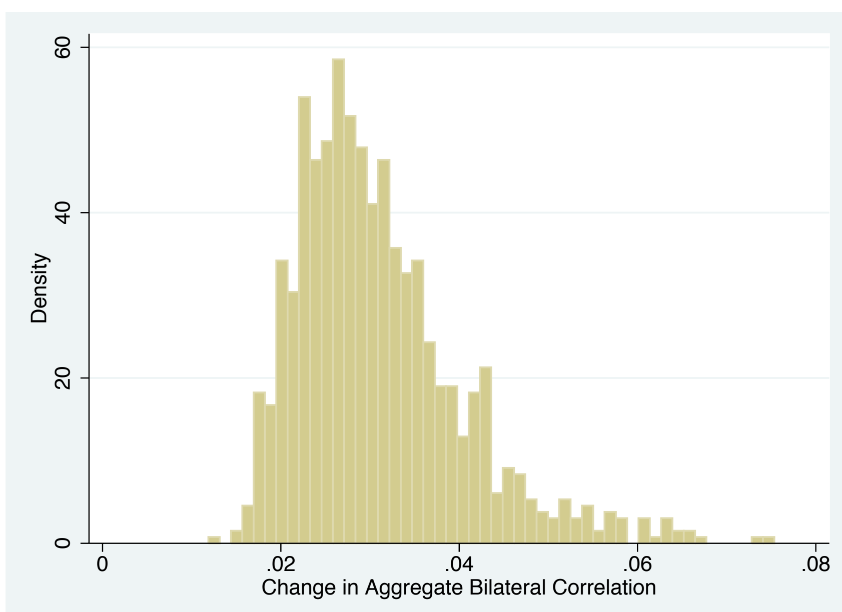
Notes: The y-axis variable for all figures is the correlation of manufacturing real output growth. The x-axis has a log scale, and variables are (a) Log(Manufacturing Bilateral Trade/GDP), (b) Log(Manufacturing Bilateral Trade/Output), (c) Log(Manufacturing Bilateral Trade/Total Trade), and (d) Log(Manufacturing Bilateral Trade/Total Trade within a Sector), respectively.

Figure 3. Contour Representation of the BEA Input-Output Matrix for 28 Manufacturing Sectors



Notes: The figure represents the Total Requirements Table constructed from the BEA Input-Output data for 28 manufacturing sectors. A darker color implies that an industry is used by another at a higher rate than an industry-pair with a lighter color. The cut-off rates, from light to dark, are 0.01, 0.03, and 0.09, respectively.

Figure 4. Impact of Trade on Bilateral Aggregate Correlation Across Country Pairs



Notes: This figure reports the histogram of the impact of a change in bilateral trade intensity on aggregate bilateral correlation for the country pairs in the sample. Calculations are based on specification (4) in Table 1, and correspond to the magnitude calculations in the first row of Table 6.

Appendix A Supplementary Tables

Table A1. Country Summary Statistics: 1970–99

Country	Average correlation	Trade/ GDP	Country	Average correlation	Trade/ GDP
Australia	0.128	0.175	Bangladesh	0.101	0.120
Austria	0.161	0.427	Bolivia	0.099	0.230
Belgium-Luxembourg	0.247	0.874	Chile	0.152	0.268
Canada	0.195	0.369	Colombia	0.233	0.163
Denmark	0.175	0.421	Costa Rica	0.182	0.383
Finland	0.156	0.409	Cyprus	0.170	0.571
France	0.271	0.265	Ecuador	0.134	0.192
Greece	0.214	0.240	Egypt, Arab Rep.	-0.047	0.222
Ireland	0.145	0.734	Fiji	0.121	0.522
Italy	0.272	0.266	Guatemala	0.057	0.231
Japan	0.253	0.139	Honduras	-0.018	0.436
Netherlands	0.226	0.672	Hong Kong, China	0.135	1.278
New Zealand	0.021	0.351	Hungary	0.059	0.414
Norway	0.180	0.368	India	0.030	0.081
Portugal	0.197	0.363	Indonesia	0.103	0.238
Spain	0.258	0.197	Israel	0.138	0.352
Sweden	0.131	0.421	Jordan	0.064	0.388
United Kingdom	0.169	0.325	Korea, Rep.	0.169	0.384
United States	0.231	0.109	Malawi	-0.073	0.250
			Malaysia	0.115	0.830
			Malta	0.113	1.047
			Mauritius	-0.057	0.686
			Mexico	-0.090	0.189
			Panama	-0.095	0.892
			Peru	0.039	0.198
			Philippines	0.021	0.352
			Senegal	0.015	0.299
			Singapore	0.238	1.926
			South Africa	0.100	0.240
			Sri Lanka	-0.061	0.293
			Syrian Arab Republic	0.097	0.180
			Tanzania	0.166	0.181
			Trinidad and Tobago	0.080	0.536
			Turkey	0.027	0.160
			Uruguay	0.117	0.211
			Zimbabwe	0.059	0.131
Mean	0.191	0.375		0.095	0.354

Notes: The first column reports the average correlation of real manufacturing output growth between a country and the rest of the countries in the sample. Trade/GDP is the average share of manufacturing trade of a country to its GDP over the period.

Table A2. Subsample Summary Statistics for Manufacturing Sector: 1970–99

Sample	Average correlation	Trade/GDP
Full	0.115	0.0011
OECD/OECD	0.397	0.0036
non-OECD/non-OECD	0.065	0.0011
OECD/non-OECD	0.091	0.0005

Notes: Average correlation is the sample average of bilateral correlation of manufacturing output growth. Trade/GDP is sample average of the share of total bilateral sectoral trade of two countries to their GDP.

Table A3. Sector Summary Statistics: 1970–99

ISIC	Sector name	Average ρ_{ii}	Average ρ_{ij}	Trade/ GDP	Vertical Intensity	Upstream Intensity
311	Food products	0.054	0.057	0.053	0.195	0.150
313	Beverages	0.068	0.066	0.006	0.022	0.524
314	Tobacco	0.029	0.027	0.005	0.105	0.082
321	Textiles	0.133	0.087	0.022	0.313	0.481
322	Wearing apparel, except footwear	0.093	0.064	0.020	0.106	0.678
323	Leather products	0.034	0.046	0.003	0.273	0.517
324	Footwear, except rubber or plastic	0.045	0.049	0.001	0.017	0.709
331	Wood products, except furniture	0.076	0.080	0.008	0.323	0.204
332	Furniture, except metal	0.078	0.082	0.002	0.014	0.571
341	Paper and products	0.228	0.094	0.008	0.301	0.312
342	Printing and publishing	0.069	0.064	0.003	0.081	0.685
351	Industrial chemicals	0.126	0.086	0.030	0.421	0.192
352	Other chemicals	0.095	0.075	0.014	0.141	0.355
353	Petroleum refineries	0.079	0.063	0.036	0.084	0.060
354	Misc. petroleum and coal products	0.040	0.040	0.001	0.012	0.498
355	Rubber products	0.082	0.066	0.004	0.064	0.563
356	Plastic products	0.131	0.093	0.004	0.070	0.570
361	Pottery, china, earthenware	0.126	0.086	0.001	0.052	0.146
362	Glass and products	0.119	0.091	0.002	0.088	0.282
369	Other non-metallic mineral products	0.104	0.085	0.004	0.118	0.193
371	Iron and steel	0.155	0.087	0.016	0.236	0.258
372	Non-ferrous metals	0.150	0.086	0.015	0.606	0.195
381	Fabricated metal products	0.109	0.076	0.014	0.103	0.433
382	Machinery, except electrical	0.045	0.048	0.045	0.088	0.545
383	Machinery, electric	0.068	0.053	0.031	0.327	0.268
384	Transport equipment	0.071	0.047	0.107	0.368	0.580
385	Professional & scientific equipment	0.056	0.047	0.009	0.043	0.423
390	Other manufactured products	0.045	0.056	0.011	0.060	0.533
	AVERAGE	0.090	0.068	0.017	0.165	0.393

Notes: The first two columns report the average correlation of real sector-level output growth between a pair of countries, averaged over country pairs within a sector and with all other sectors of the economy, respectively. Trade/GDP is, for each sector, the average (across countries) of the share of sectoral trade of a country to its GDP. Vertical Intensity and Upstream Intensity are calculated from the BEA input-output matrix after aggregating up to the 28 manufacturing sectors for which there is production data. Vertical Intensity is the diagonal term of the I-O matrix. It represents the value of output of the sector needed as an intermediate input to produce a dollar of final output in that same sector. Upstream Intensity is the sum across rows for a given column of the I-O matrix, excluding the diagonal. It represents the value of output of all other sectors needed as intermediate inputs to produce one dollar of final output a given sector.

Table A4. Estimates of the Impact of Total Bilateral Trade on Aggregate Comovement in Real GDP and Total Manufacturing Real Output

	Aggregate		
	Trade/ GDP	*Trade/ Output*	*Trade/ Total Trade*
	(1)	(2)	(3)
Trade	17.56**	16.08**	20.04**
	(3.59)	(3.33)	(3.59)
Observations	1967	1967	1967
R^2	0.383	0.383	0.385
	Manufacturing		
	Trade/ GDP	*Trade/ Output*	*Trade/ Total Trade*
	(1)	(2)	(3)
Trade	13.55**	14.43**	15.58**
	(3.95)	(3.30)	(3.86)
Observations	1496	1496	1496
R^2	0.465	0.467	0.467
$\mu_{c1} + \mu_{c2}$	yes	yes	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. The sample period is 1970–99. The dependent variables are the correlations of the growth of real GDP (top panel) and the growth of real manufacturing output (bottom panel). All regressors are in natural logs. μ_{c1} and μ_{c2} denote the country fixed effects All specifications are estimated using OLS.

Table A5. Impact of Trade on Comovement at the Sector-Level: All Specifications for HP-Filtered Data

	Specification I				*Specification II*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	7.24**	4.05**	3.71**	2.75**	7.11**	3.92**	3.57**	2.62**
	(0.07)	(0.10)	(0.11)	(0.12)	(0.07)	(0.10)	(0.11)	(0.12)
Trade×Same Sector	–	–	–	–	3.41**	3.71**	3.81**	3.95**
	–	–	–	–	(0.39)	(0.37)	(0.34)	(0.38)
Same Sector	–	–	–	–	108.31**	116.39**	118.47**	–
	–	–	–	–	(10.58)	(9.88)	(9.16)	–
Observations	653,588	653,588	653,588	653,588	653,588	653,588	653,588	653,588
R^2	0.015	0.091	0.198	0.176	0.016	0.091	0.198	0.176
	Specification III				*Specification IV*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	6.84**	3.68**	3.36**	2.41**	6.85**	3.65**	3.33**	2.42**
	(0.08)	(0.10)	(0.12)	(0.12)	(0.08)	(0.11)	(0.12)	(0.12)
Trade×Same Sector	–	–	–	–	1.16+	1.83*	2.28**	1.95*
	–	–	–	–	(0.62)	(0.59)	(0.55)	(0.61)
Trade×IO	15.34**	17.44**	16.70**	16.60**	12.31**	16.92**	15.60**	13.03**
	(1.38)	(1.32)	(1.27)	(1.29)	(2.10)	(2.05)	(2.04)	(1.98)
Trade×Same Sector×IO	–	–	–	–	1.59	-4.35	-5.14+	-0.52
	–	–	–	–	(3.44)	(3.26)	(3.06)	(3.24)
Same Sector×IO	–	–	–	–	-46.42	-97.75*	-108.49*	–
	–	–	–	–	(45.05)	(42.31)	(39.57)	–
Same Sector	–	–	–	–	46.68*	65.65**	77.25**	–
	–	–	–	–	(17.27)	(16.31)	(15.12)	–
Input-Output	246.72**	264.12**	253.96**	–	236.73**	266.10**	249.06**	–
	(17.87)	(16.85)	(16.12)	–	(26.92)	(26.11)	(25.71)	–
Observations	653,588	653,588	653,588	653,588	653,588	653,588	653,588	653,588
R^2	0.016	0.092	0.198	0.176	0.016	0.092	0.198	0.176
$\mu_{c1} + \mu_{c2} + \mu_i + \mu_j$	no	yes	no	no	no	yes	no	no
$\mu_{c1} \times \mu_i + \mu_{c2} \times \mu_j$	no	no	yes	no	no	no	yes	no
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	no	no	no	yes	no	no	no	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. The sample period is 1970–99. The dependent variable is the correlation of the HP-filtered real output between sector i and sector j of the country pair. In all specifications, the trade variable is normalized by GDP. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Appendix B Logs and Levels Estimates

The estimation in the paper is carried out using logs of trade ratios on the right-hand side. The literature is split on whether logs or levels specification is more appropriate. While the original Frankel and Rose (1998) paper and several subsequent studies take logs, Kose and Yi (2006) use both levels and logs but argue that the levels specification has a more appealing quantitative interpretation. Thus, it is important to assess both which specification is favored by the data, and whether our results are robust to estimation in levels.

We chose the log specification as the baseline because the trade ratios in levels are extremely skewed, and thus a tiny share of the top values of the trade ratios affect the estimated coefficient a great deal. What the log specification does is reduce the influence of the largest trade values, providing a better fit for the data and more stable estimates. Table B1 reports the results of estimating the canonical Frankel-Rose regressions for the aggregate data in levels (Panel I) and in logs (Panel II). All the specifications include both sets of country effects. The first column reports the full sample estimates; the second column trims the most extreme 1% of the trade observations in the sample, the third column, 2.5% of the sample, the fourth, 5% of the sample, and the last column, 10% of the sample. In each case, following the best practice in the literature, we trim symmetrically on both ends (that is, in trimming 1%, we remove 0.5% of the top trade observations, and 0.5% of the bottom). The results are striking. When just 1% of the observations are removed, the levels coefficient doubles, from 9.775 to 19.336. Even more problematically, trimming more data raises the coefficient even more, to 26.007, 31.268, and then 35.175 when 10% of the sample is dropped. This is clear evidence that the levels coefficient is unstable, taking different values at different points in the sample.

Remarkably, the same problem does not occur when using logs. Panel II reports the results. The coefficients are not sensitive to trimming, oscillating between 18.45 and 15.91, with the standard error of about 4 in each specification.[19] Thus, the log specification appears

[19] As in the main text, for ease of reading the tables and to reduce the number of decimal points, the regression coefficients and standard errors for the log (but not the level) regressions are multiplied by 1000.

to capture adequately the strong nonlinearity in the data.[20]

The problem of unstable coefficients is not confined to the aggregate specifications. Table B2 reports the results of estimating the levels regression on the full sample (column 1), trimming the outlying 1% of the sample symmetrically (i.e. 0.5% from both the top and bottom of the distribution of the trade variable), trimming 2.5% of the sample, 5% of the sample, and 10% of the sample in successive columns. It is clear that the coefficients are very sensitive to the very top values. In the first panel, for example, while the full sample coefficient is 4.47, losing the top 0.5% of trade observations raises it four-fold to 20.24, top 1.25% to 30.7, where it stays when the data are trimmed further. However, the first panel is by far the most stable. In all three of the other trade measures, the coefficients do not level off, rather they keep rising all the way up to the 10% trim. When trade is normalized by output, the coefficient starts out negative and significant, becomes insignificant when 2.5% of observations are removed, and then turns positive and significant for the 5% and 10% trims. In the other two specifications, the coefficient is positive and strongly significant throughout, but rises in magnitude for each successive trim of the data.

We also carried out the trimming exercise on a subsample that excludes the zero trade observations, reaching identical results. That is, the large differences in the levels coefficients (due to trimming) are not driven by zeros. Instead, they are driven by the largest trade observations. As a side note, none of the results appear to be affected by zeros, in the sense that in all cases, the levels coefficients with and without zeros in the sample are very similar.

Table B3 reports the same trimming exercise on logged trade data. It is remarkable that the coefficient is much more stable across all the untrimmed and trimmed samples, indicating that logging the trade variables downweights the extreme observations and thus makes the estimated coefficients more reliable throughout the sample.

[20]This in turn implies that the estimated magnitudes of the impact of trade on comovement are very sensitive to trimming in the levels specification, and are not sensitive in the log specification. Moving from the 25th to the 75th percentile in the distribution of the bilateral trade variable corresponds to the same change in trade in both the level and the log specifications (since the percentiles correspond to the same actual observations in both). Depending on the trimming, in the levels specification the change in left-hand side variable changes by a factor of 3.6; in the logs specification, the difference is only 12%.

While qualitatively the results are robust to estimating in levels, as we can see the estimated coefficients are unreliable. In addition, the stability of the log coefficients indicates that logging the trade variables adequately captures the nonlinearity present in the data. Thus, in the main text of the paper we we stick to the log specifications. However, it is still important to check that the results in levels are qualitatively robust. Tables B4 through B8 report all of the regression results in the paper using levels rather than logs (they are equivalent to Tables 1-5 in the main text of the paper).[21] It is clear that all the results still hold. In particular, trade on its own is significant, and, more importantly, the interaction of bilateral trade with the I-O coefficient is always strongly significant as well.

[21]These tables use the sample trimming 2.5% of the observations (5% in the case of Trade/Output, the most unstable coefficient). This is a relatively conservative trim.

Table B1. Impact of Trade on Comovement at the Aggregate-Level: Trimming Exercise

	I. Trade/GDP				
	(1)	(2)	(3)	(4)	(5)
	Full	1%	2.5%	5%	10%
Trade	9.78**	19.34**	26.01**	31.27**	35.18**
	(1.82)	(2.73)	(4.59)	(5.93)	(8.54)
Observations	1,967	1,949	1,919	1,872	1778
R^2	0.387	0.382	0.378	0.367	0.354
	II. Log(Trade/GDP)				
	(1)	(2)	(3)	(4)	(5)
	Full	1%	2.5%	5%	10%
Trade	17.56**	18.45**	16.19**	16.81**	15.91**
	(3.59)	(3.53)	(3.58)	(3.69)	(4.14)
Observations	1,967	1,949	1,919	1,872	1778
R^2	0.383	0.378	0.373	0.362	0.352
$\mu_{c1} + \mu_{c2}$	yes	yes	yes	yes	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. The sample period is 1970–99. The dependent variable is the correlation of the growth of real GDP. μ_{c1} and μ_{c2} denote the country fixed effects All specifications are estimated using OLS.

Table B2. Impact of Trade on Comovement at the Sector-Level: Trimming Exercise for Levels

	I. Trade/GDP					*II. Trade/Output*				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
	Full	1%	2.5%	5%	10%	Full	1%	2.5%	5%	10%
Trade	4.47**	20.24**	30.70**	30.11**	30.87**	0.00*	-0.05*	-0.029	0.14**	0.26**
	(0.89)	(2.70)	(3.62)	(4.98)	(7.60)	(0.00)	(0.02)	(0.03)	(0.05)	(0.07)
Observations	813,784	801,219	793,430	773,088	732,404	809,947	797,477	789,690	769,449	728,951
R^2_o	0.157	0.157	0.155	0.153	0.151	0.157	0.158	0.158	0.158	0.156
	III. Trade/Total Trade					*IV. Trade/Sector Total Trade*				
	(1)	(2)	(3)	(4)	(4)	(1)	(2)	(3)	(4)	(5)
	Full	1%	2.5%	5%	10%	Full	1%	2.5%	5%	10%
Trade	1.09**	2.98**	5.60**	6.56**	6.27**	0.31**	0.39**	0.52**	0.74**	0.86**
	(0.24)	(0.47)	(0.62)	(0.84)	(1.25)	(0.02)	(0.03)	(0.03)	(0.04)	(0.05)
Observations	815,233	802,618	794,851	774,461	733,702	815,233	802,618	794,843	774,471	733,703
R^2	0.157	0.156	0.154	0.151	0.147	0.157	0.155	0.153	0.151	0.144
$\mu_{c1} \times \mu_i + \mu_{c2} \times \mu_j$	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Table B3. Impact of Trade on Comovement at the Sector-Level: Trimming Exercise for Logs

	I. Trade/GDP					*II. Trade/Output*				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
	Full	1%	2.5%	5%	10%	Full	1%	2.5%	5%	10%
Trade	1.47**	1.63**	1.74**	1.81**	1.91**	0.91**	1.08**	1.16**	1.26**	1.47**
	(0.09)	(0.10)	(0.10)	(0.10)	(0.11)	(0.09)	(0.09)	(0.09)	(0.10)	(0.10)
Observations	653,588	647,052	637,247	620,908	588,228	650,341	643,837	634,081	617,823	585,305
R_o^2	0.173	0.172	0.170	0.168	0.163	0.173	0.173	0.172	0.171	0.168
	III. Trade/Total Trade					*IV. Trade/Sector Total Trade*				
	(1)	(2)	(3)	(4)	(4)	(1)	(2)	(3)	(4)	(5)
	Full	1%	2.5%	5%	10%	Full	1%	2.5%	5%	10%
Trade	1.51**	1.70**	1.81**	1.93**	1.99**	1.29**	1.49**	1.66**	1.86**	2.03**
	(0.09)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)	(0.11)	(0.11)	(0.11)	(0.12)
Observations	655,011	648,459	638,635	622,259	589,509	655,011	648,459	638,635	622,258	589,509
R^2	0.173	0.171	0.169	0.165	0.160	0.173	0.170	0.169	0.165	0.158
$\mu_{c1} \times \mu_i + \mu_{c2} \times \mu_j$	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Table B4. Impact of Trade on Comovement at the Sector-Level: Pooled Estimates for Levels

	I. Trade/GDP				*II. Trade/Output*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	252.37**	93.42**	106.12**	30.70**	2.69**	0.92**	0.86**	0.13**
	(3.05)	(3.25)	(3.29)	(3.62)	(0.04)	(0.04)	(0.04)	(0.05)
Observations	793,430	793,430	793,430	793,430	769,399	769,399	769,399	769,399
R^2_o	0.010	0.096	0.222	0.155	0.007	0.098	0.223	0.158
R^2_w	–	0.0011	0.0014	0.0001	–	0.0007	0.0006	1.13E-05
	III. Trade/Total Trade				*IV. Trade/Sector Total Trade*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	51.75**	18.05**	21.02**	5.60**	2.22**	0.94**	0.88**	0.52**
	(0.52)	(0.55)	(0.55)	(0.62)	(0.02)	(0.02)	(0.02)	(0.03)
Observations	794,851	794,851	794,851	794,851	794,843	794,843	794,843	794,843
R^2_o	0.015	0.095	0.219	0.154	0.019	0.095	0.219	0.153
R^2_w	–	0.0014	0.0019	0.0001	–	0.0027	0.0026	0.0004
$\mu_{c1} + \mu_{c2} + \mu_i + \mu_j$	no	yes	no	no	no	yes	no	no
$\mu_{c1} \times \mu_i + \mu_{c2} \times \mu_j$	no	no	yes	no	no	no	yes	no
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	no	no	no	yes	no	no	no	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. R^2_o is the overall R^2 and R^2_w is the within-R^2 associated with the regressor of interest. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Table B5. Impact of Trade on Comovement at the Sector-Level: Within- and Cross-Sector Estimates for Levels

	I. Trade/GDP				*II. Trade/Output*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	248.37**	89.94**	102.44**	26.32**	2.65**	0.87**	0.82**	0.09+
	(3.09)	(3.28)	(3.31)	(3.65)	(0.04)	(0.04)	(0.04)	(0.05)
Trade×Same Sector	128.79**	118.13**	127.46**	132.42**	1.42**	1.41**	1.51**	1.44**
	(18.38)	(15.92)	(14.19)	(15.90)	(0.23)	(0.20)	(0.18)	(0.20)
Same Sector	0.01**	0.01**	0.01**	–	0.01**	0.02**	0.01**	–
	(0.00)	(0.00)	(0.00)	–	(0.00)	(0.00)	(0.00)	–
Observations	793,430	793,430	793,430	793,430	769,399	769,399	769,399	769,399
R^2_o	0.011	0.096	0.222	0.155	0.008	0.098	0.223	0.158
R^2_w	–	0.0015	0.0018	0.0002	–	0.0011	0.0011	0.0001
	III. Trade/Total Trade				*IV. Trade/Sector Total Trade*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	50.98**	17.33**	20.29**	4.71**	2.18**	0.91**	0.85**	0.49**
	(0.53)	(0.55)	(0.56)	(0.62)	(0.02)	(0.02)	(0.02)	(0.03)
Trade×Same Sector	23.22**	22.32**	22.70**	25.45**	0.98**	0.95**	0.97**	0.95**
	(3.12)	(2.69)	(2.35)	(2.70)	(0.12)	(0.10)	(0.09)	(0.10)
Same Sector	0.01**	0.01**	0.01**	–	0.01**	0.01**	0.01**	–
	(0.00)	(0.00)	(0.00)	–	(0.00)	(0.00)	(0.00)	–
Observations	794,851	794,851	794,851	794,851	794,843	794,843	794,843	794,843
R^2_o	0.015	0.095	0.219	0.154	0.020	0.096	0.220	0.154
R^2_w	–	0.0019	0.0023	0.0002	–	0.0031	0.0031	0.0005
$\mu_{c1} + \mu_{c2} + \mu_i + \mu_j$	no	yes	no	no	no	yes	no	no
$\mu_{c1} \times \mu_i + \mu_{c2} \times \mu_j$	no	no	yes	no	no	no	yes	no
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	no	no	no	yes	no	no	no	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. R^2_o is the overall R^2 and R^2_w is the within-R^2 associated with the regressors of interest. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Table B6. Impact of Trade on Comovement at the Sector-Level: Vertical Linkage Estimates for Levels

	I. *Trade/GDP*				II. *Trade/Output*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	235.44**	77.65**	93.26**	11.54**	2.48**	0.73**	0.71**	-0.044
	(3.33)	(3.50)	(3.50)	(3.85)	(0.04)	(0.04)	(0.04)	(0.05)
Trade×IO	482.11**	520.90**	429.06**	597.05**	9.83**	8.73**	7.63**	8.57**
	(52.14)	(45.40)	(40.68)	(44.34)	(0.77)	(0.65)	(0.60)	(0.64)
Input-Output	0.06**	0.03**	0.03**	–	0.06**	0.03**	0.03**	–
	(0.00)	(0.00)	(0.00)	–	(0.00)	(0.00)	(0.00)	–
Observations	793,430	793,430	793,430	793,430	769,399	769,399	769,399	769,399
R_o^2	0.011	0.096	0.222	0.155	0.009	0.098	0.224	0.158
R_w^2	–	0.0017	0.0020	0.0004	–	0.0014	0.0014	0.0003
	III. *Trade/Total Trade*				IV. *Trade/Sector Total Trade*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	48.68**	15.14**	18.69**	2.01**	2.08**	0.82**	0.77**	0.41**
	(0.57)	(0.59)	(0.59)	(0.66)	(0.02)	(0.02)	(0.02)	(0.03)
Trade×IO	88.58**	95.57**	76.36**	112.19**	6.94**	6.12**	5.42**	5.94**
	(8.78)	(7.63)	(6.69)	(7.48)	(0.46)	(0.39)	(0.35)	(0.37)
Input-Output	0.05**	0.03**	0.03**	–	0.06**	0.02**	0.03**	–
	(0.00)	(0.00)	(0.00)	–	(0.00)	(0.00)	(0.00)	–
Observations	794,851	794,851	794,851	794,851	794,843	794,843	794,843	794,843
R_o^2	0.016	0.095	0.220	0.154	0.021	0.096	0.220	0.154
R_w^2	–	0.0021	0.0025	0.0005	–	0.0035	0.0034	0.0008
$\mu_{c1} + \mu_{c2} + \mu_i + \mu_j$	no	yes	no	no	no	yes	no	no
$\mu_{c1} \times \mu_i + \mu_{c2} \times \mu_j$	no	no	yes	no	no	no	yes	no
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	no	no	no	yes	no	no	no	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. R_o^2 is the overall R^2 and R_w^2 is the within-R^2 associated with the regressors of interest. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Table B7. Impact of Trade on Comovement at the Sector-Level: Vertical Linkages, Within- and Cross-Sector Estimates for Levels

	I. Trade/GDP				*II. Trade/Output*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	48.33**	14.68**	18.43**	1.64*	2.45**	0.71**	0.69**	-0.05
	(0.58)	(0.60)	(0.60)	(0.67)	(0.04)	(0.04)	(0.04)	(0.05)
Trade×Same Sector	16.10**	16.54**	19.94**	15.80**	0.0632	0.202	0.57*	0.20
	(5.49)	(4.77)	(4.15)	(4.81)	(0.33)	(0.30)	(0.27)	(0.30)
Trade×IO	95.64**	113.09**	78.68**	126.68**	12.11**	10.13**	8.25**	9.26**
	(12.36)	(10.78)	(9.50)	(10.65)	(1.21)	(1.00)	(0.91)	(0.97)
Trade×Same Sector×IO	-64.03**	-76.82**	-59.44**	-72.59**	-4.19*	-2.75+	-2.50+	-1.81
	(23.50)	(20.31)	(17.55)	(20.18)	(1.85)	(1.59)	(1.44)	(1.56)
Same Sector×IO	-0.07**	-0.03**	-0.04**	–	-4.19*	-2.75+	-2.50+	–
	(0.01)	(0.01)	(0.01)	–	(1.85)	(1.59)	(1.44)	–
Same Sector	0.01**	0.01**	0.01**	–	0.01**	0.02**	0.01**	–
	(0.00)	(0.00)	(0.00)	–	(0.00)	(0.00)	(0.00)	–
Input-Output	0.10**	0.04**	0.04**	–	0.12**	0.04**	0.04**	–
	(0.00)	(0.00)	(0.00)	–	(0.00)	(0.00)	(0.00)	–
Observations	794,851	794,851	794,851	794,851	769,399	769,399	769,399	769,399
R^2_o	0.016	0.095	0.220	0.154	0.009	0.099	0.224	0.158
R^2_w	–	0.0019	0.0021	0.0004	–	0.0016	0.0015	0.0003
	III. Trade/Total Trade				*IV. Trade/Sector Total Trade*			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Trade	48.33**	14.68**	18.43**	1.64*	2.04**	0.79**	0.75**	0.39**
	(0.58)	(0.60)	(0.60)	(0.67)	(0.02)	(0.02)	(0.02)	(0.03)
Trade×Same Sector	16.10**	16.54**	19.94**	15.80**	0.428	0.48**	0.64**	0.46**
	(5.49)	(4.77)	(4.15)	(4.81)	(0.18)	(0.15)	(0.13)	(0.15)
Trade×IO	95.64**	113.09**	78.68**	126.68**	9.36**	8.06**	6.90**	7.47**
	(12.36)	(10.78)	(9.50)	(10.65)	(0.70)	(0.58)	(0.52)	(0.57)
Trade×Same Sector×IO	-64.03**	-76.82**	-59.44**	-72.59**	-5.36**	-4.62**	-4.38**	-3.91**
	(23.50)	(20.31)	(17.55)	(20.18)	(1.08)	(0.92)	(0.80)	(0.89)
Same Sector×IO	-0.07**	-0.03**	-0.04**	–	-0.07**	-0.03**	-0.03**	–
	(0.01)	(0.01)	(0.01)	–	(0.01)	(0.01)	(0.01)	–
Same Sector	0.01**	0.01**	0.01**	–	0.001	0.01**	0.01**	–
	(0.00)	(0.00)	(0.00)	–	(0.00)	(0.00)	(0.00)	–
Input-Output	0.10**	0.04**	0.04**	–	0.11**	0.03**	0.03**	–
	(0.00)	(0.00)	(0.00)	–	(0.00)	(0.00)	(0.00)	–
Observations	794,851	794,851	794,851	794,851	794,843	794,843	794,843	794,843
R^2_o	0.016	0.095	0.220	0.154	0.022	0.096	0.220	0.154
R^2_w	–	0.0022	0.0026	0.0005	–	0.0037	0.0036	0.0009
$\mu_{c1} + \mu_{c2} + \mu_i + \mu_j$	no	yes	no	no	no	yes	no	no
$\mu_{c1} \times \mu_i + \mu_{c2} \times \mu_j$	no	no	yes	no	no	no	yes	no
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	no	no	no	yes	no	no	no	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. R^2_o is the overall R^2 and R^2_w is the within-R^2 associated with the regressors of interest. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.

Table B8. Impact of Trade on Comovement at the Sector-Level: Vertical Linkages and Elasticities of Substitution Estimates for Levels

	I. Trade/GDP		*II. Trade/Output*	
	(1)	(2)	(1)	(2)
Trade	184.93**	56.33**	1.14**	0.14**
	(16.63)	(4.84)	(0.15)	(0.04)
Trade×IO	549.35**	571.21**	3.57**	4.58**
	(45.22)	(44.52)	(0.44)	(0.45)
Trade×(Production Elasticity)	-106.32**	–	-0.69**	–
	(9.51)	–	(0.09)	–
Trade×(Consumption Elasticity)	–	-6.46**	–	-0.04**
	–	(0.44)	–	(0.00)
Observations	657,062	793,430	657,006	789,690
R^2_o	0.176	0.156	0.178	0.158
R^2_w	0.0006	0.0002	0.0004	0.0004
	III. Trade/Total Trade		*IV. Trade/Sector Total Trade*	
	(1)	(2)	(1)	(2)
Trade	31.10**	11.87**	1.76**	0.82**
	(2.90)	(0.83)	(0.12)	(0.04)
Trade×IO	101.57**	107.47**	5.01**	5.82**
	(7.56)	(7.50)	(0.38)	(0.37)
Trade×(Production Elasticity)	-17.92**	–	-0.81**	–
	(1.66)	–	(0.07)	–
Trade×(Consumption Elasticity)	–	-1.42**	–	-0.06**
	–	(0.08)	–	(0.00)
Observations	658,143	794,851	658,384	794,843
R^2_o	0.174	0.155	0.174	0.154
R^2_w	0.0006	0.0007	0.0010	0.0015
$\mu_{c1} \times \mu_{c2} + \mu_i \times \mu_j$	yes	yes	yes	yes

Notes: Robust standard errors in parentheses. ** significant at 1%; * significant at 5%; + significant at 10%. R^2_o is the overall R^2 and R^2_w is the within-R^2 associated with the regressors of interest. The sample period is 1970–99. The dependent variable is the correlation of the real output growth between sector i and sector j of the country pair. μ_{c1} and μ_{c2} are country 1 and 2 fixed effects, respectively. Production Elasticity taken from Luong (2008), and Consumption Elasticity taken from Broda and Weinstein (2006). μ_i and μ_j are sector i and j fixed effects, respectively. Variable definitions and sources are described in detail in the text.