Trade and Synchronization in a Multi-Country Economy*

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Abstract

Substantial evidence suggests that countries or regions with stronger trade linkages tend to have business cycles that are more synchronized. The standard international business cycle framework cannot replicate this finding. In this paper, we study a multi-country model of international trade with vertical trade linkages, imperfect competition, and variable markups. We embed it in a real business cycle framework by including aggregate technology shocks and allowing for a variable labor supply. A carefully calibrated version of the theoretical economy that fits the model to data on the bilateral trade volume between 210 distinct country-pairs explains between 20 and 41 percent of the relation between trade intensity and business cycle synchronization. We provide empirical evidence supporting the model's predictions for the association between trade costs and business cycle synchronization, and trade costs and exchange rate volatility.

Keywords: Trade Integration, Business Cycle Synchronization.

JEL Classification: F15; F41; E30.

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1 Introduction

Substantial empirical evidence suggests that countries or regions with stronger trade linkages have more correlated business cycles. Frankel and Rose (1998), Clark and van Wincoop (2001), Calderon, Chong, and Stein (2007), Baxter and Kouparitsas (2004), and Imbs (2004), among others, show that pairs of countries that trade with each other exhibit a high degree of business cycle comovement. These findings have been interpreted as evidence that trade integration leads to business cycle synchronization.

From a theoretical perspective, however, international business cycle models have had difficulty in replicating this empirical fact (see Kose and Yi, 2001, and Kose and Yi, 2006). In the latter paper, the authors' baseline model explains one-tenth of the responsiveness of comovement to trade intensity. This has given rise to the so-called trade-comovement puzzle: Standard models are unable to generate high output correlations arising from high bilateral trade intensity.

These models are either two-country or three-country representations of the world economy. However, it is likely that pairs of countries with higher bilateral trade intensity also share substantial trade linkages with common trading partners. A two-country or three-country model is unable to capture this feature of the data and leads to an attenuated link between trade and business cycle synchronization. Instead, by considering a multi-country world economy and calibrating the model's trade costs to match each bilateral trade volume we capture both the bilateral trade linkages and the trade linkages with common trading partners.

Therefore, we consider a model that consists of 21 countries, as is the case in our data sample. We calibrate the model's trade costs to match each country-pair's bilateral trade volume—that is, there are 210 country-pairs. We assess the model's ability to generate high business cycle correlations between countries with strong trade linkages. The model is quite successful at solving the trade-comovement puzzle. Quantitatively, it explains up to 41 percent of the empirical relation between trade intensity and comovement.

Our theoretical framework contains the following ingredients: vertical trade linkages, imperfect competition, and trade costs. In particular, we build on Bernard, Eaton, Jensen, and Kortum (2003), and allow for endogenous markups to vary across producers of different efficiencies who set prices à la Bertrand. Our proposed mechanism operates as follows:

(i) Higher trade costs decrease the level of vertical specialization and, hence, trade intensity.

(ii) At lower levels of vertical specialization, there are fewer opportunities for countries to benefit from foreign efficiency shocks, reducing comovement.

(iii) Trade costs lead to a failure of the relative purchasing power parity (PPP) relation and increased exchange rate volatility.

In this way higher trade costs prevent arbitrage, which generates pricing-to-market, reduces trade, and hampers the transmission of shocks across countries, lowering business cycle synchronization.[1] Instead, if trade costs are absent, there is full vertical specialization and price discrimination is not possible. In this case, the business cycles are perfectly synchronized and the PPP relation holds perfectly. Given that pricing-to-market is associated with higher exchange rate volatility, our model contains two additional predictions: (i) Exchange rate volatility is higher for countries with higher trade costs; and (ii) higher trade costs are associated with lower business cycle synchronization. We use a measure of bilateral transaction costs to provide empirical evidence supporting these predictions.

In addressing the association between trade and comovement, the literature has suggested the importance of the key elements of our model. The role of vertical integration was highlighted in Burstein, Kurz, and Tesar (2008). The authors show that countries with tighter links in the chain of production exhibit higher bilateral manufacturing output correlations.[2] Arkolakis and Ramanarayanan (2009) develop an international business cycle model augmented with vertical specialization. Although vertical specialization provides a potential mechanism for the model to generate increased business cycle correlation with higher trade, this mechanism is not sufficiently strong. The authors note that an extension of their setup to a model with more than two countries, calibrated to match bilateral trade shares would be essential to address this question. Our paper shows that a multicountry model featuring imperfect competition that is carefully calibrated to match bilateral trade shares goes a long way towards resolving the trade-comovement puzzle.

[1] The term pricing-to-market refers to the decision by a single producer to change the relative price at which she sells her output abroad and at home in response to changes in international relative costs.

[2] In a recent paper, Di Giovanni and Levchenko (2009) emphasize the empirical relevance of vertical linkages in production to explain the effect of bilateral trade on business cycle synchronization.

Our theoretical model considers a setting with balanced trade (i.e., financial autarky). Heathcote and Perri (2002) show that the financial autarky economy is closest to the data along most dimensions compared with the complete markets economy and the bond-only economy. In particular, the financial autarky model better accounts for the observed cross-country output, consumption and employment correlations. Kose and Yi (2006) find that financial autarky helps to resolve the trade-comovement puzzle.

The remainder of the paper is organized as follows. In Section 2, we present the equilibrium model of trade and the business cycle that we use to analyze the relation between trade integration and business cycle synchronization. The model results are presented in Section 3. In Section 4, we estimate the Frankel and Rose (FR, 1998) regressions using our data and sample period and assess the potential of our model to replicate the empirical relation between trade and comovement. We also investigate further the empirical link between trade costs, real exchange rate volatility, and business cycle synchronization. Finally, Section 5 concludes.

2 The Theoretical Economy

In this section we develop a simple model of the link between trade integration and business cycle synchronization. The setup of the model builds on Bernard et al. (2003). The global economy consists of K countries, each represented by a continuum of unit measure of identical and infinitely lived households. In each period of time t, the global economy experiences one of finitely many states, or events, s_t. We denote by $s^t = (s_0, \ldots, s_t)$ the history of events through period t. The probability, as of period 0, of any particular history s^t is $\pi(s^t)$. The initial realization s_0 is given.

2.1 Technology and Market Structure

Each country consumes a non-traded final good that is produced competitively by domestic final-good firms. The representative final-good firm in country i makes use of a continuum of differentiated manufactured intermediate commodities indexed by $n \in [0, 1]$ that are combined as follows

$$Y_i\left(s^t\right) = \left[\int_0^1 X_i\left(n, s^t\right)^{\phi} dn\right]^{1/\phi}, \tag{1}$$

where $Y_i\left(s^t\right)$ is final-good output in country i, and $X_i\left(n, s^t\right)$ is the input of the differentiated intermediate commodity of type n. The parameter $\phi \in (0,1)$ relates to the elasticity of substitution across differentiated intermediate commodities, given by $\sigma = 1/\left(1-\phi\right)$. Hence, the demand in country i for intermediate variety n satisfies the relation

$$X_i\left(n, s^t\right) = \left[\frac{p_i\left(n, s^t\right)}{P_i\left(s^t\right)}\right]^{-\sigma} Y_i\left(s^t\right), \tag{2}$$

where $p_i\left(n, s^t\right)$ is the price of intermediate variety n in country i and

$$P_i\left(s^t\right) = \left[\int_0^1 p_i\left(n, s^t\right)^{(1-\sigma)} dn\right]^{1/(1-\sigma)}$$

is the *ideal price index* in country i of the final good.

Trade barriers: The differentiated intermediate commodities are subject to trade barriers taking the form of an *iceberg cost*: To successfully deliver in country j one unit of any differentiated intermediate commodity produced in country i, $\tau_{ji} \geq 1$ units need to be shipped, with $\tau_{ii} = 1$.

Intermediate-good sector: The structure of the intermediate-good sector is inspired by Bernard et al. (2003) and, in particular, we treat productivity differences across producers adopting a probabilistic formulation. Each intermediate commodity $n \in [0,\, 1]$ has many potential producers in each country. However, these firms differ in productivity—indexed by φ. The kth most efficient producer of commodity n in country i requires $1/\left[\varphi_{ki}^n\left(s^t\right)\right]$ units of the input bundle to produce one unit of the intermediate good. The unit cost of the input bundle in country i is ω_i. Therefore, the cost for the kth most efficient producer in country i of delivering in country j a unit of intermediate commodity n is

$$z_{ji}^k\left(n, s^t\right) = \left[\frac{\omega_i}{\varphi_{ki}^n\left(s^t\right)}\right]\tau_{ji}. \tag{3}$$

It follows that the most efficient potential supplier of commodity n to country j faces the cost

$$Z_j^1\left(n, s^t\right) = \min_i\left[z_{ji}^1\left(n, s^t\right)\right]. \tag{4}$$

We assume that the individual-goods producing firms are engaged in imperfect competition. In particular, the price charged for each intermediate commodity is assumed to be determined from Bertrand competition. Hence, each country j is captured by the lowest-cost supplier to that market but this supplier is constrained to not charge a price higher than the second-lowest cost of supplying the market. If the lowest-cost supplier to country j is a country i firm, the price set by this firm cannot exceed

$$Z_j^2\left(n,s^t\right)=\min\left\{z_{ji}^2\left(n,s^t\right),\min_{i'\neq i}\left[z_{ji'}^1\left(n,s^t\right)\right]\right\}. \tag{5}$$

Therefore, if the lowest-cost supplier to country j is a country i firm, this firm is directly competing against the second-lowest-cost supplier from country i and the lowest-cost supplier from the other countries.

However, equation (5) is not enough to characterize the equilibrium price charged by the firm capturing the market as it imposes only an upper bound to the price charged by the lowest-cost supplier. In equilibrium, the firm capturing each market either sets a price equal to the upper bound or, if the upper bound is higher than the monopoly price, the firm charges the monopoly price, given by $Z_j^1\left(n,s^t\right)/\phi$. It follows that the price in country j of each intermediate commodity n is given by

$$\begin{aligned} p_j\left(n,s^t\right) &= \underbrace{\mu_j\left(n,s^t\right)}_{\text{endogenous markup}} \quad Z_j^1\left(n,s^t\right) \\ &= \min\left[Z_j^2\left(n,s^t\right),\frac{Z_j^1\left(n,s^t\right)}{\phi}\right]. \end{aligned} \tag{6}$$

Suppose that the same firm (a country i firm) is the lowest-cost supplier to both country j and country i. There is pricing-to-market when the change in the markup in export price, $\mu_j\left(n,s^t\right)$, differs from the change in the markup in domestic prices, $\mu_i\left(n,s^t\right)$. The markup in country j is given by

$$\mu_j\left(n,s^t\right)=\min\left[\bar{\mu}_j\left(n,s^t\right),\frac{1}{\phi}\right],$$

with $\bar{\mu}_j\left(n,s^t\right) = Z_j^2\left(n,s^t\right)/Z_j^1\left(n,s^t\right)$.[3] Hence, it follows from equations (4) and (5), that the presence of trade costs is a necessary condition for pricing-to-market to arise. In the absence of trade costs, the law of one price is satisfied for each intermediate commodity and the PPP condition holds perfectly.

Complete characterization of the equilibrium prices requires the specification of how the efficiencies are distributed across firms and countries. We follow Bernard et al. (2003) and model

[3] See Appendix A.3 for details.

firms' efficiency using a probabilistic approach: It is assumed that the joint distribution of the lowest-cost supplier and of the second-lowest-cost supplier from country i is characterized by the following cumulative distribution function:

$$\begin{aligned} F_i\left(\varphi_1,\varphi_2;s^t\right) &= Prob\left[\varphi_i^1 \le \varphi_1,\, \varphi_i^2 \le \varphi_2 \mid s^t\right] \\ &= \left[1+T_i\left(s^t\right)\left(\varphi_2^{-\theta}-\varphi_1^{-\theta}\right)\right]\exp\left[-T_i\left(s^t\right)\varphi_2{}^{-\theta}\right], \end{aligned} \tag{7}$$

where $0 \le \varphi_2 \le \varphi_1$.[4] The parameter $\theta > 1$ controls the degree of heterogeneity across firms, with higher θ implying less heterogeneity. Given θ, the parameter $T_i\left(s^t\right)$ determines aggregate productivity and is both stochastic and country specific.

Using equations (3), (4) and (5), it follows that the implied joint distribution of the lowest-cost, $Z_j^1\left(n,s^t\right)$, and second-lowest-cost, $Z_j^2\left(n,s^t\right)$, of supplying commodity n in country j is given by the following cumulative distribution function:

$$\begin{aligned} G_j\left(Z_1,Z_2;s^t\right) &= Prob\left[Z_j^1\left(s^t\right) \le Z_1,\, Z_j^2\left(s^t\right) \le Z_2 \mid s^t\right] \\ &= 1-\exp\left[-\Phi_j\left(s^t\right)Z_1^\theta\right]-\Phi_j\left(s^t\right)Z_1^\theta\exp\left[-\Phi_j\left(s^t\right)Z_2^\theta\right], \end{aligned} \tag{8}$$

for $Z_1 \le Z_2$. The aggregate stochastic variable $\Phi_j\left(s^t\right)$ is given by

$$\Phi_j\left(s^t\right) = \sum_{i=1}^{K} T_i\left(s^t\right)\left(\omega_i\tau_{ji}\right)^{-\theta} \tag{9}$$

and determines the distribution of prices and markups. The result is that aggregate fluctuations in country j are determined by the behavior of this variable. In particular, in equilibrium the *ideal price index* in country j of the final good is given by

$$P_j\left(s^t\right) = \kappa\Phi_j\left(s^t\right)^{-1/\theta}, \tag{10}$$

where κ is a positive constant.[5]

The numéraire good: We assume that production of each manufactured intermediate commodity combines labor and a homogeneous, nonmanufactured input, with labor having a constant share

[4] This joint distribution is a generalization of the univariate Fréchet distribution.

[5] $\kappa = \left[1-\left(\frac{1}{\phi}\right)^{-\theta}\left(1-\frac{\theta}{1+\theta-\sigma}\right)\Gamma\left(\frac{1-\sigma-2\theta}{\theta}\right)\right]^{1/(1-\sigma)}$, where $\Gamma(.)$ is the Gamma function. See Appendix A.3 for details.

α. The nonmanufactured input is freely traded and is used as the numéraire. It is produced under constant returns to scale using only labor, with one unit of labor in country i producing W_i units of the nonmanufactured commodity. Labor is immobile across countries but mobile across sectors. Therefore, the wage rate in country i is W_i. Moreover, it follows that ω_i, the unit cost of the input bundle in country i, is equal to W_i^{α}.

Stochastic technology shocks: In each period $t = 0, 1, \ldots$, the event s_t yields a realization for the stochastic technology level in each country, $T_i\left(s^t\right)$. In particular, it is assumed that the fluctuations in each country's technology level obey a dynamic factor structure and can be decomposed, without loss of generality, as follows:

$$\ln\left[T_i\left(s^t\right)\right] = \Psi\left(s^t\right) + \epsilon_i\left(s^t\right), \tag{11}$$

where $\Psi\left(s^t\right)$ captures the common component of the technology stochastic process, and $\epsilon_i\left(s^t\right)$ denotes the country-specific portion of the technology stochastic process. Any positive correlation across $T_i\left(s^t\right)$, for $i = 1, \ldots, K$, is captured in the common component, $\Psi\left(s^t\right)$.[6]

The common component $\Psi\left(s^t\right)$ follows a serially correlated discrete Markov process. In particular, we use a finite state Markov process with states and transition probabilities set to approximate the continuous autoregressive model given by (up to a constant)

$$\Psi\left(s^t\right) = \rho\Psi\left(s^{t-1}\right) + \eta\left(s_t\right), \tag{12}$$

where $\eta\left(s_t\right)$ is a normally distributed and zero-mean *i.i.d.* shock with standard deviation ϑ_η. In turn, each country's idiosyncratic technology component, $\epsilon_i\left(s^t\right)$, follows a serially correlated discrete stochastic process independent across countries. For the idiosyncratic components, we also use a finite-state Markov process with states and transition probabilities set to approximate the continuous autoregressive model given by

$$\epsilon_i\left(s^t\right) = \rho\epsilon_i\left(s^{t-1}\right) + \upsilon_i\left(s_t\right), \tag{13}$$

where $\upsilon_i\left(s_t\right)$ is a normally distributed and zero mean *i.i.d.* shock with standard deviation ϑ_υ.

[6] The common component is included so that the calibration matches the median level of cross-country correlations observed in the data. However, the common component is entirely exogenous and does not affect the relation between trade intensity and business cycle synchronization.

Trade barriers and real exchange rate volatility: Fluctuations in the countries' level of technology lead to fluctuations in the terms of trade and the real exchange rate. Moreover, it is clear that unless there are no trade costs, the law of one price does not hold for each intermediate commodity. The consumption-based real exchange rate between country j and country i is given by $Q_{ji}\left(s^t\right) = P_i\left(s^t\right)/P_j\left(s^t\right)$, where $P_j\left(s^t\right)$ is the price of the final good in country j, given by (10). Thus, the real exchange rate can be expressed as

$$Q_{ji}\left(s^t\right) = \left[\Phi_i\left(s^t\right) \Big/ \Phi_j\left(s^t\right)\right]^{-1/\theta}. \tag{14}$$

It follows that the volatility of the real exchange rate falls as the trade costs become smaller. To illustrate this point, suppose $\tau_{ij} = \tau_{ji} = \tau \geq 1$. Imposing symmetry, the log real exchange rate can be approximated as follows

$$\log\left[Q_{ji}\left(s^t\right)\right] \approx \frac{1-\tau^{-\theta}}{\theta\bar{\Phi}}\left[T_j\left(s^t\right) - T_i\left(s^t\right)\right],$$

where $\bar{\Phi}$ is a positive constant.[7] Thus, the variance of the (log) real exchange rate is given by

$$\text{variance of } \log\left[Q_{ji}\left(s^t\right)\right] = \left(\frac{1-\tau^{-\theta}}{\theta\bar{\Phi}}\right)^2 \text{ variance of } T, \tag{15}$$

and it is immediately apparent that as τ falls toward 1 the volatility of the real exchange rate falls towards zero. At high levels of trade costs, country-specific aggregate shocks translate into movements in the domestic price of intermediate commodities but do not imply movements in the foreign price of the commodity since the high trade costs allow producers to price discriminate. However, at low trade costs price discrimination is often precluded and the law of one price holds for many intermediate commodities. In turn, this implies a low volatility of the real exchange rate and, as we will see, the synchronization of business cycles.

[7] See Appendix A.3 for details.

2.2 Preferences

The stand-in household in country i has preferences represented by a utility function of the form introduced by Greenwood, Hercowitz, and Huffman (1988), given by

$$u\left(C_i, N_i; s^t\right) = \ln\left[C_i\left(s^t\right) - \xi\,\frac{N_i\left(s^t\right)^{1+\nu}}{1+\nu}\right] \tag{16}$$

where C_i and N_i are consumption and time spent working by the stand-in household, respectively. The parameter ν is the inverse of the Frisch elasticity of labor supply and $\xi > 0$. The choice of preferences excludes wealth effects and therefore excludes intertemporal substitution in the labor choice.[8] For simplicity, we assume that there are no international financial markets so that the bilateral trade balance between any country-pair must always be zero.[9] Moreover, the country i firms are owned fully by country i residents. Hence, the period budget constraint faced by the stand-in household in country i is

$$P_i\left(s^t\right) C_i\left(s^t\right) = W_i N_i\left(s^t\right) + \Pi_i\left(s^t\right), \tag{17}$$

where $\Pi_i\left(s^t\right)$ are the aggregate profits of intermediate firms in country i. The first-order condition solving the household problem in country i is

$$N_i\left(s^t\right)^{\nu} = \frac{W_i}{\xi}\left[\frac{\Phi_i\left(s^t\right)^{1/\theta}}{\kappa}\right]. \tag{18}$$

2.3 Macroeconomic Aggregates

The probability λ_{ji} that country i is the lowest-cost supplier to j for any particular intermediate commodity is given by

$$\lambda_{ji}\left(s^t\right) = \frac{T_i\left(s^t\right)\left(\omega_i \tau_{ji}\right)^{-\theta}}{\Phi_j\left(s^t\right)}. \tag{19}$$

Since the distribution of differentiated intermediate commodity prices in the destination country is independent of the source country i, the measure λ_{ji} corresponds to country j's expenditure on country i's differentiated intermediate goods as a fraction of country j's total expenditure

[8] In a recent paper, Jaimovich and Rebelo (2009) find evidence favoring a weak wealth effect in labor supply choices.

[9] This assumption is obviously not entirely satisfactory; nonetheless, Heathcote and Perri (2002) show that assuming financial autarky in an international real business cycle model helps resolve important puzzles.

on differentiated intermediate goods. The bilateral trade intensity measure used in our study correspond to one of the measures proposed by FR, which is the sum of a country's bilateral exports divided by the sum of each country's aggregate net income. In our theoretical economy this is given by

$$\text{Bilateral trade intensity between } j \text{ and } i \equiv \left[\frac{\lambda_{ji}\left(s^t\right) E_j\left(s^t\right)+\lambda_{ij}\left(s^t\right) E_i\left(s^t\right)}{E_j\left(s^t\right)+E_i\left(s^t\right)}\right], \tag{20}$$

where $E_i\left(s^t\right)$ is the aggregate consumption expenditure in country i.[10]

Finally, as shown in Bernard et al. (2003), the aggregate share of costs in total revenue for the differentiated intermediate good producers in each country is given by $\theta/\left(1+\theta\right)$.[11] Therefore, the aggregate profits in country i are given by

$$\Pi_i\left(s^t\right)=\left[\frac{E_i\left(s^t\right)}{1+\theta}\right]. \tag{21}$$

In equilibrium, aggregate expenditure on the final good, $E_i\left(s^t\right)$, must be equal to domestic net income, given by the sum of domestic labor income and profits, yielding

$$\begin{aligned} E_i\left(s^t\right) &= W_i N_i\left(s^t\right)+\left(\tfrac{1}{1+\theta}\right) E_i\left(s^t\right) \\ &= \left(\tfrac{1+\theta}{\theta}\right) W_i N_i\left(s^t\right) \end{aligned}$$

It follows that net income in country i measured in domestic prices, $E_i\left(s^t\right)/P_i\left(s^t\right)$, is given by

$$Y_i\left(s^t\right)=\zeta\left[W_i \Phi_i\left(s^t\right)^{1/\theta}\right]^{1+1/\nu}, \tag{22}$$

where $\zeta=\left(\frac{1+\theta}{\theta}\right)\left(1/\xi\right)^{1/\nu}\left(1/\kappa\right)^{1+1/\nu}$. Naturally, market clearing in the good's market requires $C_i\left(s^t\right)=Y_i\left(s^t\right)$. To conclude, an equilibrium in our economy is defined as follows

Definition 1 *An equilibrium for this economy is a collection of allocations for each country i consumers, $C_i\left(s^t\right)$ and $N_i\left(s^t\right)$, allocations and prices for intermediate-good producers, $p_i\left(n,s^t\right)$, $X_i\left(n,s^t\right)$, and allocation and prices for final-good producers $P_i\left(s^t\right)$ and $Y_i\left(s^t\right)$, such that: (i) the consumer allocations solve the consumers' problem; (ii) the prices of intermediate-good producers solve their maximization problem; (iii) the final-good producers' allocations solve their problem; (iv)*

[10] We consider only the trade in manufactured commodities.

[11] See Appendix A.3 for proofs.

the market-clearing conditions hold.

3 Trade and Synchronization in the Theoretical Economy

We use a simulation approach to determine whether our model quantitatively reproduces the trade-comovement relation. We simulate several sets of time-series for the world economy and reproduce the FR. In this section, we describe the calibration used to evaluate the model and the main findings.

3.1 Calibration

Before turning to the quantitative findings, we describe the targets informing the choice of parameter values used to evaluate the theoretical economy. The number of countries K is set equal to 21 to replicate the empirical analysis—implying 210 distinct country-pairs.

The list of technology parameters that have to be determined includes the following: the elasticity of substitution between intermediate inputs σ; the parameter that controls the level of firm heterogeneity θ; the 420 trade-cost parameters τ_{ij} for each $i, j = 1, \ldots 21$, with $i \neq j$; the unit cost of the input bundle in each country ω_i; and the share of labor in the input bundle, α. The first two parameters are chosen based on evidence in Bernard et al. (2003), who choose the parameters θ and σ matching the productivity and size advantage of exporters as in the U.S. plant-level data. In particular, the parameter θ is chosen to match the productivity advantage of exporters, and the parameter σ corresponds to the price elasticity of demand for differentiated intermediate commodities and therefore relates to the size advantage of exporting establishments. The values estimated by Bernard et al. (2003) for θ and σ are, respectively, 3.60 and 3.79 (see Table 1).

[Table 1 about here]

The trade-cost parameters τ_{ij} are chosen to match each country-pair's bilateral trade volume in the deterministic static-equilibrium, in which $T_i\left(s^t\right) = 1$ for all i and t. From equation (19) it follows that country j's expenditure on intermediate commodities manufactured by country i as a share of country j's total spending in manufactured commodities is denoted as:

$$\lambda_{ji} = \frac{\left(\omega_i \tau_{ji}\right)^{-\theta}}{\sum_{i=1}^{K} \left(\omega_i \tau_{ji}\right)^{-\theta}}.$$

If we consider for the purpose of calibration an approximately symmetric world economy (i.e. the same total expenditure in each country), it follows from equation (20) that the bilateral trade intensity between any country-pair j and i is given by $(\lambda_{ji} + \lambda_{ij})/2$. Moreover, assuming $\omega_j \tau_{ij} \approx \omega_i \tau_{ji}$ and $\sum_{i=1}^{K}(\omega_i \tau_{ji})^{-\theta} \approx \sum_{j=1}^{K}(\omega_j \tau_{ij})^{-\theta}$ for all $j, i = 1, \ldots 21$ implies

$$\text{Bilateral trade intensity between } j \text{ and } i \approx (\omega_i \tau_{ji})^{-\theta} \Big/ \sum_{i=1}^{K} (\omega_i \tau_{ji})^{-\theta}.$$ [12]

Finally, by normalizing the bilateral trade intensity between country j and country i by the expenditure in domestic manufactured commodities by country j producers, that is given by $\omega_j^{-\theta} / \sum_{i=1}^{K} (\omega_i \tau_{ji})^{-\theta}$, yields the following normalized trade intensity measure:

$$\left(\frac{\omega_i}{\omega_j}\right)^{\theta} \left(\frac{\text{Bilateral trade intensity between } j \text{ and } i}{1 - \sum_{k \neq j} \text{Bilateral trade intensity between } j \text{ and } k}\right) = \tau_{ji}^{-\theta}. \tag{23}$$

There are 210 distinct country-pairs and, hence, 420 equations such as (23).[13] We use each of these equations to solve for the 420 trade costs τ_{ji}, matching the bilateral trade intensities (see Table 12). A description of the data can be found in the Appendix A.1. Figure 1 illustrates the calibration's fit. Despite the symmetry approximation (i.e., the approximation $\sum_{i=1}^{K} (\omega_i \tau_{ji})^{-\theta} \approx \sum_{j=1}^{K} (\omega_j \tau_{ij})^{-\theta}$ for all $j, i = 1, \ldots 21$) the fit is very good. The scatter points are located very close to the 45−degree line, and the correlation between the simulated bilateral trade intensities and the data's counterpart is 0.9965. The median bilateral trade intensity in the data is 0.0023 while in the simulation it is 0.0029.

[Figure 1 about here]

Figure 2 illustrates the distribution of the calibrated iceberg costs. Table 2 shows the relation between the calibrated values of the iceberg trade costs and the empirical proxies for trade frictions that we use in Section 4—log distance, border dummy and language dummy. As can be seen, the relation between each of these variables and the iceberg costs has the expected sign. Moreover, the R^2 of the regression is quite high: 66 percent. The correlation between the calibrated values of

[12] These approximations are not exact because the countries differ in productivity. However, they allow for an analytically tractable calibration, and Figure 1 shows that the approximation errors are very small. In particular, the correlation between the calibrated trade shares and the empirical trade shares is 0.9965.

[13] We allow for $\tau_{ij} \neq \tau_{ji}$.

the iceberg costs and the data for transaction costs that we use in Section 4 is 88 percent. These results suggest that our calibrated values of iceberg costs capture well the empirical trade barriers.

[Figure 2 about here]

[Table 2 about here]

The remaining technology parameters that need to be chosen are the unit cost of the input bundle in each country ω_i and the share of labor in the input bundle α. The latter is set equal to 0.21 following, once again, Bernard et al. (2003). The unit cost of the input bundle in each country is chosen so that the wage rate, given by $W_i = \omega_i^{1/\alpha}$, is equal to the real total compensation per employee obtained from the OECD and shown in Figure 3 (See Appendix A.1. for details).

[Figure 3 about here]

The remaining technology parameters that need to be chosen are the parameters of the stochastic process for the technology shocks. Three parameters need to be calibrated: the standard deviation of the innovations to the common component of technology and of the innovations to the idiosyncratic components (respectively, ϑ_η and ϑ_υ) and the autocorrelation coefficient ρ, which is assumed to be the same for both the common and the idiosyncratic component. The choice of values for the parameters of the stochastic processes for technology are informed by two targets. First, we choose parameter values so that the theoretical economy is consistent with quarterly aggregate time-series for the U.S. economy—in particular the volatility and autocorrelation of (log and H–P filtered) output.[14] Second, we choose the standard deviation of the innovations to the common component of technology, ϑ_η, to match the bilateral output correlation of the U.S. and Belgium (30.89 percent). We choose this specific bilateral correlation as a target because this country-pair bilateral trade share coincides with the median bilateral trade share (0.0023). The resulting value of the autocorrelation coefficient ρ is 0.8620 to match the autocorrelation of (log and H–P filtered) output in the data (86.20 percent). The parameter values for the innovations' standard deviations ϑ_η and ϑ_υ are, respectively, 0.0089 and 0.0143.

[14] We use quarterly time-series to maintain consistency with the empirical results shown in Section 4, which we later use for comparison.

Finally, we need to fix the labor supply elasticity parameter ν. The value for ν is chosen so that the standard deviation of (log) hours relative to the standard deviation of (log) output is equal to its empirical counterpart (69.93 percent). This yields a value of $\nu = 0.43$. This value implies a Frisch labor supply elasticity of 2.33, which is too high compared with the usual estimates. However, our findings regarding the model's ability to match the relation between trade integration and business cycle synchronization do not change if we set the labor supply elasticity to unity, a more conventional choice.

3.2 Findings

This section examines whether higher trade intensity in the theoretical economy, resulting from lower transportation costs, leads to higher cross-country output correlations. We answer this question by proceeding as follows: We use our model of the world economy (composed of 21 countries) to simulate 500 replications of time series for output for each country and the bilateral trade shares for each country-pair.[15] Next, we compute the average output correlation and bilateral trade intensity for each country-pair to examine the link between trade and business cycle synchronization in the theoretical economy.

Table 3 shows the empirical properties of output and hours in the U.S., and the international business cycle correlations for comparison with the theoretical economy, which is calibrated to match the world's bilateral trade shares. Overall, the theoretical economy matches the data well. Although the median bilateral output correlation in the simulated world economy is relatively close to its empirical counterpart, the distribution of output correlations is much more concentrated in the simulated data than in the actual data. This may indicate that some dimensions of the data are omitted in the theoretical economy.

[Table 3 about here]

Figure 4 provides a first insight into whether the model replicates the empirical relation between trade and comovement. It compares the empirical data (panels (a) and (b)) with the simulated data from the theoretical economy (panels (c) and (d)). Panels (a) and (c) illustrate the relation

[15] To mimic the empirical analysis in Section 4, the time series length is 240 quarters.

between trade intensity and business cycle synchronization, and panels (b) and (d) illustrate the relation between trade intensity and the real exchange rate volatility. Clearly, the theoretical model of the world economy is successful at qualitatively replicating the positive relation between business cycle synchronization and trade intensity and the negative relation between trade intensity and real exchange rate volatility.

[Figure 4 about here]

In fact, in the theoretical economy, these two relations are closely linked because of the presence of trade costs, which lead to failures of the law of one price for the intermediate commodities. In particular, deviations from relative PPP at the aggregate level arise as a result of the decisions by individual firms to price to market. When the trade costs are absent, price discrimination is not possible and the law of one price holds for each intermediate commodity; therefore, business cycles are perfectly synchronized. However, with higher trade costs, intermediate producers are able to charge different prices in different countries. Pricing-to-market by intermediate-good firms leads to violations of the law of one price. Moreover, higher bilateral trade costs obviously reduce the bilateral trade intensity. Therefore, higher trade costs simultaneously raise real exchange rate volatility—as indicated by equation (15)—and decrease business cycle synchronization.

In order to compare the potential of our model to generate high business cycle correlations between countries with stronger trade linkages, we use the simulated data to estimate the following regression equation:

$$\rho_{ji} = \alpha + \beta \left(\text{Bilateral trade intensity between } j \text{ and } i \right) + \epsilon_{ji}, \tag{24}$$

where ρ_{ji} is the correlation between (log) output in country j and in country i. We consider the level of bilateral trade intensity in addition to the logarithm, as suggested by Kose and Yi (2006). Kose and Yi (2006) recommend this specification because they judge that the relation between business cycle synchronization and trade is not a semi-log relation. As they put it, the semi-log specification implies that an increase in trade intensity from 0.1 percent to 0.2 percent would have the same impact on GDP correlation as an increase in trade intensity from 20 percent to 40 percent, which is counter-factual and inconsistent with the international business cycle model.

Table 4 reports the estimates for the coefficient β using the simulated data. The table shows both the level regression results and the semi-log regression. The β coefficients are 3.520 and 0.028 for the level and semi-log regressions, respectively.

[Table 4 about here]

3.3 Interpretation of the Findings

Country-specific technology shocks propagate internationally by lowering the price of the intermediate commodities and, therefore, increasing efficiency in the production of the final good across countries. In particular, two factors combine to explain why the lower the trade barriers are the stronger the propagation of the country-specific shocks. First, with lower trade barriers, the level of vertical specialization increases; therefore, there is more scope for each country to benefit from favorable foreign technology shocks. Second, for a given level of vertical specialization, the efficiency gains following a favorable shock are more likely to be transmitted. This follows from the fact that when trade barriers are lower, foreign exporters are compelled by their competitors to pass through the favorable technology shocks, implying lower export prices. The upshot is that when trade barriers are lower, the price of the imported intermediate commodities is more likely to fall following a positive foreign technology shock because foreign exporters are forced to lower their export prices. Hence, country-specific shocks are better transmitted with lower trade barriers.

What happens to real exchange rate volatility? The mechanism explaining the positive association between trade integration and real exchange rate volatility is the same. Given that the final good sector is perfectly competitive, the reduction in the price of intermediate inputs translates fully into a lower price of the final good. With low trade barriers, the country-specific shocks propagate across countries strongly because vertical specialization is high and the transmission of foreign shocks through lower intermediate input prices is easy. Therefore, the prices of the final good in each country move together. The result is that when trade barriers are low, real exchange rate volatility is low.

Hence, the model predicts: (i) A negative relation between trade barriers and business cycle synchronization; and (ii) a positive relation between real exchange rate volatility and trade barriers.

4 Relation Between Trade and Comovement: Model vs Data

In this subsection, we reproduce the well-known empirical link between trade integration and business cycle synchronization shown in FR. Our results confirm the positive and significant relation between trade and comovement. We also estimate an augmented version of the FR benchmark regression that controls for both financial integration and trade intensity. In this case the positive link between trade and comovement remains robust. However, the effect of trade intensity on comovement is attenuated once we control for financial integration.[16]

We then assess the potential of our model to replicate the empirical relation between trade and comovement. Our findings indicate that our theoretical model explains up to 41 percent of the empirical relation between trade intensity and business cycle synchronization. In this way, it is successful in solving the trade-comovement puzzle.

Our model outlined in Section 2 contains two other predictions. First, correlations should be lower for countries with higher trade costs. Second, exchange rate volatility is higher for countries with higher trade costs. We provide empirical evidence supporting this link.

4.1 Link Between Trade Integration and Comovement

In this subsection we replicate the estimation method of FR on our data and sample period. Our estimated regression is as follows:

$$\rho_{ji} = \alpha + \beta \ \ln \Big(Trade_{ji} \Big) + \varepsilon_{ji}, \tag{25}$$

where ρ_{ji} is the GDP correlation between country j and country i, $\ln \Big(Trade_{ji} \Big)$ is the logarithm of the average bilateral trade intensity measure, and ε_{ji} is an error term. Moreover, as suggested by Kose and Yi (2006), we estimate a second equation, given by

$$\rho_{ji} = \alpha + \beta \, Trade_{ji} + \varepsilon_{ji}, \tag{26}$$

where instead of using the measure of trade intensity in logs, we consider the level of trade intensity. When we later compare the data to our theoretical economy, the benchmark we use for comparison is the levels regression, although we also report results for the semi-log regression for completeness.

[16] As highlighted later this point was addressed by Imbs (2004).

In any case, we are interested in the sign and magnitude of the regression coefficient β. A positive β indicates that increased trade integration generates more synchronized business cycles. However, the OLS estimation of equations (25) and (26) is likely to be biased.[17] The issues of simultaneous causation and omitted variable bias are likely to be serious given that trade integration is endogenous. For this reason we use a GMM instrumental variable estimator to identify the effect of trade integration on business cycle correlation. The instrumental variables used are in accordance with the gravity model of trade. In particular, we use the natural logarithm of distance between the business centers of the country-pairs, a dummy variable that takes the value of 1 when the countries share a common border, and a dummy variable that indicates if the country-pair shares a common language. Each of these variables is expected to be correlated with bilateral trade but uncorrelated with other conditions that may affect bilateral correlations. We show the OLS results in Table 5. The instrumental variable (IV) results including the first-stage regression are presented in Tables 6 and 7.

4.2 Estimation

The OLS estimates of β in Table 5 indicate that there is a positive association between trade integration and comovement. The specification (in levels) is shown in column (1) and the semi-log specification in column (2). The coefficient β takes the value 10.864 in the levels regression and 0.090 in the log regression.

Finally, we notice that the residuals in regressions (1) and (2) are correlated with the level of trade intensity.[18] This implies the presence of an endogeneity bias; hence, in what follows we explore the IV regressions.

As expected, the IV estimation results are in line with the OLS estimation and are actually stronger. Table 6 presents the first-stage regression of bilateral trade intensity on our three IVs. The estimates in columns (1) and (2) support the predictions of the gravity model of trade. Distance has a negative effect on trade intensity, and countries tend to trade more when they share a border or have a common language.

[Table 5 about here]

[17] We nevertheless report the OLS regression results below.

[18] These results are not reported.

[Table 6 about here]

Table 7 shows the IV estimates of the β coefficient. Overall, the IV estimates of β confirm the seminal result by FR: Trade intensity has a positive and significant effect on GDP correlation. Our benchmark specification in levels yields a coefficient equal to 17.250 (column (1)). For the semi-log specification, the β coefficient is 0.102 (column (2)).

The slope coefficient from the level regression implies that a doubling of the median trade intensity (a level increase of 0.0023) is associated with an increase in GDP correlation of 0.0397. In the log regression, the β coefficient implies that doubling the trade intensity leads to an increase of 0.069 in GDP correlations. Our estimates are slightly higher than those generally reported in the literature. For example, Kose and Yi's (2006) estimates imply increases in GDP correlations of 0.029 for the levels regression and 0.063 for the logs regression.[19] By contrast, FR's estimates imply that doubling trade intensity increases GDP correlations by 0.033.

[Table 7 about here]

4.2.1 Accounting for Financial Integration

In their empirical work, FR control only for bilateral trade intensity. As noted by Imbs (2004), international trade plays a relatively moderate role in transmitting business cycles across countries after controlling for financial integration and patterns of specialization. This result has important implications for the relation we are assessing. Thus, we estimate an augmented version of equation (26) that includes a measure of financial integration:

$$\rho_{ji} = \alpha + \beta \, Trade_{ji} + \gamma \, Fin_{ji} + \varepsilon_{ji}, \tag{27}$$

where Fin_{ji} is the bilateral cross-country bank stock of assets and liabilities divided by the sum of the countries' GDP. We estimate Equation (27) using IVs. Portes and Rey (2005) show that gravity variables explain international transactions in financial assets and goods.[20] Therefore, we use this result to also instrument Fin_{ji} using distance, border and language. For the sake of completeness, we also estimate the semi-log model.

[19] One source of difference is the data span. Kose and Yi (2006) consider data from 1970-2000.

[20] Lane and Milesi-Ferretti (2008) show that country portfolios are strongly biased towards trade partners. They also find that gravity variables such as distance and common language are associated with bilateral asset holdings.

The first-stage results are shown in columns (3) and (4) of Table 6. Overall, we confirm that the gravity variables are good instruments for the level of financial integration. The R^2 is high and, except for the border dummy variable, all the covariates are significant. In particular, distance has a negative and significant effect on financial integration, while language has a significant positive effect.

The results of the IV estimation are shown in Table 8. The regression in column (3) yields a significant effect of trade on output correlation. However, compared with the IV model that does not include financial integration (shown in Table 7), the β coefficient drops substantially, from 17.250 to 8.537. Moreover, financial integration has a positive and significant effect on business cycle synchronization.[21] By contrast, the log regression presented in column (4) yields a β coefficient equal to 0.106, which is similar to the one reported in Table 7. Thus, the IV estimate of β in the model with financial integration seems robust.

[Table 8 about here]

4.3 Quantitative Assessment of the Relation Between Trade and Comovement

In this subsection, we compare the average FR regression coefficient obtained using the simulated data with the empirical counterpart. Table 9 summarizes the empirical estimates of the coefficient β, and compares it with the coefficient obtained using the simulated data in Section 3. In the level regression, we see that the OLS estimate of β for the simulated data is about one-third of the size of the OLS coefficient for the empirical data—it is 10.864 for the data, compared with 3.520 for the theoretical economy. Thus, if we assume the OLS model is well specified, our benchmark theoretical economy explains 32 percent of the empirical relation. Figure 4 considers the linear regression equation (24) estimated using the simulated data from the theoretical economy and contrasts it with the empirical relation between trade intensity and output correlations.

[Table 9 about here]

[21] These results agree with those of Imbs (2006), who finds a positive association between financial integration and GDP correlation.

However, there are reasons to believe that the simple OLS model is inappropriate. Trade intensity is, of course, endogenous and many potential determinants of bilateral trade (e.g., bilateral exchange rate regime, financial integration) are likely to influence business cycle synchronization. Indeed, it is clear from the scatter plot in Figure 4a that the residuals of the OLS regression are not independent of the explanatory variable. Therefore, the coefficient β in equation (24), which is estimated in the sample of the simulated data, should be compared with the empirical instrumental variable counterpart. Table 9 addresses this comparison. The baseline model—labeled (1)—is estimated by GMM, instrumenting with the usual gravity variables. While the theoretical economy explains 32 percent of the OLS relation, it explains only about 20 percent of the relation estimated using IVs.

An important potential source of omitted variable bias is related to the level of financial integration. Indeed, the analysis by Imbs (2004) indicates that countries with strong financial links are significantly more synchronized. Moreover, as discussed previously, many of the determinants of trade also contribute to explain the level of financial links. Hence, not including this variable may be an important source of bias. Therefore, instead of the baseline regression, we consider a second specification—labeled (2)—that controls for the level of financial integration. Once again, we consider the OLS and the GMM estimates of β, the coefficient on trade intensity. The explanatory power of the model increases once we control for the level of financial integration. In particular, the model explains 41 percent of the IV relation between trade intensity and business cycle synchronization, after controlling for the level of financial integration.

[Figure 5 about here]

[Figure 6 about here]

The importance of controlling for the level of financial integration is well illustrated by Figures 5 and 6, which compare the empirical relation with the theoretical economy's predicted relation between bilateral trade intensity and business cycle synchronization. The scatter plot in Figure 5 clearly shows that the best linear predictor of the empirical data points is far from the 95 percent confidence interval corresponding to the model's predicted relation between trade and comovement. The slope of the empirical best linear predictor is very different from the slope of the theoretical economy's best linear predictor. However, if there are omitted variables, the model is misspecified. Therefore, we control for the level of financial integration. The importance of doing this can be seen from Figure 6. The scatter points show in the vertical axis the adjusted bilateral correlation, corresponding to the bilateral correlation corrected for the differences in the levels of financial integration, given by

$$\hat{\rho}_{ji} = \rho_{ji} + \hat{b}_2^{IV} \left[\Big(\text{Average fin. integration}\Big) - \Big(\text{Fin. integration between } j \text{ and } i\Big) \right],$$

where "Average fin. integration" is the sample average of the bilateral financial integration measure and $\hat{b}_2^{IV}$ is the IV coefficient estimate. The figure shows that if country-pairs did not vary in their bilateral levels of financial integration, the best linear fit of the data would be within the 95 percent confidence interval for the theoretical economy's predicted relation between trade intensity and business cycle synchronization. The slope of the empirical best linear predictor (equal to 3.282) is very close to the slope of the best linear predictor for the simulated economy (equal to 3.520). Thus, the fit of the theoretical model improves substantially once we control for the level of financial integration.

Finally, the right side of Table 9 considers the semi-log specification. Overall, the findings are not very different from the model in levels. In particular, the OLS regression coefficient for the theoretical economy is about 31 percent of the empirical counterpart and the IV coefficient is 27 percent. Overall, we believe the model in levels is more reliable, although the quantitative findings are not too sensitive to the choice of model specification. The model explains between 20 percent and 41 percent of the empirical relation between trade and business cycle synchronization.

4.4 Trade Barriers, Comovement and Real Exchange Rate Volatility

Our theoretical model predicts that countries with higher trade costs will be associated with lower GDP correlations and higher real exchange rate volatility. In order to assess these predictions we construct an empirical measure of trade costs based on Novy (2008), (see Appendix A.2 for details).

We estimate the following regression:

$$\rho_{ji} = \alpha + \beta tc_{ji} + \varepsilon_{ji}, \tag{28}$$

where the variable labeled tc_{ji} is the trade cost between country j and country i.

The results in Table 10 indicate a negative association between trade costs and business cycle synchronization. This relation is important for our explanation of the trade-comovement link. Specifically, if the presence of trade barriers reduces trade and decouples the international business cycle, then we would expect higher trade costs to be associated with lower output correlation.

[Table 10 about here]

We also estimate

$$rervol_{ji} = \alpha + \beta tc_{ji} + \varepsilon_{ji}, \tag{29}$$

where $rervol_{ji}$ is the volatility of the real exchange rate between country j and country i. The results confirm that trade barriers increase real exchange rate volatility, as predicted by our theoretical model.

5 Conclusion

The positive relation between trade intensity and business cycle comovement has been documented in a broad literature. However, it is difficult for theoretical models to replicate this relation.

We developed a multi-country international business cycle model with vertical trade linkages, imperfect competition, and endogenous markups. We investigated whether this framework can account for the trade comovement puzzle identified by Kose and Yi (2001) and Kose and Yi (2006). In particular, we carefully calibrated a model of the world economy consisting of 21 countries. The model's trade costs are calibrated to match each country-pair's bilateral trade volume – that is, 210 country-pairs. The resulting calibrated trade costs are correlated as expected with the standard proxies for trade costs in the gravity model. We show that the model successfully addresses the trade-comovement puzzle. In terms of matching the data, our model explains at most 41 percent of the responsiveness of comovement to trade integration.

In their empirical work, FR control for only bilateral trade intensity. Other researchers, especially Imbs (2004), note that international trade plays a relatively moderate role in transmitting business cycles across countries after controlling for financial integration and patterns of specialization. We augment the FR regression to include financial integration. We find that (i) the impact of trade intensity on comovement is attenuated when we control for financial linkages and (ii) financial integration has a positive impact on comovement. We also show that gravity variables explain international transactions in financial assets. Given these results, an extension to our model that includes financial linkages offers a promising avenue for future research.

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A Appendix

A.1 Data

We consider a sample of 21 OECD countries composed of the United States (US), United Kingdom (UK), Austria (AT), Belgium (BE), Denmark (DK), France (FR), Germany (DE), Italy (IT), Netherlands (NL), Norway (NO), Sweden (SW), Switzerland (CH), Canada (CA), Japan (JP), Finland (FI), Greece (GR), Ireland (IR), Portugal (PT), Spain (SP), Australia (AS) and New Zealand (NZ) over the period 1974–2007. The variable definitions and data sources are as follows:

Correlation: We use real GDP, measured quarterly, to capture economic activity and compute the correlations between each country-pair, j and i, (labeled ρ_{ji}). We first transform real GDP by taking the natural logarithm. Since we are interested in business cycle fluctuations we detrend it using the H-P filter. GDP data are from the OECD (transaction B1_GE) using measure VPVOBARSA (USD, volume estimates, fixed PPPs, OECD reference year, annual levels, seasonally adjusted).

Trade intensity: We measure trade intensity between each country pair, j and i, (labeled $Trade_{ji}$) normalizing bilateral trade—that is, the sum of each country's imports from the other—by the sum of nominal GDP in the two countries, averaged over the entire period. Exports and imports data, denominated in dollars, are taken from the IMF Direction of Trade Statistics (DOTS). We normalized trade by nominal GDP. The series was from the OECD (transaction B1_GE), and the measure was CXC (USD current prices current exchange rates)

Financial integration: Bilateral bank stock of assets and liabilities data, measured quarterly and denominated in U.S. dollars, are from the Bank of International Settlements (BIS) Locational Banking Statistics Database. We normalized the stock of assets and liabilities by nominal GDP.

Gravity variables: The following variables are from Andrew Rose's website: distance between business centers, common language dummy, and border dummy.[22]

Real exchange rate volatility: Real exchange rate volatility is measured by calculating the standard deviation of the quarterly series, detrended using the H-P filter. The nominal exchange rate series were retrieved from Haver, and the source is the Federal Reserve Board. Consumer prices are from the OECD MEI database. The variable is "Consumer Prices - All Items".

[22] http://faculty.haas.berkeley.edu/arose

Wages: Total annual compensation is from the OECD's National Accounts Database. The measure is C (national currency, current prices) and the transaction is D1 (compensation of employees). These values are divided by total employment to get total compensation per employee The variable is ET (total employment) in the OECD's Economic Outlook No. 87. Germany is missing data before 1991, so the German total employment data is extrapolated using the series "Employed Persons" from Statistisches Bundesamt Deutschland (DESTATIS).[23] The compensation data are deflated using CPI data (all items) from the OECD (Dateset: Price Indices) using 2000 as the base year, and then converted to dollars using the 2000 USD exchange rate from the Federal Reserve Board.

Summary statistics of the basic data are presented in Table 11. The median bilateral trade intensity over all countries and all years is 0.0023 and the standard deviation is 0.0080. Thus, as noticed by Kose and Yi (2006), the bilateral trade flows between the typical country-pair are small.

As shown in Table 11, the level of dispersion in the output correlations is substantial. The median level is about 30 percent, but the standard deviation is just above 20 percent.

[Table 11 about here]

A.2 Methodology to Compute Trade Costs

Bilateral trade costs were calculated to correspond with equation (8) in Novy (2008). The equation is

$$\tau_{ij} = \left(\frac{x_{ii} x_{jj}}{x_{ij} x_{ji}} \right)^{\frac{1}{2(\sigma-1)}} - 1,$$

where τ_{ij} is the bilateral trade cost between countries i and j, x_{ii} (x_{jj}) represents the trade of country i (j) with itself, $x_{ij}(x_{ji})$ is exports from country i to j (j to i), and σ is the elasticity of substitution across goods. We assume σ to be 3.79, in line with the calibration of our model (see Table 1). Novy (2008) follows Anderson and van Wincoop (2004) and assumes that σ equals 8. The results are not sensitive to the value of σ.

[23] www.destatis.de

A.2.1 Computation of Intranational Trade

Intranational trade is calculated as a country's total output less its exports to the world. Following the methodology of Wei (1996), GDP is adjusted by the ratio of output to value added and the goods share of GDP to obtain total output. The equation for intranational trade is:

$$x_{ii} = \alpha_i \beta_i GDP_i - x_{iw},$$

where GDP_i is GDP of country i, x_{iw} are exports from country i to the world and α_i and β_i are the ratio of output to value added and goods share of GDP in country i, respectively.

A.2.2 Data sources

For x_{ij} and x_{ji} we used the DOTS bilateral export data from the IMF, described in A1.

x_{ii} and x_{jj} are calculated using data on exports to the world (same IMF DOTS data used before) and GDP data pulled from the OECD national accounts database (measure CXC (USD, current prices, current exchange rates), transaction B1_GA (GDP, output approach).

Data on gross output and value added for the total economy is pulled from the OECD's STAN database (variables PROD and VALU, respectively). Goods GDP is computed as the sum of transactions B1GA_B (Agriculture, hunting and forestry, fishing), B1GC_E (Industry), and B1GF (Construction). In order to maximize the coverage of trade costs across time and country pairs the assumption of a constant ratio of output to value added and goods share of GDP was adopted, where $\alpha_i = 5/2$ and $\beta_i = 1/3$ for all i. These values were informed by the available data and, in particular, the value for α_i fits in the middle of the range of values calculated by Wei(1996) for the ratio of output to value added. Ultimately, the trade cost analysis is not affected by the decision to fix α_i and β_i. Bilateral trade costs computed precisely from the data show a 97% and higher correlation with those computed under the fixed ratios.

A.3 Analytical Results

This appendix describes how we obtained the analytical results provided in the paper. Many of these derivations, in particular in sections A.3.3 and A.3.4, are adapted from Bernard et al. (2003).

A.3.1 Final-good firm's problem

The production function is given by

$$Y\left(s^{t}\right)=\left[\int_{0}^{1}X\left(n,s^{t}\right)^{\phi}dn\right]^{1/\phi}, \tag{30}$$

with $\phi=(\sigma-1)/\sigma$.

Define $P\left(s^{t}\right)$ as the ideal price index for the final good. The demand for each intermediate commodity can be found by maximizing the following profit function,

$$\Pi\left(s^{t}\right)=P\left(s^{t}\right)\left[\int_{0}^{1}X\left(n,s^{t}\right)^{\phi}dn\right]^{1/\phi}-\int_{0}^{1}p\left(n,s^{t}\right)X\left(n,s^{t}\right)dn.$$

The first-order condition is $P\left(s^{t}\right)X\left(n,s^{t}\right)^{\phi-1}\left[X\left(n,s^{t}\right)^{\phi}\right]^{\frac{1}{\phi}-1}=p\left(n,s^{t}\right)$, which yields the relative demand equation given by

$$\frac{X\left(n,s^{t}\right)}{X\left(n',s^{t}\right)}=\left[\frac{p\left(n,s^{t}\right)}{p\left(n',s^{t}\right)}\right]^{-\sigma}. \tag{31}$$

Moreover, the ideal price index $P\left(s^{t}\right)$ satisfies

$$\begin{aligned}P\left(s^{t}\right)\left[\int_{0}^{1}X\left(n,s^{t}\right)^{\phi}dn\right]^{1/\phi} &= \int_{0}^{1}p\left(n,s^{t}\right)X\left(n,s^{t}\right)dn\\ P\left(s^{t}\right)X\left(n',s^{t}\right)p\left(n',s^{t}\right)^{\sigma}\left[\int_{0}^{1}p\left(n,s^{t}\right)^{1-\sigma}dn\right]^{1/\phi} &= X\left(n',s^{t}\right)p\left(n',s^{t}\right)^{\sigma}\int_{0}^{1}p\left(n,s^{t}\right)^{1-\sigma}dn,\end{aligned}$$

which yields

$$P\left(s^{t}\right)=\left[\int_{0}^{1}p\left(n,s^{t}\right)^{1-\sigma}dn\right]^{1/(1-\sigma)}. \tag{32}$$

Finally, by combining equation (31) and the budget constraint we find the demand for each intermediate commodity as follows

$$\begin{aligned}\int_{0}^{1}p\left(n,s^{t}\right)X\left(n,s^{t}\right)dn &= E\left(s^{t}\right)\\ X\left(n',s^{t}\right)p\left(n',s^{t}\right)^{\sigma}\int_{0}^{1}p\left(n,s^{t}\right)^{1-\sigma}dn &= E\left(s^{t}\right),\end{aligned}$$

which gives the demand function

$$X\left(n', s^t\right) = \left[\frac{p\left(n', s^t\right)}{P\left(s^t\right)}\right]^{-\sigma} Y\left(s^t\right). \tag{33}$$

A.3.2 Intermediate-good firm's problem

The profit function of the intermediate-good firm supplying commodity n to market j is

$$\Pi\left(n, s^t\right) = p\left(n', s^t\right)\left[\frac{p\left(n', s^t\right)}{P\left(s^t\right)}\right]^{-\sigma} Y\left(s^t\right) - Z_j^1\left(n, s^t\right)\left[\frac{p\left(n', s^t\right)}{P\left(s^t\right)}\right]^{-\sigma} Y\left(s^t\right).$$

The first-order condition is $(1-\sigma)\, p\left(n', s^t\right)^{-\sigma} = -\sigma Z_j^1\left(n, s^t\right) p\left(n', s^t\right)^{-\sigma-1}$, implying that the monopoly price is given by $Z_j^1\left(n, s^t\right)/\phi$. Since the price is set à la Bertrand, it follows that the price of intermediate commodity n is country j is given by

$$p_j\left(n, s^t\right) = \min\left[Z_j^2\left(n, s^t\right), \frac{Z_j^1\left(n, s^t\right)}{\phi}\right]. \tag{34}$$

A.3.3 The ideal price index

The ideal price index is given by equation (32). Moreover, the price in country j of each intermediate good n is given by $p_j\left(n, s^t\right) = \mu_j\left(n, s^t\right) Z_j^1\left(n, s^t\right)$ where $\mu_j\left(n, s^t\right)$ is the markup denoted by

$$\mu_j\left(n, s^t\right) = \min\left[\bar{\mu}_j\left(n, s^t\right), \frac{1}{\phi}\right],$$

with $\bar{\mu}_j\left(n, s^t\right) = Z_j^2\left(n, s^t\right)/Z_j^1\left(n, s^t\right)$, which follows a Pareto distribution with shape parameter θ. Therefore, from (32) it follows (dropping the j subscript) that

$$\begin{aligned}
P\left(s^t\right)^{1-\sigma} &= E\left[p\left(n, s^t\right)^{1-\sigma} \mid s^t\right] \\
&= \int_1^\infty E\left[p\left(n, s^t\right)^{1-\sigma} \mid s^t, \bar{\mu}\left(n, s^t\right) = \bar{\mu}\right] \theta \bar{\mu}^{-(\theta+1)} d\bar{\mu} \\
&= \int_1^{\frac{1}{\phi}} E\left[Z^2\left(n, s^t\right)^{1-\sigma} \mid s^t\right] \theta \bar{\mu}^{-(\theta+1)} d\bar{\mu} + \int_{\frac{1}{\phi}}^\infty E\left\{\left[\frac{Z^2\left(n, s^t\right)}{\phi \bar{\mu}}\right]^{1-\sigma} \mid s^t\right\} \theta \bar{\mu}^{-(\theta+1)} d\bar{\mu}
\end{aligned}$$

which yields

$$P\left(s^t\right)^{1-\sigma} = E\left[Z^2\left(n, s^t\right)^{1-\sigma} \mid s^t\right]\left[1 - \left(\frac{1}{\phi}\right)^{-\theta}\left(1 - \frac{\theta}{1+\theta-\sigma}\right)\right]. \tag{35}$$

From equation (8) it is possible to derive the distribution of $Z_j^2\left(n, s^t\right)$, $G_{2n}\left(Z^2; s^t\right)$, which we use to calculate

$$E\left[Z^2\left(n, s^t\right)^{1-\sigma} \mid s^t\right] = \Phi\left(s^t\right)^{-(1-\sigma)/\theta}\Gamma\left(\frac{1-\sigma-2\theta}{\theta}\right). \tag{36}$$

where $\Phi_j\left(s^t\right) = \sum_{i=1}^{K} T_i\left(s^t\right)\left[\omega_i\left(s^t\right)\tau_{ji}\right]^{-\theta}$. Finally, plugging (36) in (35), yields

$$\begin{aligned} P\left(s^t\right) &= \left[1 - \left(\tfrac{1}{\phi}\right)^{-\theta}\left(1 - \tfrac{\theta}{1+\theta-\sigma}\right)\Gamma\left(\tfrac{1-\sigma-2\theta}{\theta}\right)\right]^{1/(1-\sigma)}\Phi\left(s^t\right)^{-1/\theta} \\ &= \kappa\Phi\left(s^t\right)^{-1/\theta}. \end{aligned} \tag{37}$$

A.3.4 Aggregate share of costs in total revenue

Let $e_j(n, s^t)$ denote how much country j spends on good n. It follows that the cost of producing good n for country j is

$$\begin{aligned} I_j\left(n, s^t\right) &= \frac{e_j(n, s^t)}{\mu_j\left(n, s^t\right)} \\ &= \frac{E_j\left(s^t\right)\left[p_j\left(n, s^t\right)/p_j\left(s^t\right)\right]^{1-\sigma}}{\mu_j\left(n, s^t\right)} \end{aligned}$$

Taking the expectation over the measure of commodities yields

$$\frac{I_j\left(s^t\right)}{E_j\left(s^t\right)} = \frac{E\left[p_j\left(n, s^t\right)^{1-\sigma}\mu_j\left(n, s^t\right)^{-1} \mid s^t\right]}{E\left[p_j\left(n, s^t\right)^{1-\sigma} \mid s^t\right]} \tag{38}$$

From equation (35), $E\left[p_j\left(n,s^t\right)^{1-\sigma}\mid s^t\right] = E\left[Z^2\left(n,s^t\right)^{1-\sigma}\mid s^t\right]\left[1-\left(\frac{1}{\phi}\right)^{-\theta}\left(1-\frac{\theta}{1+\theta-\sigma}\right)\right]$. To find the numerator in the right-hand-side of (38), we proceed in a similar manner:

$$\begin{aligned}
E\left[p_j\left(n,s^t\right)^{1-\sigma}\mu_j\left(n,s^t\right)^{-1}\mid s^t\right] &= \int_1^{\infty} E\left[p_j\left(n,s^t\right)^{1-\sigma}\mid s^t,\bar{\mu}_j\left(n,s^t\right)=\bar{\mu}\right]\theta\bar{\mu}^{-(\theta+1)}\bar{\mu}^{-1}d\bar{\mu} \\
&= \int_1^{\frac{1}{\phi}} E\left[Z_j^2\left(n,s^t\right)^{1-\sigma}\mid s^t\right]\theta\bar{\mu}^{-(\theta+2)}d\bar{\mu}\ldots \\
&+ \int_{\frac{1}{\phi}}^{\infty} E\left\{\left[\frac{Z_j^2\left(s^t\right)}{\phi\bar{\mu}}\right]^{1-\sigma}\mid s^t\right\}\phi\theta\bar{\mu}^{-(\theta+1)}d\bar{\mu},
\end{aligned}$$

which yields

$$\begin{aligned}
E\left[p_j\left(n,s^t\right)^{1-\sigma}\mu_j\left(n,s^t\right)^{-1}\mid s^t\right] &= E\left[Z_j^2\left(s^t\right)\mid s^t\right]\left[\frac{\theta}{1+\theta}\left(1-\phi^{1+\theta}\right)+\phi^{1+\theta}\frac{\theta}{\theta+1-\sigma}\right] \\
&= \left(\frac{\theta}{1+\theta}\right)E\left[Z_j^2\left(s^t\right)\mid s^t\right]\left(1+\phi^{1+\theta}\frac{\sigma}{\theta+1-\sigma}\right),
\end{aligned}$$

and using the fact that $\phi=(\sigma-1)/\sigma$ yields

$$\begin{aligned}
E\left[p_j\left(n,s^t\right)^{1-\sigma}\mu_j\left(n,s^t\right)^{-1}\mid s^t\right] &= \left(\frac{\theta}{1+\theta}\right)E\left[Z_j^2\left(s^t\right)\mid s^t\right]\left(1+\phi^{\theta}\frac{\sigma-1}{\theta+1-\sigma}\right) \\
&= \left(\frac{\theta}{1+\theta}\right)E\left[Z_j^2\left(s^t\right)\mid s^t\right]\left[1-\left(\frac{1}{\phi}\right)^{-\theta}\left(1-\frac{\theta}{1+\theta-\sigma}\right)\right].
\end{aligned}$$

Finally, replacing in (38) yields

$$\frac{I_j\left(s^t\right)}{E_j\left(s^t\right)}=\frac{\theta}{1+\theta}. \tag{39}$$

This share does not depend on j. Hence, $\theta/(1+\theta)$ is the share of costs in total revenues for each country's producers regardless of where they sell their output.

A.3.5 Shocks and the real exchange rate

The real exchange rate between country j and country i is given by

$$\begin{aligned}
Q_{ji}\left(s^t\right) &= P_i\left(s^t\right)/P_j\left(s^t\right) \\
&= \left[\Phi_i\left(s^t\right)\Big/\Phi_j\left(s^t\right)\right]^{-1/\theta} \\
&= \left\{\frac{\sum_{j=1}^K T_j\left(s^t\right)\left[\omega_j\left(s^t\right)\tau_{ij}\right]^{-\theta}}{\sum_{i=1}^K T_i\left(s^t\right)\left[\omega_i\left(s^t\right)\tau_{ji}\right]^{-\theta}}\right\}^{-1/\theta},
\end{aligned}$$

Assume symmetry between country i and country j, so that $\tau_{ij} = \tau_{ji} = \tau \geq 1$; $\omega_j = \omega_i = 1$; and $\sum_{k \neq i,j} T_k\left(s^t\right)\left(\omega_k \tau_{jk}\right)^{-\theta} \approx \sum_{k \neq i,j} T_k\left(s^t\right)\left(\omega_k \tau_{ik}\right)^{-\theta} = \bar{\Phi}$. Then the real exchange rate is given by

$$Q_{ji}\left(s^t\right) = \left\{\frac{\bar{\Phi} + T_j\left(s^t\right)\tau^{-\theta} + T_i\left(s^t\right)}{\bar{\Phi} + T_i\left(s^t\right)\tau^{-\theta} + T_j\left(s^t\right)}\right\}^{-1/\theta} \tag{40}$$

$$= \left\{\frac{1 + \left[T_j\left(s^t\right)\tau^{-\theta} + T_i\left(s^t\right)\right]/\bar{\Phi}}{1 + \left[T_i\left(s^t\right)\tau^{-\theta} + T_j\left(s^t\right)\right]/\bar{\Phi}}\right\}^{-1/\theta} \tag{41}$$

Finally, taking logs and using the approximation $\log\left[1 + \frac{T_j\left(s^t\right)\tau^{-\theta} + T_i\left(s^t\right)}{\bar{\Phi}}\right] \approx \frac{T_j\left(s^t\right)\tau^{-\theta} + T_i\left(s^t\right)}{\bar{\Phi}}$, yields

$$\log\left[Q_{ji}\left(s^t\right)\right] \approx \frac{1 - \tau^{-\theta}}{\theta\bar{\Phi}}\left[T_j\left(s^t\right) - T_i\left(s^t\right)\right]$$

It follows that the variance of the (log) real exchange rate is given by

$$\text{variance of } \log\left[Q_{ji}\left(s^t\right)\right] = \left(\frac{1 - \tau^{-\theta}}{\theta\bar{\Phi}}\right)^2 \text{variance of } T$$

Thus, the volatility of the real exchange rate falls as $\tau \to 1$.

A.3.6 The household's problem

The first-order condition solving the problem of the household is $\xi N^{\nu} = W/P$. The price level is given by (10). Hence, hours are given by

$$N\left(s^t\right)^{\nu} = \frac{W}{\xi}\left[\frac{\Phi\left(s^t\right)^{1/\theta}}{\kappa}\right]. \tag{42}$$

A.3.7 Other macroeconomic aggregates

The aggregate share of profits in total revenue for the intermediate-good producers is $1 - \theta/(1+\theta)$. The aggregate revenue of the intermediate good producers is simply $E\left(s^t\right)$. Therefore aggregate profits are

$$\Pi\left(s^t\right) = \left(1 - \frac{\theta}{1+\theta}\right) E\left(s^t\right) = \left[\frac{E\left(s^t\right)}{1+\theta}\right]. \tag{43}$$

In equilibrium, aggregate expenditure in the final good, $E\left(s^t\right)$, must equal domestic net income, given by the sum of domestic labor income and profits, yielding

$$\begin{aligned} E\left(s^t\right) &= WN\left(s^t\right) + \left(\tfrac{1}{1+\theta}\right) E\left(s^t\right) \\ &= \left(\tfrac{1+\theta}{\theta}\right) WN\left(s^t\right) \end{aligned}$$

It follows that net income in country i measured in domestic prices—equal to $E\left(s^t\right)/P\left(s^t\right)$—is given by

$$Y\left(s^t\right) = \zeta \left[W\Phi\left(s^t\right)^{1/\theta}\right]^{1+1/\nu}, \tag{44}$$

where $\zeta = \left(\frac{1+\theta}{\theta}\right)(1/\xi)^{1/\nu}(1/\kappa)^{1+1/\nu}$.

Figure 1. Bilateral Trade Intensities: Data vs. Simulation

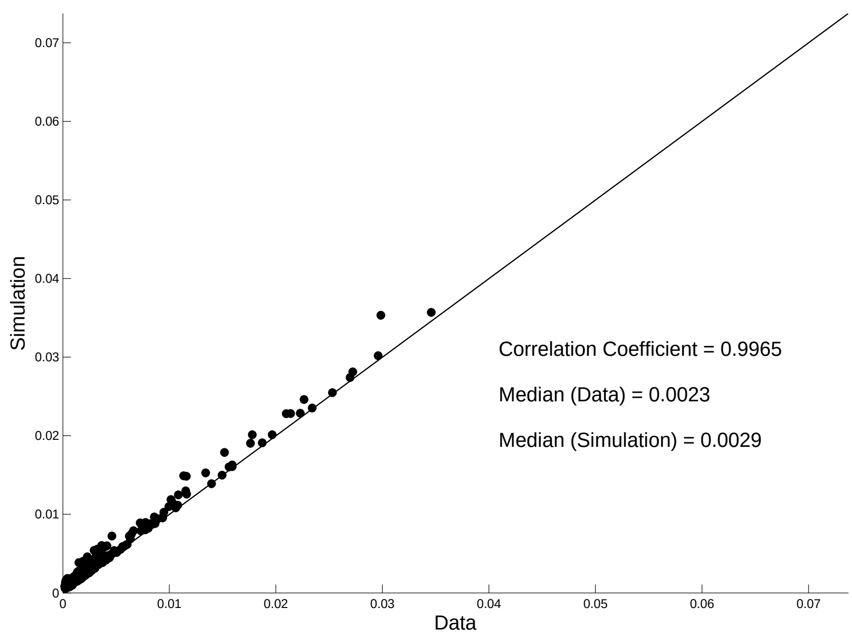


Figure 2. Calibrated Iceberg Costs

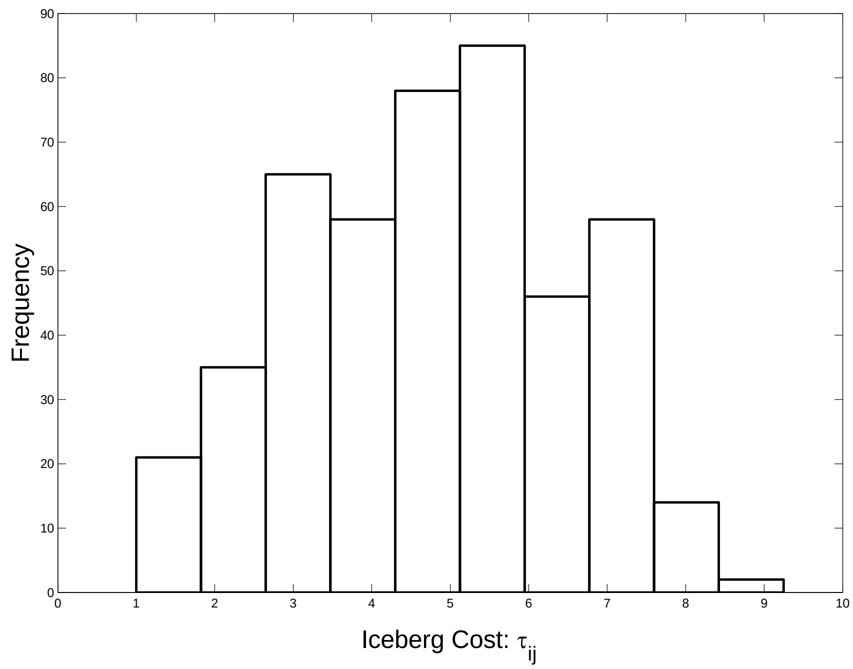


Figure 3. Total Compensation per Employee (Real USD)

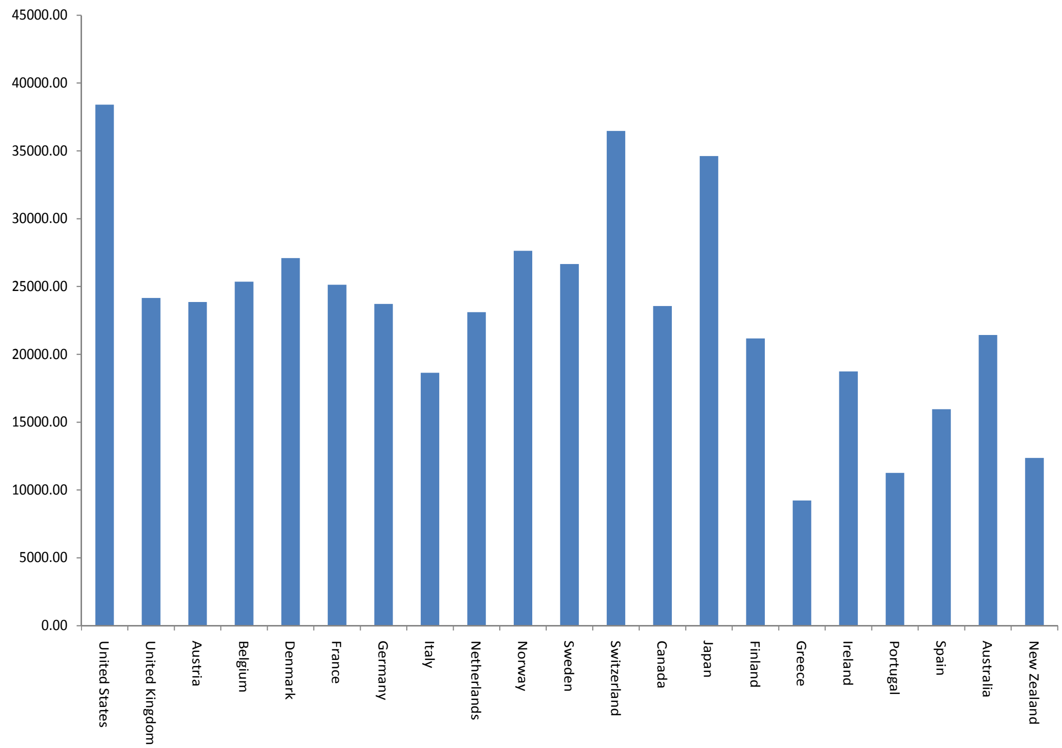
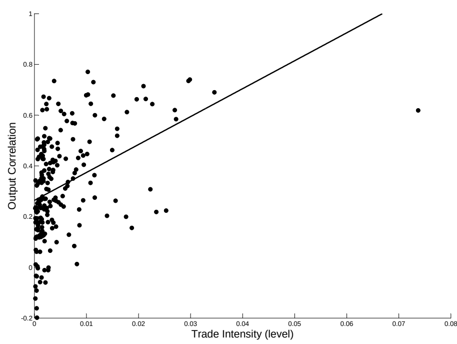
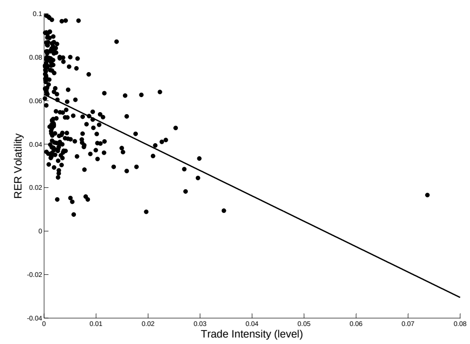


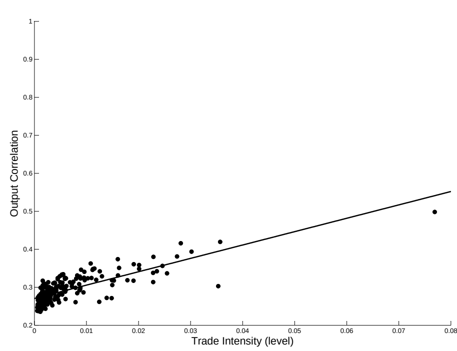
Figure 4. Trade and Business Cycle Synchronization: Data vs Model



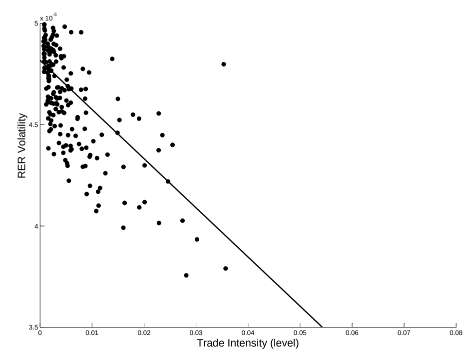
(a) Trade and Output Correlation: Data



(b) Trade and RER Volatility: Data



(c) Trade and Output Correlation: Model



(d) Trade and RER Volatility: Model

Figure 5. Data vs Model Fit

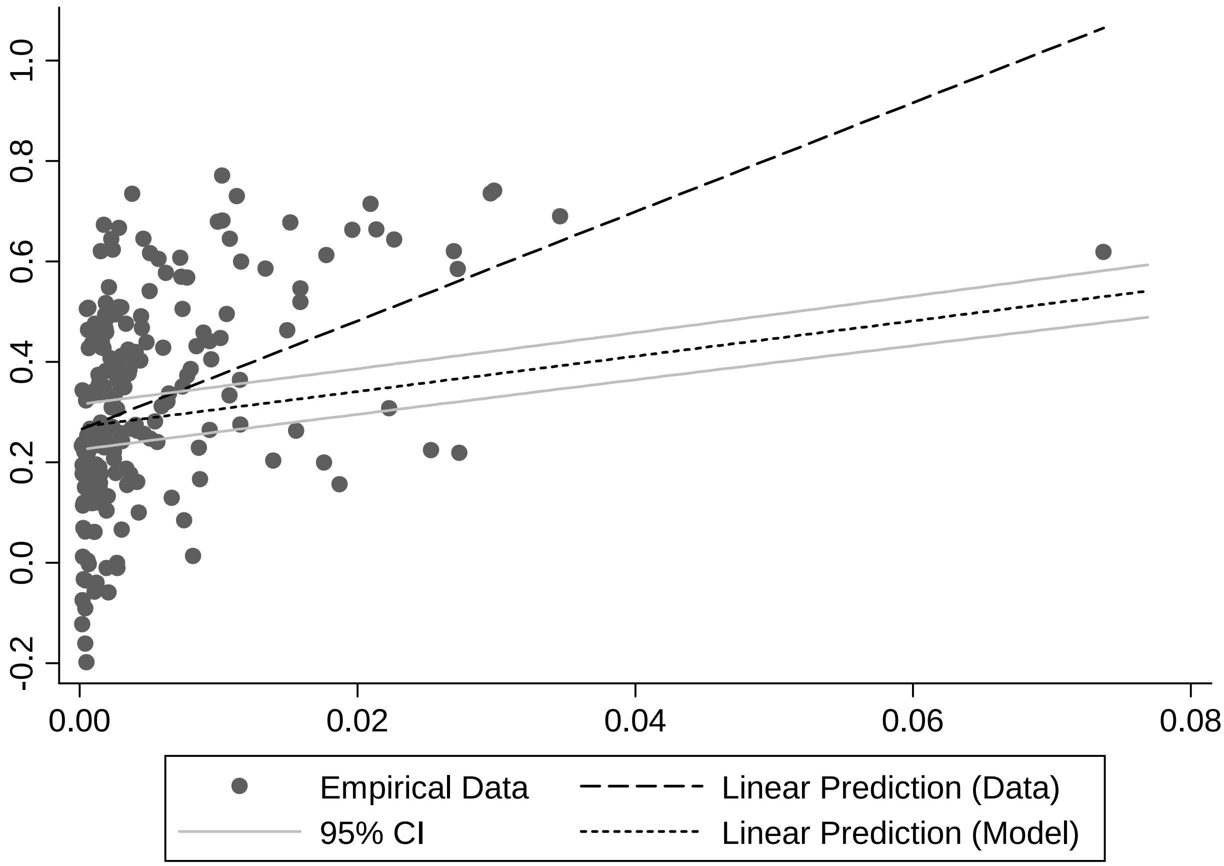


Figure 6. Data vs Model Fit Adjusting for Financial Integration

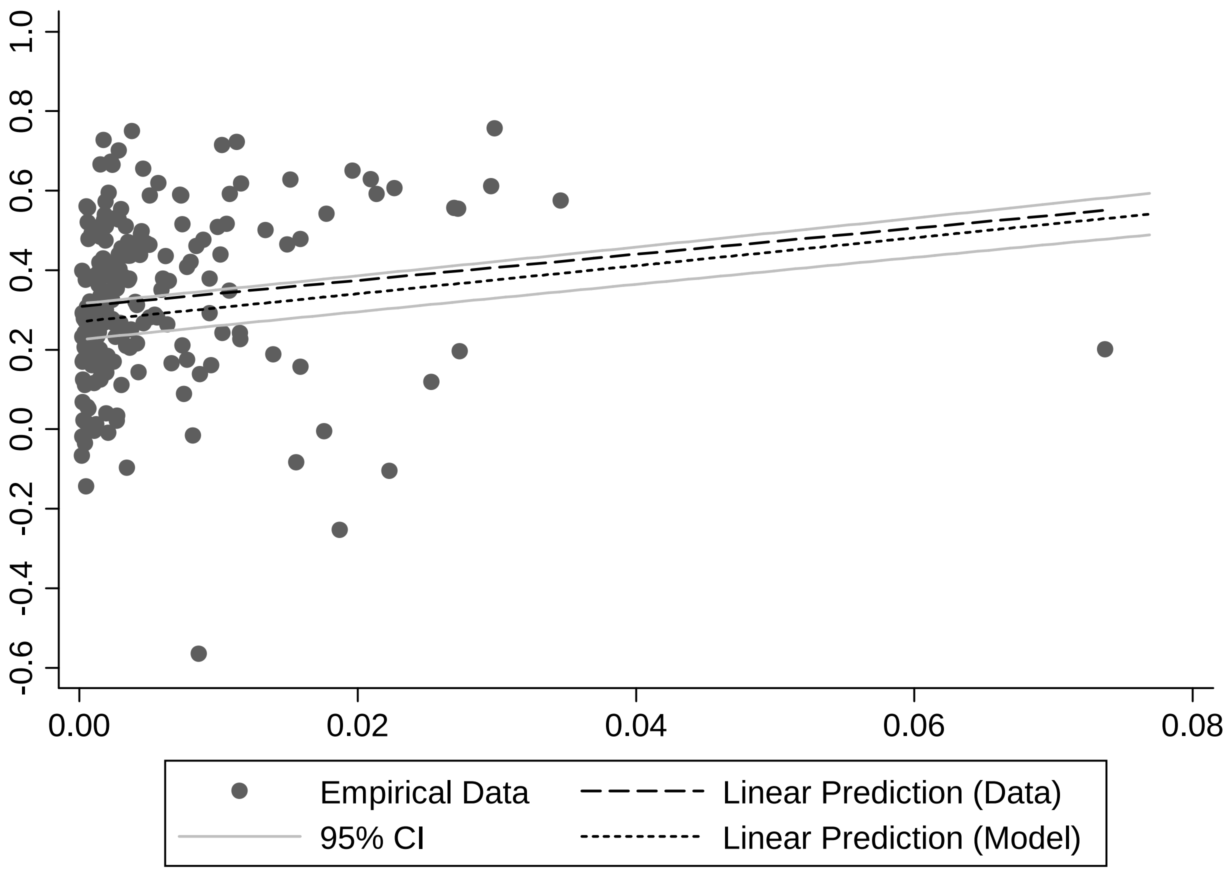


Table 1. Benchmark Parameter Values

Parameter	Value	Target/source
θ	3.60	Bernard et al. (2003)
σ	3.79	Bernard et al. (2003)
τ_{ij}	See Figure (1)	Bilateral trade shares—IMF DOTS
ν	0.43	Relative standard deviation of hours; quarterly U.S. data
α	0.21	Bernard et al. (2003)
ω_i	See Figure (3)	Total compensation per employee; 1974-2007, OECD data
ξ	1.00	Normalization
Technology stochastic process:		$\begin{cases} \ln\left[T_i\left(s^t\right)\right] = \Psi\left(s^t\right) + \epsilon_i\left(s^t\right) \\ \Psi\left(s^t\right) = \rho\Psi\left(s^{t-1}\right) + \eta\left(s_t\right), \quad \eta \sim \mathcal{N}\left(0, \vartheta_\eta^2\right) \\ \epsilon_i\left(s^t\right) = \rho\epsilon_i\left(s^{t-1}\right) + \upsilon_i\left(s_t\right), \quad \upsilon \sim \mathcal{N}\left(0, \vartheta_\upsilon^2\right) \end{cases}$
ρ	0.8620	Autocorrelation of (log and H–P filtered) U.S. output
ϑ_η	0.0089	Bilateral output correlation (U.S. – Belgium)
ϑ_υ	0.0143	Std. dev. of (log and H–P filtered) U.S. output

Table 2. Calibrated Iceberg Costs and Their Empirical Proxies

	Iceberg cost $= \tau_{ij} + \tau_{ji}$			
	coefficient	p-value	95% conf. int.	
$\log\left(distance\right)$	1.8576	0.000	[1.6305	2.0846]
border	-0.8715	0.082	[-1.8536	0.1105]
language	-1.0573	0.008	[-1.8414	-0.2732]
R^2		0.66		
Sample size		210		

Notes: The dependent variable is the calibrated iceberg trade cost. The independent variables are the log of distance between the business centers of the relevant pair of countries, a dummy variable that indicates if the countries share a common border, and a dummy variable that indicates whether the pair of countries shares a common language. Bilateral data from 21 OECD countries. Data definitions and sources are in Appendix A.1.

Table 3. Properties of Output and Hours: Model vs Data

	Std. Dev.		Corr. with output	
	Data	Model	Data	Model
Output	0.0143	0.0138		
Hours	0.0100	0.0096	0.8262	1.0000
Autocorrelation output	0.8620	0.8446		
	Mean	Median	Min	Max
Output correlation (data)	0.3225	0.3099	-0.1984	0.7706
Output correlation (model)	0.2917	0.2844	0.2355	0.4981

Table 4. Theoretical Relation Between Trade and Comovement

Dep. Variable: ρ	Theoretical economy					
	Level regression			Semi-log regression		
	coef.	s.e.	95% conf. int.	coef.	s.e.	95% conf. int.
$Trade$	3.520	0.189	[3.146 3.894]	0.028	0.001	[0.025 0.031]
R^2			0.622			0.614

Notes: The dependent variable, ρ, is the simulated pairwise correlation of output. $Trade$ is the simulated bilateral trade intensity.

Table 5. OLS Estimates. Trade and Comovement

	ρ	ρ
	(1)	(2)
$Trade$	10.864***	
	[0.00]	
$\log\left(Trade\right)$		0.090***
		[0.00]
$Constant$	0.264***	0.861***
	[0.00]	[0.00]
Observations	210	210
R^2	0.18	0.31

Notes: ρ is the pairwise correlation of H–P filtered GDP and $Trade$ denotes bilateral trade intensity. p-values are in brackets. *,**,*** denote significance at the 10, 5, and 1 percent levels, respectively. Bilateral data from 21 OECD countries averaged from 1974-2007. Data definitions and sources are in Appendix A.1.

Table 6. First-Stage Estimation

	$Trade$	$\ln\left(Trade\right)$	Fin	$\ln\left(Fin\right)$
	(1)	(2)	(3)	(4)
$\log\left(distance\right)$	-0.003***	-0.770***	-0.007***	-1.077***
	[0.00]	[0.00]	[0.00]	[0.00]
border	0.012***	0.556***	-0.0040	-0.284
	[0.00]	[0.00]	[0.38]	[0.24]
language	0.003*	0.500***	0.011***	1.012
	[0.09]	[0.00]	[0.00]	[0.00]
Observations	210	210	206	206
R^2	0.59	0.67	0.26	0.53

Notes: $Trade$ denotes bilateral trade intensity and Fin denotes financial integration, measured as the bilateral bank stock of assets and liabilities normalized by GDP. The independent variables are the log of distance between the business centers of the relevant pair of countries, a dummy variable that indicates if the countries share a common border, and a dummy variable that indicates whether the pair of countries share a common language. p-values are listed in brackets. *,**,*** denote significance at the 10, 5, and 1 percent levels, respectively. Bilateral data from 21 OECD countries averaged over 1974-2007. Data definitions and sources are in Appendix A.1.

Table 7. IV Estimates. Trade and Comovement

	ρ (1)	ρ (2)
$Trade$	17.250***	
	[0.00]	
$\log\left(Trade\right)$		0.102***
		[0.00]
$Constant$	0.232***	0.938***
	[0.00]	[0.00]
Observations	210	210
R^2	0.12	0.30

Notes: ρ is the pairwise correlation of H–P filtered GDP and $Trade$ denotes bilateral trade intensity. The instrumental variables for trade intensity are: log of distance, dummy variable for common border, and dummy variable for common language. p-values are in brackets. *,**,*** denote significance at the 10, 5, and 1 percent levels, respectively. Bilateral data from 21 OECD countries averaged over 1974-2007. Data definitions and sources are in Appendix A.1.

Table 8. Trade, Financial Integration and Comovement

	OLS		IV	
	ρ		ρ	
	(1)	(2)	(3)	(4)
$Trade$	10.57***		8.537**	
	[0.00]		[0.04]	
$\log\left(Trade\right)$		0.086***		0.106*
		[0.00]		[0.08]
Fin	0.051		6.383*	
	[0.96]		[0.05]	
$\log\left(Fin\right)$		0.003		-0.004
		[0.82]		[0.94]
$Constant$	0.269***	0.860***	0.223***	0.938***
	[0.00]	[0.00]	[0.00]	[0.00]
Observations	206	206	206	206
R^2	0.18	0.30	0.19	0.30

Notes: ρ is the pairwise correlation of H–P filtered GDP. $Trade$ denotes bilateral trade intensity and Fin denotes financial integration, measured as the bilateral bank stock of assets and liabilities normalized by GDP. The instrumental variables for trade intensity and financial integration are: log of distance, dummy variable for common border, and dummy variable for common language. p-values are listed in brackets. *,**,*** denote significance at the 10, 5, and 1 percent levels, respectively. Bilateral data from 21 OECD countries averaged over 1974-2007. Data definitions and sources are in Appendix A.1.

Table 9. Quantitative Assessment of the Relation Between Trade and Comovement

	Empirical data							
	Level regression				Semi-log regression			
	OLS		IV		OLS		IV	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Trade Intensity	10.864	10.570	17.250	8.537	0.090	0.086	0.102	0.106
Fin. Integration		0.051		6.383		0.003		-0.004
	Percentage explained:				Percentage explained:			
$\left(\beta \text{ model} \middle/ \beta \text{ data}\right)$	32%	33%	20%	41%	31%	33%	27%	26%

Notes: This table summarizes the empirical results of the β coefficient reported in Tables 5, 7 and 8, and compares it with the β coefficient implied by the theoretical model reported in Table 4.

Table 10. Trade Costs, Comovement and Real Exchange Rate Volatility

	ρ	ρ	$rervol$	$rervol$
	(1)	(2)	(3)	(4)
$trade\ costs$	-0.0280***		0.002***	
	[0.00]		[0.00]	
$\log\left(trade\ costs\right)$		-0.191***		0.018***
		[0.00]		[0.00]
$Constant$	0.511***	0.655***	0.042***	0.026***
	[0.00]	[0.00]	[0.00]	[0.00]
Observations	210	210	210	210
R^2	0.299	0.312	0.161	0.227

Notes: ρ is the pairwise correlation of H–P filtered GDP and $rervol$ is the standard deviation of the H–P filtered real exchange rate. tc denotes trade costs. p-values are listed in brackets. *,**,*** denote significance at the 10, 5, and 1 percent levels, respectively. Bilateral data from 21 OECD countries averaged over 1974-2007. Data definitions and sources are in Appendix A.1.

Table 11. Descriptive Statistics

	Bilateral trade intensity	GDP correlation	Real exchange rate volatility
Median	0.0023	0.3099	0.0528
Max	0.0737	0.7706	0.0991
Min	0.0002	-0.1985	0.0076
Standard deviation	0.0080	0.2047	0.0221

Table 12. Bilateral Trade Intensities

	US	UK	AT	BE	DK	FR	DE	IT	NL	NO	SW	CH	CA	JP	FI	GR	IR	PT	SP	AS
UK	0.0062																			
AT	0.0004	0.0025																		
BE	0.0023	0.0156	0.0051																	
DK	0.0005	0.0060	0.0025	0.0054																
FR	0.0037	0.0159	0.0028	0.0296	0.0027															
DE	0.0064	0.0187	0.0197	0.0272	0.0080	0.0270														
IT	0.0030	0.0095	0.0073	0.0103	0.0027	0.0210	0.0226													
NL	0.0030	0.0223	0.0057	0.0737	0.0084	0.0159	0.0346	0.0116												
NO	0.0007	0.0087	0.0015	0.0051	0.0149	0.0030	0.0059	0.0014	0.0077											
SW	0.0013	0.0094	0.0041	0.0106	0.0253	0.0044	0.0094	0.0035	0.0108	0.0234										
CH	0.0017	0.0086	0.0134	0.0103	0.0034	0.0100	0.0178	0.0113	0.0078	0.0019	0.0046									
CA	0.0299	0.0051	0.0007	0.0018	0.0006	0.0019	0.0025	0.0019	0.0017	0.0022	0.0013	0.0011								
JP	0.0140	0.0034	0.0006	0.0014	0.0007	0.0022	0.0048	0.0015	0.0018	0.0007	0.0010	0.0014	0.0042							
FI	0.0004	0.0044	0.0024	0.0045	0.0082	0.0018	0.0043	0.0016	0.0056	0.0077	0.0214	0.0026	0.0006	0.0005						
GR	0.0002	0.0015	0.0015	0.0029	0.0014	0.0019	0.0032	0.0041	0.0036	0.0008	0.0014	0.0015	0.0002	0.0005	0.0011					
IR	0.0012	0.0176	0.0013	0.0115	0.0027	0.0029	0.0035	0.0019	0.0063	0.0026	0.0029	0.0035	0.0009	0.0007	0.0019	0.0009				
PT	0.0003	0.0031	0.0015	0.0046	0.0020	0.0038	0.0034	0.0024	0.0040	0.0021	0.0026	0.0023	0.0003	0.0002	0.0016	0.0005	0.0014			
SP	0.0013	0.0074	0.0021	0.0073	0.0018	0.0152	0.0101	0.0089	0.0074	0.0014	0.0028	0.0036	0.0008	0.0009	0.0014	0.0012	0.0019	0.0108		
AS	0.0019	0.0037	0.0005	0.0016	0.0006	0.0012	0.0019	0.0017	0.0015	0.0004	0.0015	0.0011	0.0018	0.0066	0.0009	0.0002	0.0007	0.0002	0.0007	
NZ	0.0004	0.0020	0.0003	0.0010	0.0004	0.0003	0.0004	0.0004	0.0006	0.0002	0.0005	0.0004	0.0006	0.0011	0.0003	0.0004	0.0005	0.0002	0.0002	0.0116

Notes: US, United States; UK, United Kingdom; AT, Austria; BE, Belgium; DK, Denmark; FR, France; DE, Germany; IT, Italy; NL, Netherlands; NO, Norway; SW, Sweden; CH, Switzerland; CA, Canada; JP, Japan; FI, Finland; GR, Greece; IR, Ireland; PT, Portugal; SP, Spain; AS, Australia; NZ, New Zealand.