Trade-Partner-Synchronization and Business Cycle Comovement

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Abstract

Foreign trade affects business cycle comovement directly and indirectly. On the one hand, empirical literature has found a strong relation between bilateral trade and output synchronization. On the other, countries with common trade partners face similar foreign shocks and present higher rates of comovement. This paper shows that previous literature has underestimate the overall effect of trade by not considering the impact of common trade partners. Once it is included the effect of trade on output synchronization doubles. On the theoretical side, the paper shows that a standard international real business cycle model is consistent with the empirical relations but fails to reproduce their magnitudes, creating two puzzles. Also, the model generates GDP components that are not volatile enough. Then, the model is extended to include correlated productivity shocks and counter-cyclical trade barriers. These modifications alleviate the puzzles and replicate the volatilities of GDP components.

Keywords: Trade, Business Cycles Fluctuations, Open Economy Macroeconomics, International Business Cycles

JEL Classification: F1, E32, F41, F44

1 Introduction

Foreign trade affects business cycle comovement through different channels. For instance, Frankel and Rose (1998) argue that business cycles are more synchronized when countries trade more intensively with each other. Similarly, common trade partners act as an indirect source of business cycle comovement. If two countries are highly exposed to a common partner, they face similar foreign shocks and co-move more. I define these foreign shocks as *trade-partner synchronization*, since similar trade partners imply more correlated external shocks. In this paper, I explore the effect of bilateral trade and trade-partner-synchronization on business cycle comovement. Using data from 1990-2016 for developed and developing economies, I document three facts: *1) Bilateral trade and trade-partner-synchronization are important sources of business cycle comovement; 2) Omitting the effect of trade-partner-synchronization creates an upward bias on the trade-comovement relation; 3) The combined effect of bilateral trade and trade-partner-synchronization (on output comovement) is stronger than the one of bilateral trade alone.* These results show that previous literature has underestimate the contribution of trade on business cycle comovement by not including the impact of common trade partners.

It is useful to think of Mexico and Canada, countries that trade a small fraction with each other and are highly synchronized. Between 1990 and 2016 bilateral trade for these countries represented less than 3% of their total exports and imports, while output synchronization was around 40%. Of course, both trade large amounts with the US, which in fact is their main trading partner and accounts for almost 70% of their total trade. As a result, the comovement rate between Canada and the US is 80%, while that for Mexico is 57%. The intuition would suggest that, *ceteris paribus*, countries with more equal trading partners should have more synchronized business cycles, since they are subject to similar foreign shocks. In particular, their foreign demand should be more correlated. Despite the low bilateral trade shares, Canada and Mexico have relatively high levels of trade intensity[1] and output synchronization, which

[1] Defined as the ratio between total bilateral trade and the sum of nominal GDP.

are at least four times larger than for the average country-pair. Considering that a significant fraction of output comovement between Canada and Mexico may be explained by their close relations with the U.S, omitting the effect of sharing a main trading partner and therefore not accounting for the effect of common foreign shocks, can potentially bias the impact of trade intensity on business cycle comovement.

In this paper, I revisit the *Trade-Comovement* relation controlling for the effect of trading-partner synchronization. As Frankel and Rose (1998) highlight trade intensity and business cycle comovement are endogenously determined. On the one hand, countries that trade intensively with each other may be subject to similar disturbances; also, the transmission of shocks between countries may be stronger. On the other hand, economies that are more synchronized may have more incentives to boost their trade by signing trade agreements. To isolate the causal effect of trade intensity on output synchronization, Frankel and Rose (1998) instrument bilateral trade using gravity determinants, such as distance, common language, colony relations, population, among others. On the other hand, to analyze the causal effect of trade-partner synchronization on output comovement, I focus on country-pairs of small open economies, for which the cycle of their trading partners is completely exogenous. For the group of small open economies, increasing bilateral trade or trade-partner-synchronization by one standard deviation raises output comovement by 2.9 and 4.0 percentage points (pp), respectively. If I omit the effect of trade partner synchronization, the impact of bilateral trade raises by 20%. Notice that increasing both, trade intensity and trade-partner synchronization, by one standard deviation raises comovement by almost 7 pp, while the effect of bilateral trade by its own is less than half.

On the theoretical side, I argue that a standard international real business cycle (IRBC) model is qualitatively consistent with the empirical results, but fails to reproduce the magnitudes of the *Trade-Comovement* and *Trade-Partner-Comovement* relations. This result compliments the evidence presented by Kose and Yi (2001) and Kose and Yi (2006) regarding the *Trade-Comovement-Puzzle*, and adds a new puzzle to the literature, the *Trade-Partner-Comovement-Puzzle.* According to Kose and Yi (2006) the correlation between business cycle synchronicity and bilateral trade is hard to rationalize in standard IRBC models, as business cycle synchronicity at best rises moderately with bilateral trade. As noted by Engel and Wang (2011), another failure of the standard IRBC model is the low volatility of the trade flows. Consistent with previous literature, exports and imports are less volatile than GDP. The model fails to reproduce the empirical (comovement) relations because it generates too little transmission between economies. To alleviate the puzzles and match the volatility of the trade flows I include correlated productivity shocks and counter-cyclical trade barriers. These modifications improve the performance of the model considerably.

The structure of the model assumes N economies, each one produces a differentiated intermediate good using capital and labor. Intermediates are internationally traded after paying an iceberg cost. Domestic and foreign intermediates are combined to produce non-traded final goods that are allocated into consumption and investment. Countries are assumed to be in financial autarky[2]. The model assumes uncorrelated productivity shocks to capture the full effect of trade on business cycle comovement. For the calibration, I assume that the world economy is populated by four economies, two small economies that account for 6% of the world GDP, and two rest of the world (ROW). With four economies it is possible to reproduce the trade-partner similarities observed in the data. Most of the parameter values are taken directly from Kose and Yi (2006). The productivity levels, home bias and the preference for foreign goods are targeted to match relative size, trade intensity, trade partner similarity and trade openness. After having a benchmark calibration, the model is re-calibrated to match the trade intensity and trade partner similarity for each country-pair in the data. Then, it is simulated for each configuration of parameters for 1000 periods and the last 26 periods are used to estimate the *Trade-Comovement* and *Trade-Partner-Comovement* relations. As already mentioned, the model is consistent with the empirical relations, but fails to reproduce their magnitudes. It

[2]This assumption is relaxed in one of the extensions

also generates exports and imports that are less volatile than in the data.

If I simulate the model without productivity shocks in the SOEs, the *Trade-Partner-Comovement* relation is more than six times stronger than in the data, while the *Trade-Comovement* one is negative. This means that one reason the full model does not replicate the *Trade-Partner-Comovement* relation is the presence of idiosyncratic shocks in SOEs. In other words, the *Trade-Partner-Comovement* puzzle can be solved by reducing the volatility of shocks in the SOEs. On the other hand, if I simulate the model without productivity shocks in the ROWs, the *Trade-Comovement* relation weakens with respect to the benchmark model, while the *Trade-Partner-Comovement* one strengths. These results imply that idiosyncratic shocks in SOEs generate comovement directly through trade, and indirectly by affecting the cycle of the ROWs.

To solve the puzzles and generate more volatility of trade flows I assume correlated productivity shocks, as in Kose and Yi (2006), and counter-cyclical trade barriers. In particular, I consider that a fraction of the productivity shock in each country is transmitted to its trading partner's productivity. If a country depends more on its trading partner, the transmission is stronger. Under this assumption, it is possible to generate a coefficient for the *Trade-Partner-Comovement* relation closer the data; however, the *Trade-Comovement puzzle* remains. The low levels of bilateral trade between SOEs constraint the model to generate enough comovement. To alleviate this puzzle, I consider a stronger productivity transmission for low levels of bilateral trade, *biased correlated productivity.* In all cases, counter-cyclical iceberg costs allow the model to match the volatility of trade flows. Consistent with the data, omitting the effect of trade-partners biases upwards the *Trade-Comovement* relation. In a different extension I reduce the trade elasticity[3], and re-do the quantitative exercise assuming uncorrelated shocks and constant iceberg costs. Under this scenario, the relations are consistent with the data but far from

[3]Heathcote and Perri (2002) and Kose and Yi (2006) suggest that a low trade elasticity increases output comovement.

their empirical counterparts. However, with biased correlated productivity and counter-cyclical iceberg costs the model does a better job solving the puzzles and replicating the volatilities from the data.

To check if the proposed mechanisms work in a richer environment I extend the model in two dimensions. First, I consider that households are allowed to trade a non-contingent bond that is in zero net supply. Second, as in Boileau (1999) and Engel and Wang (2011), I assume that consumption and investment goods are produced with different technologies. In particular, investment is more intensive on foreign intermediates. As Engel and Wang (2011) suggests, this modification increases the volatility of trade flows. Under this set up I re-calibrate the model to target a share of investment-imported intermediates of 40%, and assume that in the long-run countries have no debt. As in the benchmark model, with uncorrelated productivity shocks the model is consistent with the empirical relations but fails to reproduce their magnitudes. However, with biased correlated productivity shocks and counter-cyclical trade barriers it is possible to solve the *Trade-Partner-Comovement* puzzle and to alleviate the *Trade-Comovement* one. A version of the model with these modifications and low trade elasticity solves the two puzzles and generates volatilities similar to the data.

I finally consider a three-country version of the model that abstracts from any difference on trade-partner synchronization. Under this set-up I assume that the world economy is composed by two symmetric SOEs and one ROW. By assumption the two SOEs are equally exposed to the ROW. The model is calibrated to match the mean trade intensity, trade openness and relative size of SOEs. As in the full version, the model is re-calibrated to match the empirical distribution of trade intensity. I first simulate the model with uncorrelated productivity shocks and find that the *Trade-Comovement* relation is no significant. The negligible impact of bilateral trade on output synchronization comes from the low bilateral exposure between SOEs. To match trade intensity, the three-country version requires lower levels of bilateral exposure than in the 4-country case. With more countries, the model allows for higher exposure between

SOEs and generates a stronger *Trade-Comovement* relation. Finally, with biased correlated productivity shocks the three-country model is able to alleviate the *Trade-Comovement-Puzzle*.

In section 2, I present a brief literature review. Next, I report the empirical results for the *Trade-Comovement* and *Trade-Partner-Comovement* relations. In section 4, I describe the multi-country model. Then, I report the calibration technique and the quantitative results. Section 6 presents the model extensions and section 7 concludes.

2 Related Literature

Frankel and Rose (1998) were the first to document the causal relation between bilateral trade and output synchronization. Using thirty years of data for twenty industrialized economies the authors find that countries that trade more intensively with each other have more correlated business cycles. To identify the causal effect of bilateral trade on output correlations they instrument bilateral trade using distance, geographic adjacency and common language. Quantitatively, the authors find that increasing trade intensity by one standard deviation raises output comovement by 13 percentage points (pp). Following a similar approach and a broader set of countries, Calderon et al. (2007) find that the impact of trade intensity on business cycle correlation is smaller among developing economies than among industrial countries. In particular, the authors observe that for country-pairs of industrial countries increasing bilateral trade by one standard deviation raises output comovement by 8 pp. For the rest of economies the effect is less than 2 pp. The authors suggest that these differences can be explained by patterns of industry specialization and of bilateral trade. Countries with more similar production structures or with a higher share of intra-industry trade have a stronger *Trade-Comovement* relation. Similarity in the production structure as a driver of business cycle comovement was initially proposed by Imbs et al. (2000). Other studies that support the positive relation between trade and business cycle comovement are, Canova and Dellas (1993), Clark and Van Wincoop (2001), Otto et al. (2001), Imbs (2004) Baxter and Kouparitsas (2005), and Blonigen et al. (2014). Baxter and Kouparitsas (2005) find that bilateral trade is a robust determinant of business cycle comovement, meaning that the *Trade-Comovement* survives to the inclusion of different controls. Other determinants, like industrial structure, do not survive to the robustness checks.

From a theoretical perspective, Kose and Yi (2001) and Kose and Yi (2006) assess whether the standard international business cycle framework can replicate the *Trade-Comovement* relation. The authors extend the Backus et al. (1992) and Backus et al. (1994) model to include three countries and endogenous transportation costs. They simulate a drop in trading costs that raises goods market integration, and analyze its effects on output synchronization[4]. Their main finding states that the model is qualitatively consistent with the *Trade-Comovement* relation, but fails to reproduce its magnitude. This failure is known as the *Trade-Comovement-Puzzle* and has motivated a growing theoretical literature. Kose and Yi (2006) highlight that with more correlated productivity shocks the model is able to alleviate the puzzle. This has encourage several authors to include mechanisms in the model that generate higher rates of comovement for a given level of trade intensity.

Burstein et al. (2008) document that countries that are more engaged in production sharing exhibit higher bilateral manufacturing correlations. They develop a quantitative model that generates a positive link between the extent of vertically integrated production sharing trade and business cycle synchronization[5]. Similar to Kose and Yi (2006) the authors find that the theoretical link between trade and output correlations is weaker than in the data. On a different extension, Arkolakis and Ramanarayanan (2009) develop an international business cycle model augmented with production of goods in multiple stages spread across countries. The model generates stronger business cycle synchronization between countries that trade more

[4]Following Heathcote and Perri (2002) the authors perform the simulations under complete markets and financial autarky.

[5]One important assumption is the low elasticity of substitution between home and foreign inputs in the production of the vertically integrated good

with each other, but still fails to solve the *Trade-Comovement-Puzzle.* Empirically, Ng (2010) argues that pairs of countries with more bilateral production fragmentation arrangements have more synchronized business cycles.

Ambler et al. (2002) argue that standard multi-country models predict cross-country correlations of output that are too low when compared to the data. They modify the benchmark two-country model by adding multiple sectors and trade in intermediate goods. Even though they do not provide any evidence on the *Trade-Comovement* relation, they show that under this set up the model predicts higher cross-country output correlations. Johnson (2014) also incorporates input trade into a dynamic multi-sector model with many countries. With correlated productivity shocks, the model generates strong a *trade-comovement* relation in the goods sector, but zero correlations for services, and thus low aggregate correlations. As in Heathcote and Perri (2002), Kose and Yi (2006), and Burstein et al. (2008) comovement is higher when the aggregate elasticity is low. Drozd et al. (2017) show that modeling the disconnect between the low short and the high long run trade elasticity is a promising avenue in resolving the *Trade-Comovement* puzzle.

Finally, from a micro perspective, di Giovanni et al. (2018) document that trade and multinational linkages are important sources of output correlations between a firm and a particular country. These links account for almost a third of the aggregate correlation between a country and its trading partners. This evidence is reinforce by Cravino and Levchenko (2016) who show that multinational firms contribute the the transmission of shocks across countries. The presence of multinationals and vertical integration provide empirical evidence that may justify the inclusion of more correlated shocks in standard international real business cycle models.

3 Data and Empirical Analysis

To estimate the *Trade-Comovement* and *Trade-Partner-Comovement* relations I initially require information on bilateral trade flows and Gross Domestic Product (GDP). Feenstra et al. (2005) provides a good data set for nominal imports in US dollars, and the World Development Indicators (WDI) data base from the World Bank includes nominal and real variables for the GDP and its components. Following the *Trade-Comovement* literature it is useful to have information on economic development and population, which are also included in the WDI; gravity determinants, such as distance, common language, colony relations and geographic characteristics. This variables are publicly available at the Centre D'Études Prospectives Etd' Informations Internationales (CEPPI) database. The last set of variables include bilateral trade agreements from the Economic Integration Agreement Data Sheet. Most of the information is available at the annual level since 1962; however, in order to get a balanced panel with a richer set of countries I focus on the period 1990-2016.

Three indicators are required for the empirical exercise: business cycle comovement (output synchronization); trade intensity; and trade-partner synchronization. Output synchronization for two countries is defined as the correlation between the cyclical component of their real GDP (ΔGDP_i), as in equation (1)[6].

$$Comov_{i,j} = Corr(\Delta GDP_i, \Delta GDP_j) \tag{1}$$

As suggested by Frankel and Rose (1998) bilateral trade intensity can be measured as the ratio between bilateral trade and the sum of the nominal GDP, as equation (2), or as the

[6]One easy way to estimate the ΔGDP_i is to use the HP filtered the log of GDP. For annual data the suggested smoothing parameter of 100.

As shown in the Appendix the results are robust if I use different filters to calculate the cycle, such as log-first differences and Band Pass filtering ratio between bilateral trade and total trade, as in equation (3).

$$TI_{i,j}^{GDP} = \frac{X_{i,j} + M_{i,j} + X_{j,i} + M_{j,i}}{Y_i + Y_j} \tag{2}$$

$$TI_{i,j}^{trade} = \frac{X_{i,j} + M_{i,j} + X_{j,i} + M_{j,i}}{X_i + M_i + X_j + M_j} \tag{3}$$

Where $X_{i,j}$ and $M_{i,j}$ are exports and imports from country i to country j, respectively, and X_i and M_i are total exports and imports of country i.

To measure trade-partner synchronization, I first calculate the trade-partner cycle of country i as the weighted average of the cycle of its trading partners, equation (4). Then, I define trade partner synchronization for countries i and j as the correlation between their trade-partner cycles, equation (5).

$$\Delta TPC_i = \sum_n s_{i,n} \Delta GDP_i \tag{4}$$

$$s_{i,n} = \frac{X_{i,n} + M_{i,n}}{X_i + M_i}$$

$$Comov_{i,j}^{TPC} = Corr(TPC_i, TPC_j) \tag{5}$$

I finally propose an indicator that measures how similarly exposed two countries are to their trading partners. I first calculate the trade share for two countries, $s_{i,n}$, which estates the fraction of $i\text{`}s$ total trade that is performed with country n. Using the trade shares of countries i and j with a common trade-partner n I determine if i and j are similarly exposed to n. One simple way to do this is by calculating the absolute value of the difference between the two trade shares. If the two countries are equally exposed to n then the difference is zero;

in the opposite case, it takes a maximum value of 1. In the latter, one country concentrates all of its trade with n while the other does not trade with it. By adding up these differences for all of the trading partners of i and j I create the *trade partner similarity* indicator, TPS, as in equation (6). The TPS takes values between 0 and 2. The former indicates that the two economies are equally exposed, while the latter establishes that their trade is concentrated in two different counterparts. As I will further explain, this indicator allows me to map similarity in foreign demand from the data to the model.

$$TPS_{i,j} = \sum_{n \neq j,i} |s_{i,n} - s_{j,n}| \tag{6}$$

Notice that by construction, countries with more similar trading partners, meaning a lower TPS value, are economies with higher trade-partner synchronization.

3.1 Trade-Comovement

As Frankel and Rose (1998) highlight trade intensity and business cycle comovement are endogenously determined. On the one hand, countries that trade intensively with each other may be subject to similar disturbances; also, the transmission of shocks between countries may be stronger. On the other hand, economies that are more synchronized may have more incentives to boost their trade by signing trade agreements. To isolate the causal effect of trade intensity on output synchronization, Frankel and Rose (1998) instrument bilateral trade using gravity determinants, such as distance, common language, colony relations, population, and geographic characteristics. Here, I follow a similar approach and instrument trade intensity by estimating the following equation:

$$TI^{gdp}_{i,j} = \beta_0 + \beta_1 X_i + \beta_2 X_j + \beta_3 X_{i,j} + \epsilon_{i,j} \tag{7}$$

Where, $TI_{i,j}^{gdp}$ is the mean value of trade intensity for the period 1990-2016 for the country-pair i, j. The independent variables, X_i, X_j, include country specific characteristics, such as population; latitude; longitude; area; and an indicator for being landlocked. Furthermore, the independent variables for the country-pair, $X_{i,j}$, include distance and indicators for common language, common border, colony relations, and common region. Table 1 reports the results for the ordinary least squares (OLS) regression for equation (7). As in other studies, gravity determinants have a significant explanatory power on bilateral trade intensity. In a second stage, I estimate the Trade-Comovement relation, as in equation .

$$Comov_{i,j} = \alpha_0 + \alpha_1 \widehat{TI}_{i,j}^{gdp} + \alpha_2 Z_i + \alpha_3 Z_j + \alpha_4 Z_{i,j} + v_{i,j} \tag{8}$$

$\widehat{TI}_{i,j}^{gdp}$ is the predicted level of trade intensity; Z_i, Z_j are country fixed effects and controls that account for trade openness and GDP per capita; and $Z_{i,j}$ include interactions for levels of development and trade agreements. Table 2 reports the regression results for equation (8). For comparison reasons the first column in the table includes the estimation without instrumenting trade intensity. As expected, there is a positive relation between trade intensity and business cycle comovement. For the IV case, increasing bilateral trade by one standard deviation raises output comovement by 3.4 pp.

3.2 Trade-Comovement and Trade-Partner-Synchronization

As Mexico and Canada, countries that trade with each other may also have a common set of trading partners and therefore share similar foreign shocks. A first inspection to the data shows a significant relation between trade partner similarity and bilateral trade intensity, as well as between trade-partner synchronization and bilateral trade. As shown in Table 3, countries with more similar trading partners (lower TPS) or with more synchronized partners, trade more intensively. Given that TPS and $Comov_{i,j}^{TPC}$ are strongly correlated (-0.44), and both aimed to capture common exposure to foreign shocks, I will focus the analysis on the latter. Also, when

I concentrate on Small Open Economies, the exogeneity assumption is more natural on Trade-Partner-Cycle than on trade partner similarity. To see the effect of trade-partner synchronicity on the *Trade-Comovement* relation, I include $Comov_{i,j}^{TPC}$ as an additional control on equation (8):

$$Comov_{i,j} = \alpha_0 + \alpha_1 \widehat{TI}_{i,j}^{gdp} + \gamma Comov_{i,j}^{TPC} + \alpha_2 Z_i + \alpha_3 Z_j + \alpha_4 Z_{i,j} + v_{i,j} \quad (9)$$

Table 4 reports the estimation results with and without instrumenting trade intensity. In both cases, omitting the effect of foreign synchronicity biases upwards the coefficient for trade intensity. For the IV case, if I do not control for comovement in trading partners, the impact of bilateral trade is 1.3 times higher. Once I include the latter, increasing trade intensity by one standard deviation raises GDP comovement by 2.7 pp. It is worth noticing that the effect of trade-partner synchronization is quite strong. However, in order to make a causal statement I first need to make an exogeneity assumption, since these two variables are likely to be determined endogenously. For example, if an economy is big enough, domestic output fluctuations not only affect its trading partners cycle, but also the one of their partners. By focusing on country-pairs of small open economies it is possible to overcome with this problem, since SOEs are assumed to not affect the cycle of their trading-partners; therefore, foreign shocks are completely exogenous. Under this assumption it is possible to estimate the effect of trade-partner comovement on business cycle synchronization.

I identify SOEs as countries with a share of World GDP less than 0.5%. To guarantee that a SOE is not affecting the trade-partner cycle of another SOE, I focus on country-pairs for which their bilateral trade share is less than 10%[7]. I first re-estimate the instrumental variable for this group of economies and then run the OLS regression indicated by equation (9). As Table 6 shows the sample of SOEs country-pairs represents almost 2/3 of the data

[7]The latter assumption does not constraint the data significantly

and the results are consistent with the fact trade-partner-synchronization reduces the effect of bilateral trade. For SOEs increasing trade intensity by 1 std raises output synchronization by 2.9pp, while the effect of trade-partner-comovement is 4.0pp. The latter, despite being and intuitive channel of business cycle synchronization has not been explored in detail in the trade-comovement literature[8].

Tables 7 to 10 report some robustness checks to the empirical results. In general, controlling for comovement in trade-partner-cycles reduces the impact of trade intensity on business cycle synchronization, and the effect of former is always positive and statistically significant. The additional checks include different ways of filtering the data (Table 7), extending the time-frame (Table 8), excluding the global recession of 2007-2009 (Table 9), and controlling for additional sources of common foreign shocks, as movements in the terms of trade (Table 10).

4 Model

The model presented in this section extends the two-country, free trade, complete market BKK framework by having N countries, iceberg transportation costs, and allowing for international financial autarky. In this sense, the model is more close to the set up proposed by Kose and Yi (2006). Opposed to the latter, iceberg costs are assumed to be constant, meaning that there is role for a transportation sector. Also, the relative size of the countries is not assumed in the market clearing condition but from the calibration of productivity levels and home bias parameters.

Each economy produces one differentiated intermediate good that is traded in inter-

[8]Calderon et al. (2007) includes an indicator variable for common-trade partner as an additional instrument for trade intensity

national markets after "paying" an iceberg cost[9]. Domestic capital and labor are combined to produce intermediate goods in each country. Then, foreign and domestic intermediates are aggregated to produce non-traded final goods that are allocated in domestic investment and consumption. As in Heathcote and Perri (2002) international financial markets are in financial autarky.

4.1 Households

Each country is populated by a unitary mass of homogeneous consumers that maximize their lifetime utility over consumption ($C_{i,t}$) and leisure ($1 - L_{i,t}$) subject to a budget constraint. Consumers choose over consumption, leisure, investment ($I_{i,t}$) and physical capital ($K_{i,t+1}$). Preferences are represented by equation (10), the budget constraint is given by equation (11). I finally assume investment adjustment costs as in equation (12).

$$U(C_{i,t}, L_{i,t}) = \left(\sum_{t=0}^{\infty} \beta^t \frac{(C_{it}^{\mu}(1 - L_{i,t})^{1-\mu})^{1-\gamma}}{1-\gamma} \right), 0 < \mu < 1; 0 < \beta < 1; 0 < \gamma, i = 1, ..., N \quad (10)$$

$$P_{i,t}^{c} \left(C_{i,t} + I_{i,t} \right) = w_{i,t} L_{i,t} + r_{i,t} K_{i,t} \quad (11)$$

$$K_{i,t+1} = I_{i,t} + (1 - \delta) K_{i,t} - \frac{\phi_{k,i}}{2} \left(\frac{I_{i,t}}{K_{i,t}} - \delta \right)^2 \quad (12)$$

Where, μ is the share of consumption in the intratemporal utility, β is the discount factor, γ is the intertemporal elasticity of substitution, and $\phi_{k,i}$ is the adjustment costs for capital. Similarly, $P_{i,c}, w_i, r_i$ are the prices of consumption, labor and capital. Each household has a fixed endowment of labor that is normalized to 1.

[9] That is, in order to sell 1 unit of domestic goods in foreign markets, the country has to send $\tau > 1$ units of the good

4.2 Intermediate goods and transportation costs

Intermediate goods are produced by competitive firms that use capital and labor. Each country produces a differentiated good that is traded both in domestic and foreign markets. The problem of the representative firm is to maximize profits by choosing capital and labor.

$$Max_{\{K_{i,t},L_{i,t}\}} P^x_{i,t} Y_{i,t} - r_{i,t} K_{i,t} - w_{i,t} L_{i,t} \tag{13}$$

$P^x_{i,t}$ is the f.o.b or factory gate price of the intermediate good produced in country i, and $Y_{i,t}$ is the production of the intermediate good in country i, which is represented by a Cobb-Douglas production function with a constant capital share α and productivity process given by $z_{i,t}$.

$$Y_{i,t} = z_{i,t} K^{\alpha}_{i,t} L^{1-\alpha}_{i,t} \tag{14}$$

The market clearing condition in each period for the intermediate goods producing firms in country i is:

$$Y_{i,t} = \sum_{j}^{N} Y_{ij,t} \tag{15}$$

When the intermediate goods are exported to the other country, they are subject to transportation costs that follow an iceberg-cost specification. According to this assumption, if the country i sends $Y_{i,j}$ units of intermediate goods to country j a fraction of the shipment is meltdown during the shipping, and the quantity that arrives is $X_{ij} = Y_{ij}/\tau_{ij}$, where $\tau_{ij} \geq 1$ represents the iceberg cost. Due to the presence of iceberg costs, the price of the intermediate good is not the same in every destination. It can be shown that the price at destination j of the good produced by i is $P_{i,j} = \tau_{i,j} P^x_i$.

4.3 Final goods

Competitive firms in the final good sectors combine domestic and foreign intermediates according to an Argminton aggregator to produce consumption and investment goods, and to maximize profits given by equation (16). These goods are not traded in foreign markets.

$$Max_{\{X_{ij,t}\}} P^c_{i,t} \left(\sum_j \omega_{ji}^{1/\sigma} X_{ji,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} - \sum_j P^x_{ji,t} X_{ji,t} \tag{16}$$

σ is the elasticity of substitution between home and foreign intermediates and ω_{ij} determines how important domestic and foreign varieties are for the production of final goods (home-bias). Finally, the market clearing condition for the final goods is given by equation (17).

$$C_{i,t} + I_{i,t} = \left(\sum_j \omega_{ji}^{1/\sigma} X_{ji,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{17}$$

4.4 Productivity shock

The only exogenous variables in the model are the productivity shocks, which are assumed to followed an auto-retrogressive process of the form:

$$log(z_{i,t}) = (1 - \rho_z) log(z_{i,ss}) + \rho_z log(z_{i,t}) + \epsilon_{i,t} \tag{18}$$

Where $\rho_z \in (0, 1)$, $z_{i,ss}$ is the steady state value for the productivity, and $\epsilon_{i,t}$ is an independent and identically distributed random variable.

4.5 Competitive equilibrium

Under financial autarky, a competitive equilibrium is a set of prices $\{P^c_{i,t}, w_{i,t}, r_{i,t}, P^x_{i,t}, P^x_{ji,t}\}_{i,j}$ and allocations $\{C_{i,t}, K_{i,t+1}, L_{i,t+1}, I_{i,t+1}, Y_{i,t}, Y_{ij,t}, X_{ij,t}\}_{i,j}$ such that for the exogenous productivity process z_{i,t_i} the following conditions hold:

- Given prices $\{P^c_{i,t}, w_{i,t}, r_{i,t}\}_i$, consumers maximize their utility by choosing $\{C_{i,t}, L_{i,t}, K_{i,t+1}, I_{i,t}\}_i$ subject to their budget constraint and the capital law of motion.
- Given prices $\{P^x_{i,t}, r_{i,t}, w_{i,t}\}_i$, intermediate goods producer maximize profits by choosing $\{K_{i,t}, L_{i,t}\}_i$.
- Given prices $\{P^c_{i,t}, P^x_{ji,t}\}_{i,j}$, final goods producers maximize profits by choosing $\{X_{ji,t}\}_{i,j}$.
- Labor, intermediate goods and final goods markets clear.

5 Calibration and Simulations

The world economy is composed by four economies, grouped into two SOEs and their two trading partners that account for the rest of the world (ROW). Most of the parameters are taken directly from Kose and Yi (2006) and reported in Table 11. The productivity levels are normalized to 1 in the two SOEs, while for the ROWs are set at 1.5, this is consistent with the Penn World Tables. The rest of parameters, 12 in total, determine how important intermediates from country i are for the production of final goods in country j. If I assume that the SOEs and the ROW are symmetric, I only need to calibrate 6 parameters. I specifically consider that $\omega_{SOE_i,SOE_i} = \omega_{SOE_j,SOE_j}$, $\omega_{SOE_i,ROW_i} = \omega_{SOE_j,ROW_j}$, $\omega_{ROW_i,ROW_i} = \omega_{ROW_j,ROW_j}$ and $\omega_{ROW_i,SOE_i} = \omega_{ROW_j,SOE_j}$, where $i, j = \{1, 2\}$. These parameters are calibrated to match the mean values of: trade openness in SOEs and in the ROW, two measures of trade intensity in the SOEs[10], the relative size of SOEs, and the trade partner similarity in the SOEs. Table 12 reports the targeted moments and their model counterpart. In general, the model does a good job replicating the targets. The calibrated parameters can be found in Table 13. Given that SOEs are relatively more open that the ROW the home bias parameters take a lower value; also, since trade intensity is relatively low the preference for intermediates produced in the other SOE is closed to zero. The different exposure to the two countries that represent the ROW come from that fact that the mean country-pair in the data is differently exposed to its trading partners.

Notice that foreign demand is endogenously determined in the model, meaning that it is not possible to feed into it the observed external comovement from the data. To solve this issue I take a short cut and use the similarity in trading partners as a proxy for foreign demand. Table 14 reports an OLS regression of trade-partner-similarity (TPS) on external demand comovement and shows that countries with more similar trading partners have a more correlated foreign demand, as expected. The advantage of the TPS is that it can be easily mapped into the model by changing the importance of foreign intermediates in the production of domestic final goods. One of the reasons I consider four economies, instead of three as in Kose and Yi (2006), is that the TPS indicator takes values higher than 1, as in Figure 1, and with three countries is impossible to generate those values.

To quantify the effects of bilateral trade and trade-partner synchronization on output comovement implied by the model. I re-calibrate the parameters for each country pair to match their bilateral trade intensity and trade partner similarity. To this purpose I only modify the parameters related with the importance of foreign intermediates in the production of final goods, *ceteris paribus*. By doing this, I'm able to keep almost constant the levels of trade openness and relative size. Figures 2 and 3 show the quantile plots for the data and the model. Both,

[10]The second measure of trade intensity instead of dividing by the sum of GDP divides by total trade in both countries.

trade intensity and TPS, laid on the 45 degree line, indicating the the model fits the data well. Figures 4 and 5 compare the data and model distributions and confirm the previous results. The last set of parameters describes the productivity process in the intermediate goods sector. Using the productivity levels reported on the Penn World Tables (PWT), I extract the cyclical component of productivity with a HP-filter and estimate a first-order autorregresive process, as in equation 19. The estimated persistence $\widehat{\rho_{i,1}}$ and standard deviation of the error term, $sd(\epsilon_{i,t})$, is finally used to simulate the model. For the ROW I assume that the productivity behaves as in the U.S, and for the countries with no data in the PWT I use the mean process for SOEs.

$$TFP^{hp}_{i,t} = \rho_0 + \rho_{i,1} TFP^{hp}_{i,t-1} + \epsilon_{i,t} \tag{19}$$

For each configuration of parameters the model is simulated for 1000 periods and the last 26 are used to calculate the relevant moments, such as output comovement, trade intensity and trade-partner synchronization. As in the data, GDP components are logged and HP-filtered. Table 15 reports the estimated coefficients implied by the model. To estimate equation 9, I use the level of trade intensity in the steady state[11]. According to the results, the model is consistent with the qualitative implications for the *Trade-Comovement* and *Trade-Partner-Comovement* relations but it fails to reproduced their magnitudes. The implied coefficients from the model are at least ten times smaller than those in the data, implying that increasing either trade intensity or trade-partner synchronization by one standard deviation affects output comovement by less than 0.4 pp. Finally, table 16 reports that the GDP components are less volatile in the model than in the data. These results suggest that the benchmark model can be improved on several dimensions.

The model is able to get the qualitative relations because trade works as a transmitter

[11] The results do not change if I use the value at the beginning of the period.

of business cycle fluctuations. A positive productivity shock in country i raises the demand for capital and labor, and pushes up wages and the interest rate. Higher wages increase the demand for final domestic goods and for foreign intermediates. The later has a positive effect on $i's$ trading partners, which increase production and exports. To raise production, they demand more labor and push wages up. This raise consumption and the demand for foreign goods (imports). This channel can be called the *Demand Channel* and is consistent with an increase in comovement and trade. On the other hand, the productivity shock reduces the price of intermediates from i and creates a substitution effect towards them. Countries demand less of their intermediates and more of $i's$. This reduces production and exports of $i's$ trading partners and increases exports from i. The net effect on trade is ambiguous. The final effect on $i's$ trading partners' production depends on how these two forces interact. If the demand channel is strong enough, production increases. Trade may increase also in the second case under certain conditions. According to the simulation results, there is a positive relation between trade and co-movement, meaning that when trade is higher it is more likely the the demand channel is stronger, therefore output moves in the same direction. Given that the relation between trade and comovement is weak, the substitution effect is playing an important role in the transmission of shocks.

Notice that if two countries are equally exposed to i they face the same forces and their output should move in the same direction. Given this, no matter which channel is more important, demand or substitution, the model should be consistent with the *Trade-Partner - Comovement*. The model is qualitatively consistent but fails to reproduce the magnitude. This failure may indicate that that idiosyncratic shocks represent a mayor source of fluctuations in the model and reduce the effect of common shocks. The model fails to replicate the *Trade-Comovement* relation because it cannot generate enough synchronization for a given level of bilateral trade (trade intensity). In other words, a productivity shock in one country generates a positive but relatively low effect in the production of its trading partners. This lack of comovement also affects the *Trade-Partner-Comovement* relation.

5.1 Sources of Comovement

Before trying to match the data better, it is important to understand how the assumptions regarding productivity shocks and the distributions of trade intensity and trade partner similarity affect the *Trade-Comovement* and *Trade-Partner-Comovement* relations. Table 17 reports the estimated coefficients for the benchmark model under different scenarios. For instance, row 2 shows the results with no productivity shocks in the ROW ($\overline{z}_{ss}^{ROW}$). Under this assumption, business cycle fluctuations in SOEs and the ROWs are generated by shocks in the former. The simulations show that the *Trade-Comovement* relation gets weaker but remains positive, while the *Trade-Partner-Comovement* strengths. In other words, idiosyncratic shocks in the SOEs generate comovement directly through trade, and indirectly by affecting the business cycle of the ROWs[12].

From rows 3 to 5, I settle trade partner similarity to its mean and simulate the model under different scenarios for the productivities. Specifically, in row 3, I consider productivity shocks everywhere and find that the *Trade-Comovement* and *Trade-Partner-Comovement* relations are not qualitatively consistent with the data. The former is not statistically significant, while the latter is negative. Rows 4 and 5 report the coefficients for the model with only productivity shocks in the SOEs or in the ROWs, respectively. In both cases, the coefficients are qualitatively consistent with the empirical evidence but fail to replicate their magnitudes. These results evidence that by reducing the idiosyncratic sources of volatility, trade forces are able to work in the model and generate comovement gains that are weaker than in the data.

Next, I simulate the model with no productivity shocks in SOEs and maintain the

[12] It is important to clarify that this channel is present in the model but not necessarily consistent with the data

dispersion trade intensity and trade partner similarity, row 6. This scenario reports a negative coefficient for the *Trade-Comovement* relation and a positive and big coefficient for the *Trade-Partner-Comovement* relation. The later is almost seven times bigger than the empirical one. In other words, without idiosyncratic shocks in SOEs, small changes in trade-partner-synchronization have huge effects on business cycle comovement. In this scenario, output fluctuations are originated in the ROWs and output synchronization is a consequence of exposure to common partners. If I also eliminate the heterogeneity in the trade intensity, as in row 8, the coefficient for the *Trade-Partner-Comovement* relation is not affected significantly. The *Trade-Comovement* relation is undefined in this case. These results suggest that idiosyncratic shocks in SOEs constraint the model to replicate the empirical *Trade-Partner-Comovement* relation. Finally, for rows 7 and 9, I consider that trade intensity is constant, meaning that the *Trade-Comovement* relation is undefined. In row 7, I assume productivity shocks everywhere, while in row 9 only in the SOEs. In both cases, the *Trade-Partner-Comovement* relation is positive and far from its empirical counterpart.

5.2 Modifications to the benchmark model

In this section I propose two mechanisms that generate more output comovement and volatility in the trade flows. These changes include modifying the productivity process and making trade barriers counter-cyclical. The advantage of these modification is that they do not need a new calibration of the model. In the next section, I propose additional mechanisms that require to re-calibrate the model.

To generate more comovement I assume that productivity shocks are correlated. Specifically, this correlation depends on how important a country is for its trading partner. The relative importance is captured by the ω_{ij} shares, as in equation 20. The parameter $\nu > 1$ scales up the weighted productivity shock, ν is constraint by $\nu \leq 1/\omega_{ij\cdot}$, meaning that the main source of productivity fluctuations in country i is its idiosyncratic shock.

$$log(z_{i,t}) = (1-\rho_{z,i})log(z_{i,ss}) + \rho_{z,i}log(z_{i,t}) + \epsilon_{i,t} + \nu\sum_{j\neq i}\omega_{ji}\epsilon_{j,t} \tag{20}$$

On the other hand, to generate more volatility on trade flows, and keep the procyclicality of exports and imports, I consider that trade barriers (iceberg costs) are negatively correlated with productivity shocks, as in equation 21. The parameters κ_i and κ_j are adjusted to generate the right volatilities of exports and imports in the data.

$$log(\tau_{ij,t}) = log(\tau_{ij,ss}) - (\kappa_i\epsilon_{i,t} + \kappa_j\epsilon_{j,t}) \tag{21}$$

The first two columns of table 18 report the coefficients for the *Trade-Comovement* and *Trade-Partner-Comovement* relations. As in the benchmark case, increasing trade intensity or trade-partner synchronization has a positive effect on business cycle comovement. Differently, with correlated productivity shocks the model is able to generate a coefficient for the *Trade-Partner-Comovement* relation that is close to the one observed in the data. However, regarding the *Trade-Comovement* relation, the puzzle remains. It is worth noticing that if I intentionally omit the effect of trade-partner-synchronization, as in the first column of table 18, the coefficient for trade intensity is four times larger, indicating a significant source of upward bias. Finally, table 19 reports the relative volatilities of GDP components. With correlated productivity shocks and counter-cyclical trade barriers the model is able to replicate the data more closely[13].

To understand the low impact of bilateral trade on output synchronization it is important to notice that SOEs are not significantly exposed to each other. The parameter that captures the relative exposure between SOEs is ω_{SOE_i,SOE_j}, and establishes how important the intermediates from SOE j are for the production of final goods in SOE i. From the calibra-

[13]Most of the volatility is coming from fluctuations in the iceberg costs

tion exercise, this parameter takes values between zero and 3.8%, meaning that intermediates from SOE j are in general not important for the production of final goods in country i. On the opposite side, the values for ω_{SOE_i,ROW_i} are in general bigger which allows the model with correlated shocks to solve puzzle more easily. Given the low levels of bilateral exposure it is too hard for the model to generate enough synchronization between SOEs, even with correlated productivity shocks. In the later case, the productivity transmission between SOEs is equal to $\partial log z_{i,t}/\partial \epsilon_{j,t} = \nu \omega_{i,j} \leq \nu 3.8\%$, which in general is a low number. To generate a higher synchronization between SOEs, equation 20 can be modified to consider a differentiated effect of productivity shocks. This compensates for the low levels of ω_{SOE_i,SOE_j}. As in the previous case ν_j is constraint, such as the main source of productivity fluctuations in county i is its idiosyncratic shock ϵ_i, meaning that $\nu_j \leq 1/\omega_{ji}$. To differentiate between scenarios, lets call this one *biased productivity correlation.*

$$log(z_{i,t}) = (1-\rho_{z,i})log(z_{i,ss}) + \rho_{z,i}log(z_{i,t}) + \epsilon_{i,t} + \sum_{j \neq i} \nu_j \omega_{ji} \epsilon_{j,t} \tag{22}$$

The coefficients for the *Trade-Comovement* and *Trade-Partner- Comovement* relations are reported on columns 3 and 4 of table 18. With biased productivity correlations it is possible to reduce the *Trade-Comovement* puzzle and still solve the *Trade-Partner- Comovement* one. It is important to notice that this modification does not affect the relative volatility of GDP components as shown in table 19. As in the previous scenario if I intentionally omit the effect of trade-partner synchronization the coefficient for bilateral trade is biased upwards.

6 Extensions

6.1 Low elasticity of substitution

Heathcote and Perri (2002) and Kose and Yi (2006) suggest that lowering the elasticity of substitution between foreign varieties allows the model to generate more comovement. In this new scenario I lower the trade elasticity, σ, from 1.5 to 0.7. To match the same moments as in the benchmark model, this modification requires a new calibration. The procedure is the same as in Section 5, first I calibrate the model to match some moments; then, I re-calibrate it to match the distributions of trade intensity and trade partner similarity in SOEs; finally, I simulate model for each configuration of parameters and estimate the *Trade-Comovement* and *Trade-Partner - Comovement* relations. As in the benchmark case, the model matches closely the target parameters, table 20, and the distributions of trade intensity and trade partner similarity, figures 6 to 9. The new set of parameters for the home bias is reported on table 21.

I first simulate the model with uncorrelated productivity shocks. The coefficients for the *Trade-Comovement* and *Trade-Partner-Comovement* relations are reported in Table 22. As in the benchmark case, the model is qualitatively consistent with the empirical relations but fails to reproduce their magnitudes. However, with lower trade elasticity, the coefficient for the *Trade-Partner-Comovement* relation almost doubles (0.7 vs 0.4). On the negative side, the volatility of investment and trade flows drops, Table 23, and real imports become counter-cyclical. Then, I extend the model to consider biased correlated productivity shocks and counter-cyclical trade barriers, as in equations 22 and 21, respectively. The coefficients for the *Trade-Comovement* and *Trade-Partner-Comovement* relations are also reported in Table 22. With this modifications, the model gets closer to the empirical relations and generates GDP components that are as volatile as their data counterparts.

6.2 Investment intensive on imported intermediates

I extend the model in two dimensions. First, I consider that households are allowed to trade a non-contingent bond that is in zero net supply. This modifies the consumers budget constraint as in equation 23, and adds an additional condition that helps to pin down the international price of the bond, equation 24. To guarantee the stationarity of the model, as suggested by Schmitt-Grohé and Uribe (2003), households pay a debt-adjustment cost, $\phi_d = 0.01$. I also assume that in the steady state households have no debt. This simplifies the calibration of the model.

$$P^c_{i,t}\left(C_{i,t}+I_{i,t}\right)+q_t B_{i,t+1}+\frac{\phi_{b,i}}{2}B^2_{i,t+1}=w_{i,t}L_{i,t}+r_{i,t}K_{i,t}+B_{i,t} \tag{23}$$

$$\sum_i B_{i,t}=0 \tag{24}$$

Second, following Boileau (1999) and Engel and Wang (2011), I consider that consumption and investment goods are produced with different technologies. In particular, investment goods use foreign imports more intensively. As suggested by Engel and Wang (2011) this increases the volatility of trade flows. With this assumption the production of final goods can be split into two different processes as described by equations 25 and 26, where $\omega^I_{ii} < \omega^C_{ii}$. Under this set up the prices of consumption and investment goods are different, and the budget constraint for the households changes, equation 27.

$$C_{i,t}=\left(\sum_j \left(\omega^c_{ji}\right)^{1/\sigma}\left(X^c_{ji,t}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{25}$$

$$I_{i,t}=\left(\sum_j \left(\omega^I_{ji}\right)^{1/\sigma}\left(X^I_{ji,t}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{26}$$

$$P^c_{i,t}C_{i,t} + P^I_{i,t}I_{i,t} + q_tB_{i,t+1} + \frac{\phi_{b,i}}{2}B^2_{i,t+1} = w_{i,t}L_{i,t} + r_{i,t}K_{i,t} + B_{i,t} \tag{27}$$

This set up adds 15 parameters to the calibration of the model, 12 related with the importance of intermediate goods in the production of investment, and 3 with the bonds. To simplify the calibration I assume that in the steady state the countries have no debt. I also assume that two SOEs and the two ROW are symmetric, This reduces the set of parameters to 6 parameters. Finally, I consider some symmetry between the production of consumption and investment goods. In particular, $\omega^c_{SOE_i,SOE_j} = \omega^I_{SOE_i,SOE_j}$, $\omega^c_{SOE_i,ROW_i} = \omega^I_{SOE_i,ROW_j}$, $\omega^c_{ROW_i,SOE_i} = \omega^I_{ROW_i,SOW_i}$, and $\omega^c_{ROW_i,SOE_j} = \omega^I_{ROW_i,SOW_j}$. Under this specification, I only need to add two conditions to the calibration exercise. Following Engel and Wang (2011) I impose that imports related to investment account 40% of total imports, both in the SOEs and the ROWs. With this condition I'm able to re-calibrate the model and match the same moments as in the benchmark calibration, that is, mean trade openness in SOEs and the ROW, the two measures of trade intensity in SOEs, the relative size of SOEs, and the trade partner similarity in SOEs. The new set of parameters is reported on Table 24 and matches closely the targeted moments in the data, Table 25[14].

For the simulations, I first re-calibrate the model to match the distributions of trade intensity and trade-partner-similarity. The parameters used for the re-calibration are $\omega^c_{SOE_i,SOE_j}$ and $\omega^c_{SOE_i,ROW_i}$. The quantile plots and the distributions for the data and the model are plotted in figures 10 to 13. As in the benchmark case, this version of the model replicates the empirical distributions closely. Then, I simulate the model under two specifications for the productivity shocks and iceberg costs. First, I consider uncorrelated productivity shocks and constant iceberg costs. Then, I assume biased correlated productivity shocks and counter-cyclical trade barriers,

[14]It is worth noticing that for the SOEs it is hard to match at the same time trade openness and the share of imported goods related with the production of investment. To match the latter exactly the model generates larger levels of trade openness.

as in equations 22 and 21, respectively. The coefficients for the *Trade-Comovement* and *Trade-Partner-Comovement* relations are reported in Table 26. With uncorrelated shocks the model is consistent with both relations but fails to reproduce the magnitudes in the data. Compared with the benchmark case, the *Trade-Partner-Comovement* relation strengths. On the other hand, the model with biased shocks and counter-cyclical iceberg costs solves the *Trade-Partner - Comovement* puzzle and alleviates the *Trade-Comovement* one. Finally, Table 27 reports the relative volatilities of the GDP components under the two scenarios. As in the benchmark case, the model with uncorrelated shocks generates GDP components that are less volatile than in the data; however, with investment intensive in imported intermediates the volatilities are higher than in the benchmark model. The extended version of the model, with correlated shocks and counter cyclical iceberg costs, overcomes these failures.

6.2.1 Investment intensive on imported intermediates + low trade elasticity

Next, I re-do the quantitative analysis assuming a lower trade elasticity $\sigma = 0.7$, as in section 6.1. The new set of parameters and the targeted moments are reported on tables 28 and 29. Similarly, the adjustment to the empirical distributions of trade intensity and trade partner similarity is shown on figures 14 to 17. As in the previous cases, the model does a good job targeting the empirical moments and the distributions. I simulate the model under two specifications for the productivity shocks and iceberg costs. First, I consider uncorrelated productivity shocks and constant iceberg costs. Then, I assume biased correlated productivity shocks and counter-cyclical trade barriers, as in equations 22 and 21, respectively. The coefficients for the *Trade-Comovement* and *Trade-Partner-Comovement* relations are reported in Table 30. With uncorrelated shocks the *Trade-Comovement* puzzle remains and the *Trade-Partner-Comovement* one alleviates[15]. The specification with biased correlated shocks is able to solve the two puzzles, generating coefficients that are close to the data. In both scenarios,

[15] One failure of this specification is that investment and imports are counter-cyclical.

omitting the effect of trade partners biases upwards the effect of bilateral trade and underestimates the overall impact of trade. In terms of volatilities, Table 31 shows that the model with correlated shocks and counter-cyclical trade barriers does a good job matching the data. Comparing all of the previous specifications the model that does a better job reproducing the empirical relations and matching the volatilities in the data is the last one.

6.3 Three Country Model

I finally consider a three-country model that abstracts from any difference on trade-partner synchronization. The idea of this extension is to compare the results with the full model and analyze if the proposed mechanisms help to alleviate the *Trade-Comovement* puzzle in a simplified environment. This version allows to understand what having four countries add to the benchmark model. Under this set-up I assume that the world economy is composed by two symmetric SOEs and one ROW. As in the previous cases, most of the parameters are taken directly from Kose and Yi (2006). For the benchmark calibration, the home bias and preference for foreign intermediates are chosen to target the mean trade intensity, the trade openness and the relative size of SOEs. Given that the 3-country version of the model has fewer parameters I won't be able to match the same moments than in the 4-country case. Tables 32 and 33 report the targeted moments and the calibrated parameters. Then, I re-calibrate the model to match the distribution of trade-intensity in the data. Figures 18 and 19 compare the model and empirical distributions. In general, the model fits the data closely.

The first column of Table 34 reports the *Trade-Comovement* coefficients for the three-country model with uncorrelated productivity shocks and no-additional disturbances. Under this scenario, increasing bilateral trade has no significant effect on business cycle synchronization. To understand the negligible impact of bilateral trade on output synchronization it is important to notice that SOEs are not significantly exposed to each other. From the calibration exercise ω_{SOE_i,SOE_j} takes values between zero and 3.31%. In general, bilateral SOE exposure is lower than in the four country-case the model, meaning that the trade channel between SOE is even weaker. Given this, the model is not able to generate a significant relation between bilateral trade and output comovement. In this dimension, the four country-model provides a better set up to solve the trade-comovement puzzle. In terms of volatilities the model also fails to generate enough moments on investment and trade flows, table 35. On a second exercise I simulate the model with bias correlated productivity shocks and counter-cyclical iceberg cost. This set up alleviates the *Trade-Comovement* puzzle and, as table 35 reports, generates more volatility in investment and trade flows.

7 Conclusions

Foreign trade affects business cycle comovement through different channels. Empirical literature has explored the causal link between bilateral trade and output synchronization, finding a positive relation between these variables. In this paper, I argue that common trading partners are an important source of output comovement, in particular, in small open economies. The empirical results suggest that trade not only affects output comovement through direct channels, but also indirectly through common trade partners. Omitting the effect of the latter, creates an upward bias on bilateral trade and reduces the overall impact of trade.

On the theoretical side, I document that a standard international real business cycle model is qualitatively consistent with the *Trade-Comovement* and *Trade-Partner-Comovement* relations, but it fails to replicate their magnitudes. It also fails to generate enough volatility of trade flows and investment. To solve the puzzles I propose correlated productivity shocks that increase the transmission of output fluctuations, even for lower levels of bilateral exposure. On the other hand, to generate enough volatility on GDP components I propose counter-cyclical trade frictions. These mechanisms work under different extensions of the standard model, such as lower trade elasticity and investment intensive on imported intermediates.

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A Figures

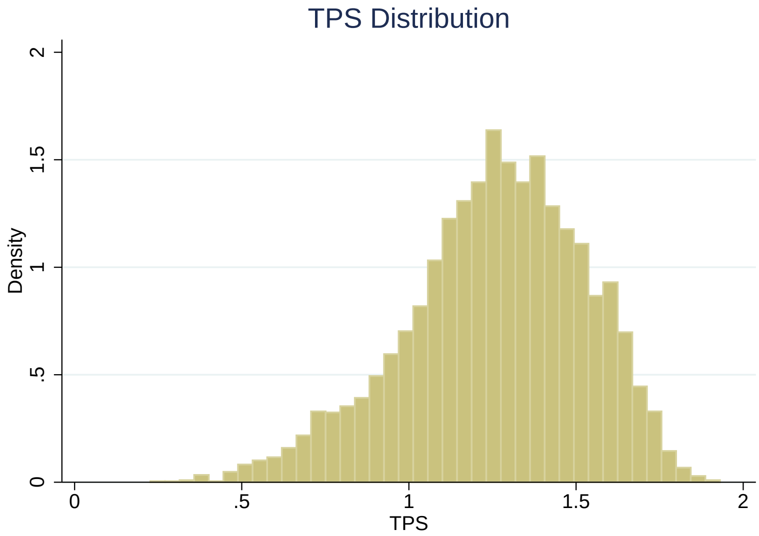

Figure 1: Trade Partner Similarity in Small Open Economies

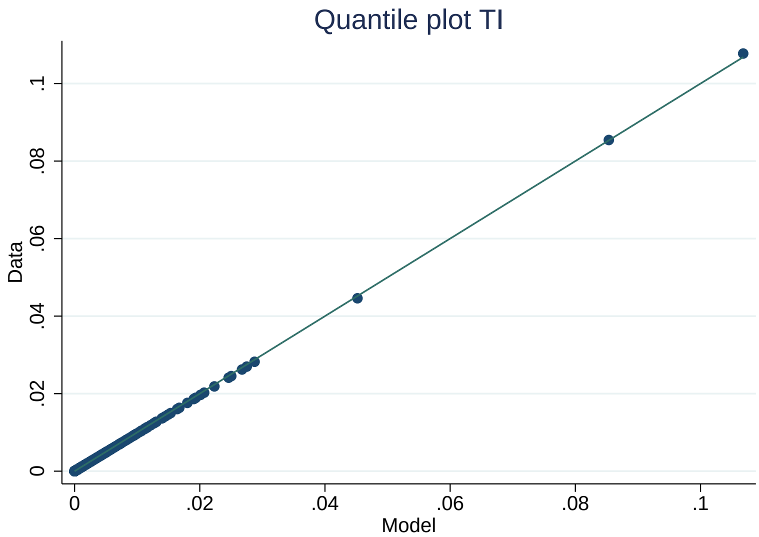

Figure 2: Quantile plot for Trade Intensity. Model vs Data

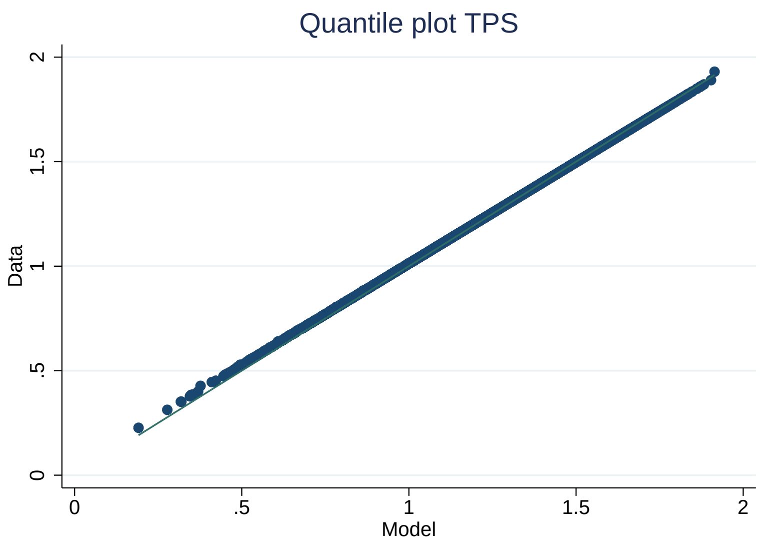

Figure 3: Quantile plot for Trade Partner Similarity. Model vs Data

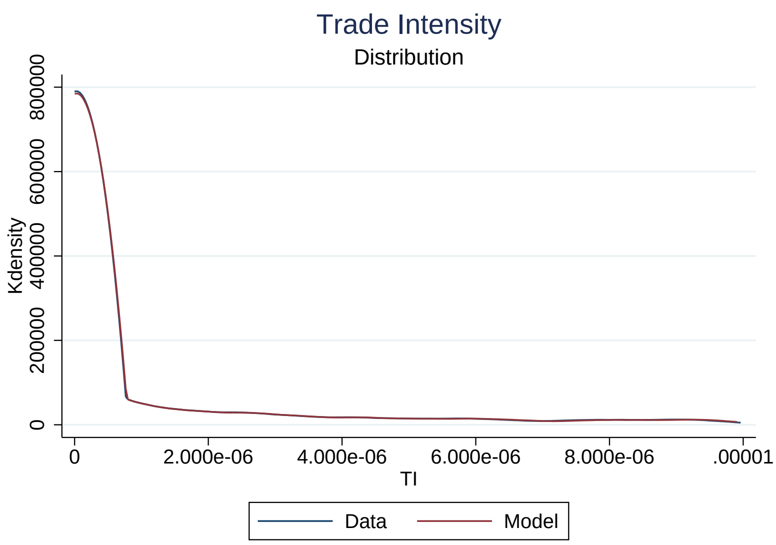

Figure 4: Trade Intensity Distribution. Model vs Data

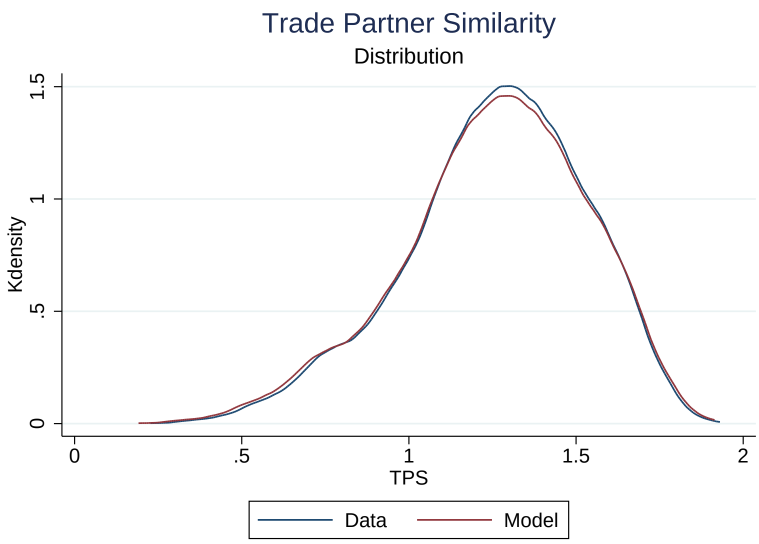

Figure 5: Trade Partner Similarity Distribution. Model vs Data

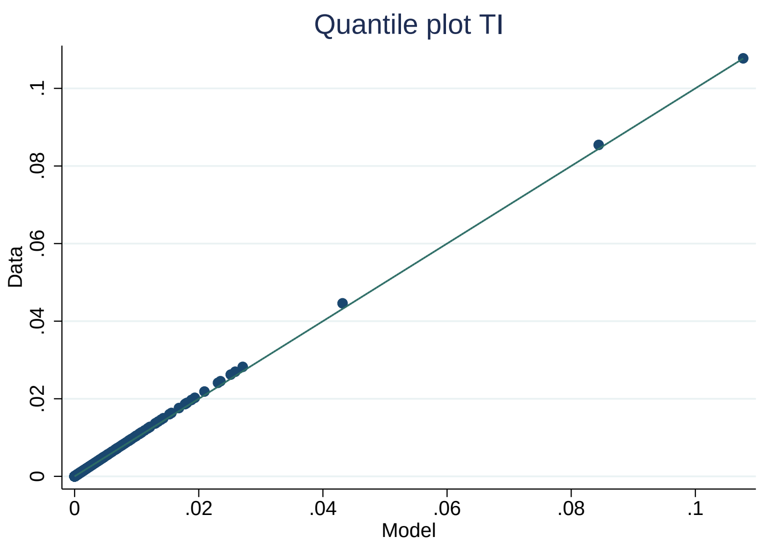

Figure 6: Quantile plot for Trade Intensity. Model vs Data. Low trade elasticity.

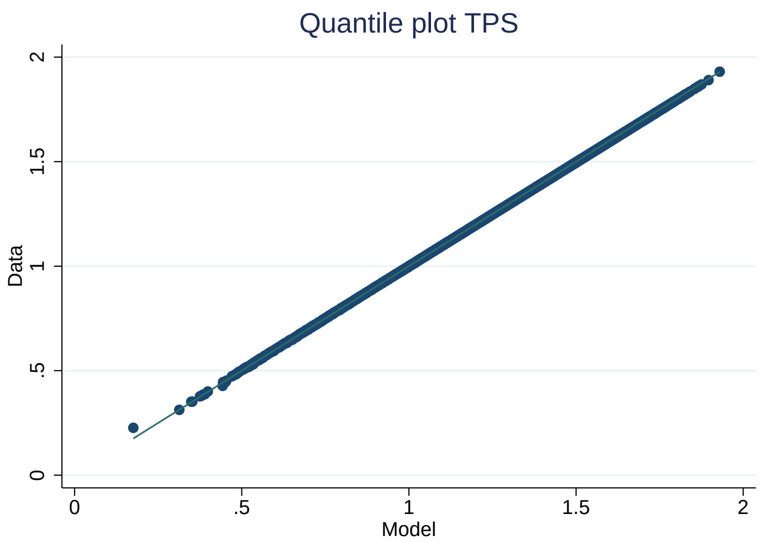

Figure 7: Quantile plot for Trade Partner Similarity. Model vs Data. Low trade elasticity.

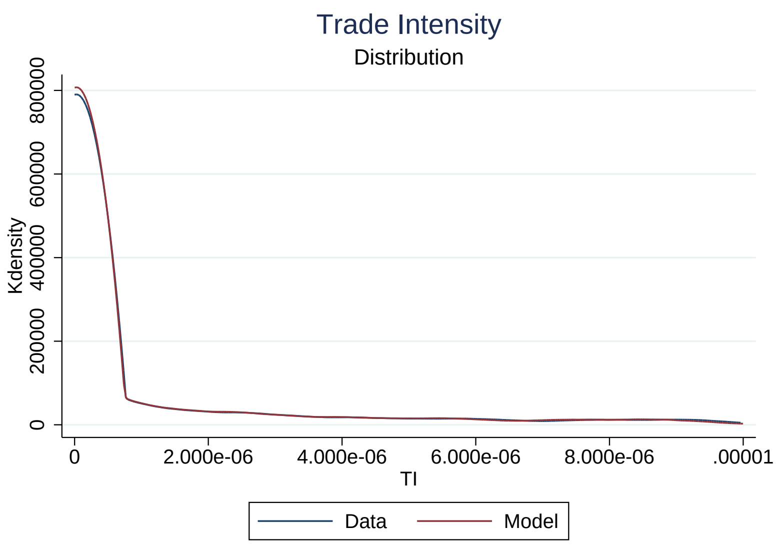

Figure 8: Trade Intensity Distribution. Model vs Data. Low trade elasticity.

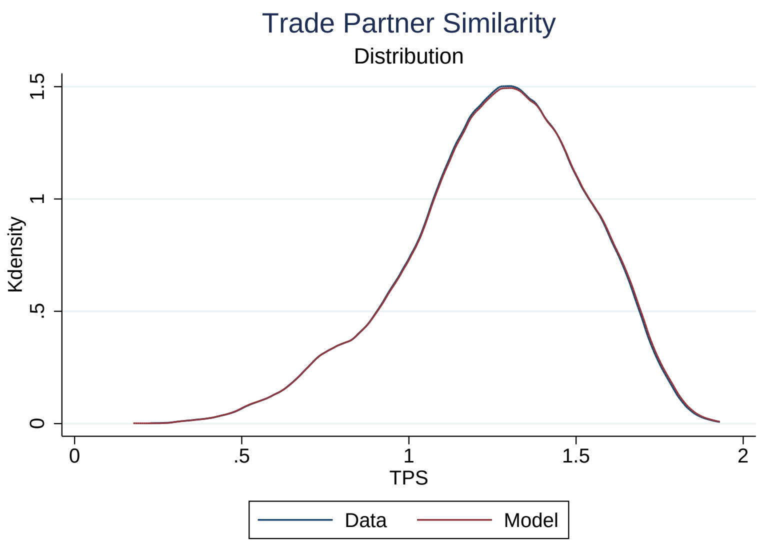

Figure 9: Trade Partner Similarity Distribution. Model vs Data. Low trade elasticity.

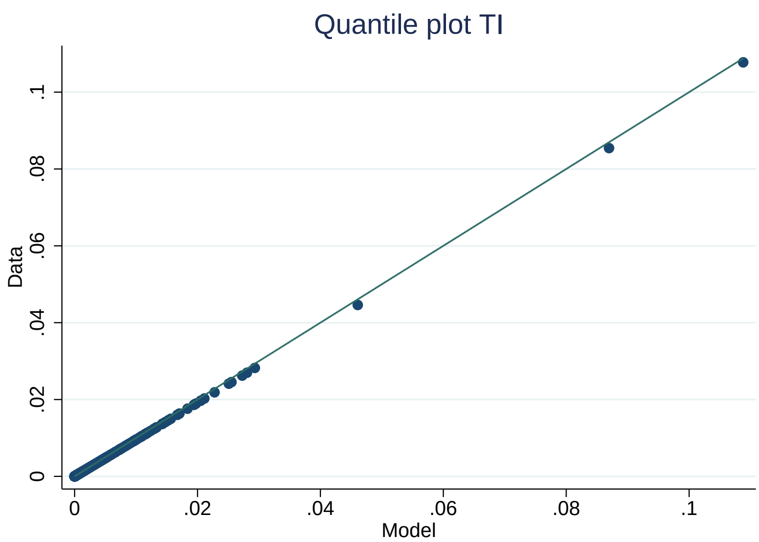

Figure 10: Quantile plot for Trade Intensity. Model vs Data. Investment intensive on imported intermediates.

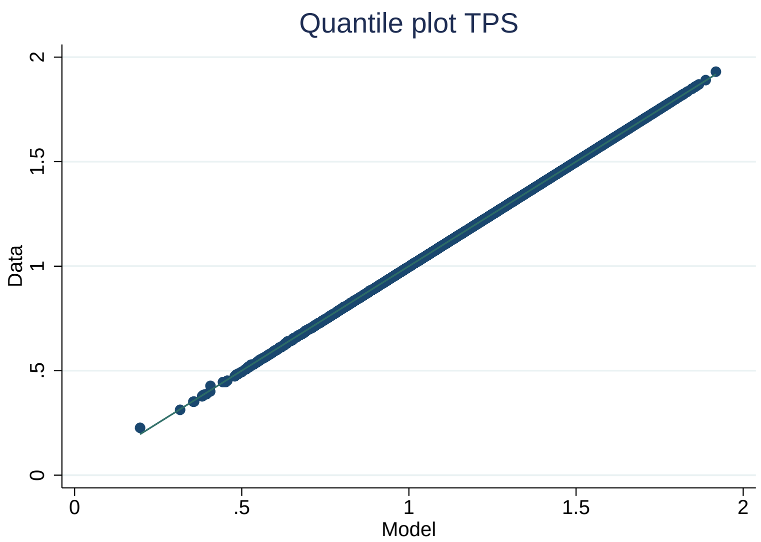

Figure 11: Quantile plot for Trade Partner Similarity. Model vs Data. Investment intensive on imported intermediates.

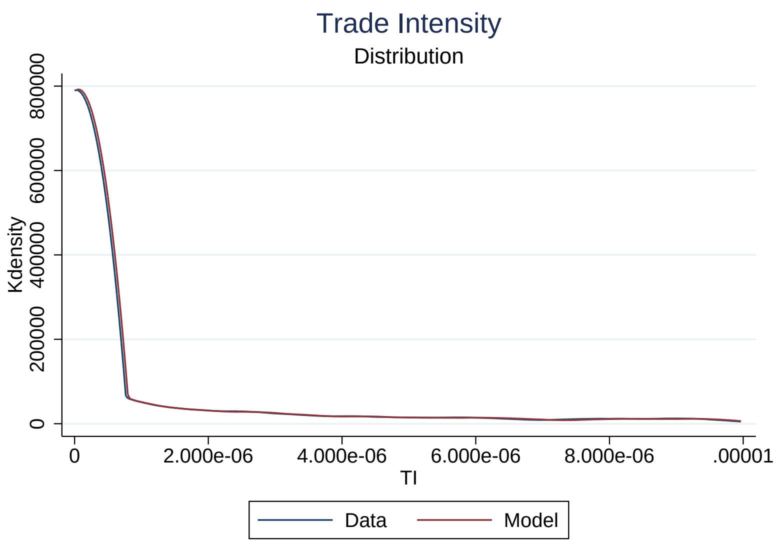

Figure 12: Trade Intensity Distribution. Model vs Data. Investment intensive on imported intermediates.

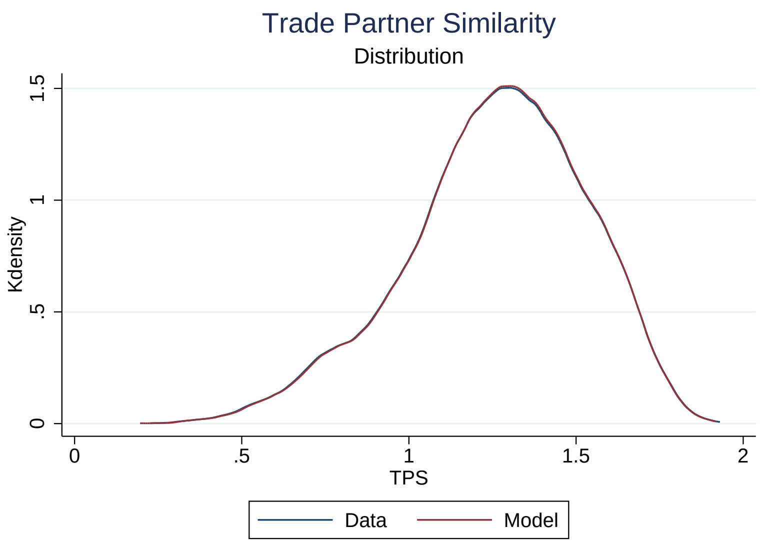

Figure 13: Trade Partner Similarity Distribution. Model vs Data. Investment intensive on imported intermediates.

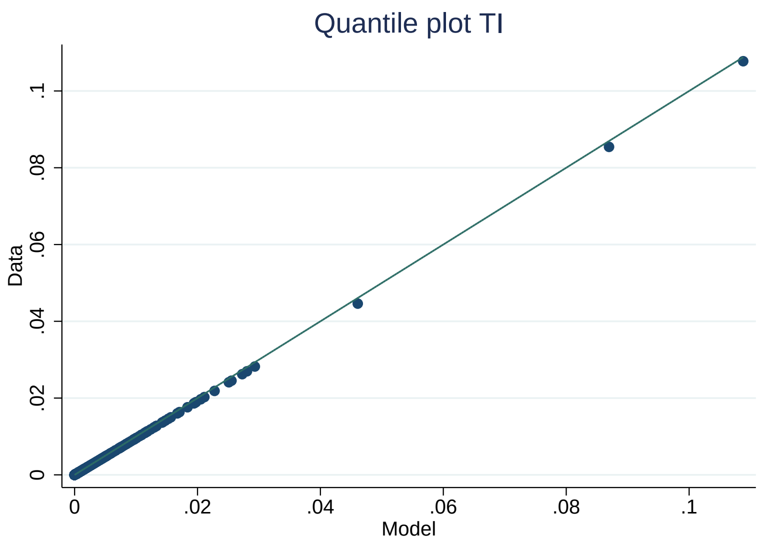

Figure 14: Quantile plot for Trade Intensity. Model vs Data. Investment intensive on imported intermediates + low trade elasticity.

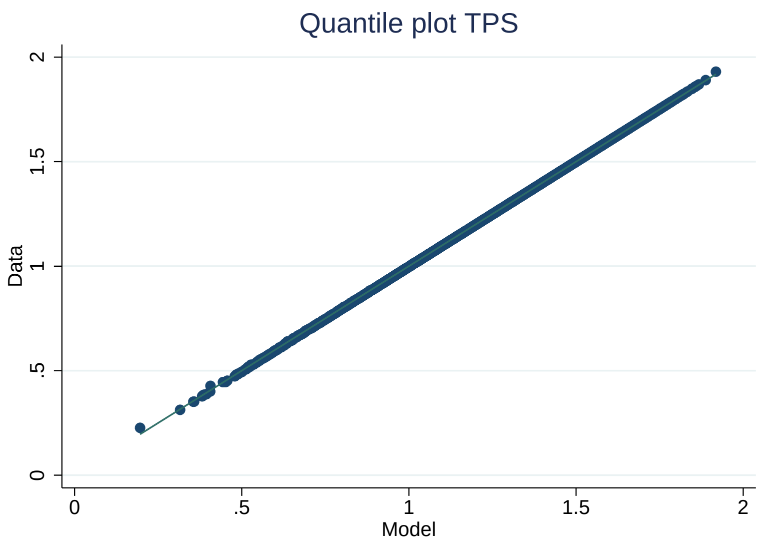

Figure 15: Quantile plot for Trade Partner Similarity. Model vs Data. Investment intensive on imported intermediates + low trade elasticity.

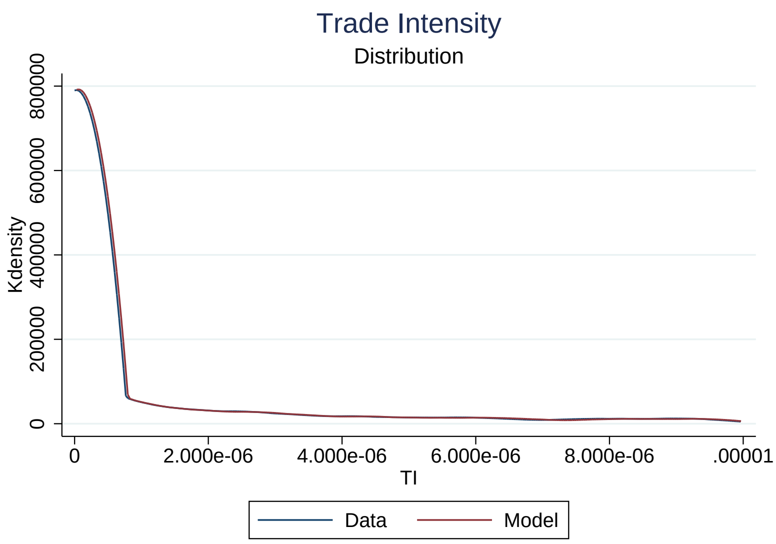

Figure 16: Trade Intensity Distribution. Model vs Data. Investment intensive on imported intermediates + low trade elasticity.

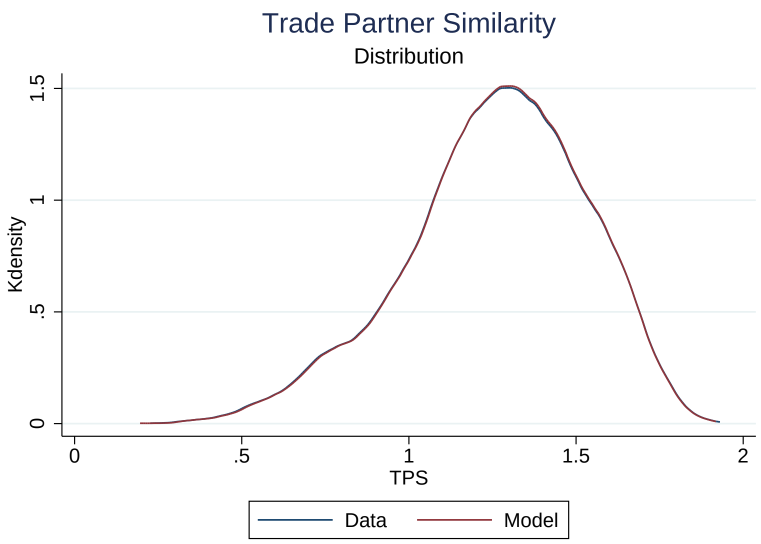

Figure 17: Trade Partner Similarity Distribution. Model vs Data. Investment intensive on imported intermediates + low trade elasticity.

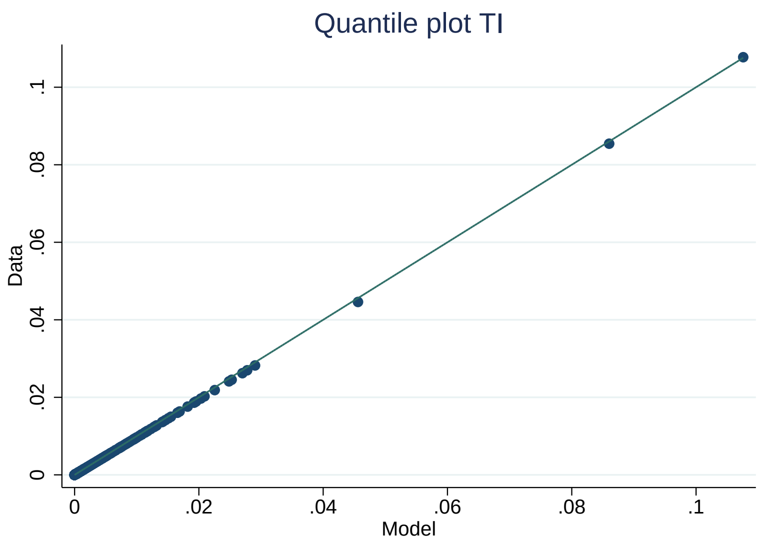

Figure 18: Quantile plot for Trade Partner Similarity. Model vs Data. Three-Country Model

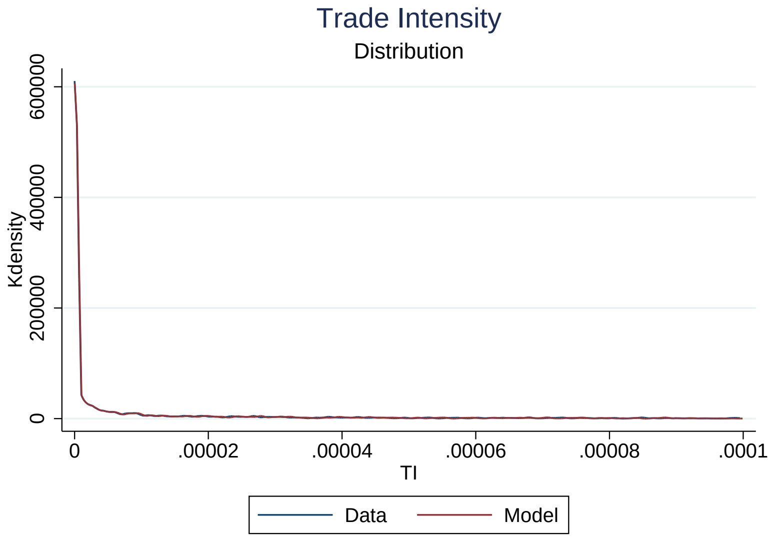

Figure 19: Trade Intensity Distribution. Model vs Data. Three-Country Model

B Tables

Variable	Sign	Significant 1%
Distance	-	✓
Region	+	✓
Border	+	✓
Language	+	✓
Country	+	✓
Colony	0	✗
Population	+	✓
Landlocked	-	✓
Latitude	+	✓
Longitude	+	✓
Area	0	✗
N	15262	
R^2	0.147	

Table 1: IV: Trade Intensity

	OLS	IV
$+1_{SD}\ TI_{GDP}$	1.9***	3.4***
N	15262	15262
R^2	0.24	0.23

Cycle HP-filter. Country FE.

Regs. with Trade and Develop. controls

* $p < .10$, ** $p < .05$, *** $p < .01$

Coefficients in percentage points

Table 2: Trade-Comovement

	TI_{GDP}	TI_{GDP}
TPS	-0.005***	
$Comov_{TPC}$		0.003***
N	15262	15262
R^2	0.057	0.008

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Trade Intensity, Trade-Partner-Similarity and Trade-Partner-Synchronization

	OLS		IV	
$+1_{SD}\ TI_{GDP}$	1.9***	1.6***	3.4***	2.7***
$+1_{SD}\ Comov_{TPC}$		5.2***		5.3***
N	15262	15262	15262	15262
R^2	0.24	0.25	0.23	0.25

Cycle HP-filter.

Regs. with Trade and Develop. controls and Country FE.

* $p < .10$, ** $p < .05$, *** $p < .01$

Coefficients in percentage points

Table 4: Trade-Comovement and Trade-Partner-Synchronization

Variable	Sign	Significant 1%
Distance	-	✓
Region	+	✓
Border	+	✓
Language	+	✓
Country	+	✓
Colony	+	✓
Population	+	✓
Landlocked	-	✓
Latitude	0	✗
Longitude	+	✓
Area	-	✓
N		9448
R^2		0.118

Table 5: IV: Trade Intensity SOE

	IV		SOE-IV	
$+1_{SD}$ TI_{GDP}	3.4***	2.7***	3.5***	2.9***
$+1_{SD}$ $Comov_{TPC}$		5.3***		4.0***
N	15262	15262	9448	9448
R^2	0.23	0.25	0.19	0.2

Cycle: HP-filter

Regs. with Trade and Develop. controls, and Country FE

* $p < .10$, ** $p < .05$, *** $p < .01$

Coefficients in percentage points

Table 6: Trade-Comovement and Trade-Partner-Synchronization. SOEs

	Baxter and King		Log-Diff	
$+1_{SD}$ TI_{GDP}	3.2***	3.0***	2.9***	2.6***
$+1_{SD}$ $Comov_{TPC}$		1.3***		2.1***
N	9448	9448	9448	9448
R^2	0.28	0.28	0.16	0.16

Regs. with Trade and Develop. controls, and Country FE.

* $p < .10$, ** $p < .05$, *** $p < .01$

Coefficients are in percentage points

Table 7: Trade-Comovement and Trade-Partner-Synchronization. SOE-IV

	SOE-IV	
$+1_{SD}\ TI_{GDP}$	4.2***	3.5***
$+1_{SD}\ Comov_{TPC}$		3.0***
N	9448	9448
R^2	0.21	0.22

Cycle: HP-filter

Regs. with Trade and Develop. controls, and Country FE.

* $p < .10$, ** $p < .05$, *** $p < .01$

Coefficients in percentage points

Table 8: Trade-Comovement and Trade-Partner-Synchronization. SOEs 1970-2016

	SOE-IV	
$+1_{SD}\ TI_{GDP}$	3.3***	2.6***
$+1_{SD}\ Comov_{TPC}$		3.7***
N	9448	9448
R^2	0.13	0.14

Cycle: HP-filter

Regs. with Trade and Develop. controls, and Country FE.

* $p < .10$, ** $p < .05$, *** $p < .01$

Coefficients in percentage points

Table 9: Trade-Comovement and Trade-Partner-Synchronization (SOEs). Excluding global recession 2007-2009.

	SOE-IV	
$+1_{SD}\ TI_{GDP}$	5.7***	4.8***
$+1_{SD}\ Comov_{TPC}$		3.0***
$+1_{SD}\ Comov_{TOT}$		2.1***
N	3386	3386
R^2	0.21	0.22

Cycle: HP-filter

Regs. with Trade and Develop. controls, and Country FE.

* $p < .10$, ** $p < .05$, *** $p < .01$

Coefficients in percentage points

Table 10: Trade-Comovement, Trade-Partner-Synchronization and Terms of Trade. SOEs

Parameter	Definition	Value	Source
μ	Share of consumption	0.34	KY
γ	Risk aversion	2	KY
β	Discount factor	0.96	KY
α	Capital share	1/3	KY
δ	Depreciation	0.1	KY
σ	Elast. of Subs	1.5	KY
$\tau_{i,j}$	Iceberg costs	1.2	KY
ϕ_k	Capital adjustment	0.0	Calibrated

Table 11: Calibration. KY stands for Kose and Yi (2006)

Variable	Data	Model
TI_{gdp}	0.041%	0.047%
TI_{trade}	0.058%	0.055%
TPS	1.26	1.26
TO_{SOE}	77%	72%
TO_{ROW}	37%	37%
GDP^{SOE}_{share}	6.5%	6.5%

Table 12: Targeted Moments. Benchmark Calibration

Demand	Source	Value
SOE_i	SOE_i	40.0%
	SOE_j	0.016%
	ROW_i	40.4%
	ROW_j	19.58%
ROW_i	ROW_i	81.0%
	SOE_i	0.90%
	SOE_j	0.04%
	ROW_j	18.06%

Table 13: Calibrated Parameters. Benchmark Calibration.

	$Comov_{hp}^{TPC}$
TPS	-0.306***
N	9448
R^2	0.191

* $p < .10$, ** $p < .05$, *** $p < .01$

Table 14: Trade-Partner-Similarity and Trade-Partner-Synchronization

	Model		Data	
$+1_{SD}$ TI_{gdp}	0.3***	0.2**	3.5***	2.9***
$+1_{SD}$ $Comov_{TPC}$		0.4***		4.0***
N	4725	4725	4724	4724

Coefficients are in percentage points

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 15: Trade Intensity, Trade-Partner-Synchronization and Comovement. Model vs Data.

Variable	*Data*	*Model*
C	1.34	0.29
I	3.33	2.60
X	2.31	0.83
M	2.68	0.32

Table 16: Standard deviations relative to GDP volatility.

Row	Scenario	TI_{gdp}	$Comov_{TPC}$
1	Base	0.2**	0.4***
2	$\overline{z}_{ss}^{ROW}$	0.1**	0.5***
3	$\overline{TPS}_{mean}$	-0.1	-0.9***
4	$\overline{TPS}_{mean} + \overline{z}_{ss}^{ROW}$	0.2***	0.5***
5	$\overline{TPS}_{mean} + \overline{z}_{ss}^{SOE}$	0.1***	0.3***
6	$\overline{z}_{ss}^{SOE}$	-1.2***	26.6***
7	$\overline{TI}_{mean}$	n.a	0.4***
8	$\overline{TI}_{mean} + \overline{z}_{ss}^{SOE}$	n.a	26.4***
9	$\overline{TI}_{mean} + \overline{z}_{ss}^{ROW}$	n.a	0.5***

Coefficients in percentage points

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 17: Sources of Comovement

	$TFP + Iceberg$		$TFP_{bias} + Iceberg$	
	(1)	(2)	(3)	(4)
$+1_{SD}$ TI_{gdp}	1.2***	0.3***	2.1***	1.3***
$+1_{SD}$ $Comov_{TPC}$		3.7***		3.7***
N	4725	4725	4725	4725

Coefficients are in percentage points

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 18: Trade Intensity, Trade-Partner Synchronization and Comovement. Correlated productivity shocks and counter cyclical trade barriers.

Variable	$Data$	$TFP + Iceberg$	$TFP_{bias} + Iceberg$
C	1.34	0.83	0.83
I	3.33	3.21	3.21
X	2.31	2.26	2.26
M	2.68	2.53	2.53

Table 19: Standard deviations relative to GDP volatility. Model with correlated TFP and counter cyclical trade barriers.

Variable	Data	Model
TI_{gdp}	0.041%	0.048%
TI_{trade}	0.058%	0.060%
TPS	1.26	1.26
TO_{SOE}	77%	81%
TO_{ROW}	37%	37%
GDP^{SOE}_{share}	6.5%	6.7%

Table 20: Targeted Moments. Benchmark Calibration. Low trade elasticity.

Demand	Source	Value
SOE_i	SOE_i	72%
	SOE_j	0.028%
	ROW_i	17.8%
	ROW_j	10.17%
ROW_i	ROW_i	81.0%
	SOE_i	4.5%
	SOE_j	0.03%
	ROW_j	14.47%

Table 21: Calibrated Parameters. Benchmark Calibration. Low trade elasticity.

	Model_{LE}		$\text{Model}_{LE+TFP+Iceberg}$		Data	
$+1_{SD}\ TI_{gdp}$	0.4^{***}	0.2^{**}	3.1^{***}	2.6^{***}	3.5^{***}	2.9^{***}
$+1_{SD}\ Comov_{TPC}$		0.7^{***}		2.4^{***}		4.0^{***}
N	4725	4725	4725	4725	4724	4724

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Coefficients are in percentage points

Table 22: Trade Intensity, Trade-Partner-Synchronization and Comovement. Low trade elasticity.

Variable	Data	Model_{LE}	$\text{Model}_{LE+TFP+Iceberg}$
C	1.34	0.10	1.47
I	3.33	0.97	3.20
X	2.31	1.33	2.29
M	2.68	0.63	2.65

Table 23: Standard deviations relative to GDP volatility. Low trade elasticity.

Parameter	Value	Parameter	Value
$\omega^{C}_{SOE_i,SOE_i}$	37%	$\omega^{I}_{SOE_i,SOE_i}$	27%
$\omega^{C}_{SOE_i,SOE_j}$	0.015%	$\omega^{I}_{SOE_i,SOE_j}$	0.015%
$\omega^{C}_{SOE_i,ROW_i}$	41.4%	$\omega^{I}_{SOE_i,ROW_i}$	41.4%
$\omega^{C}_{SOE_i,ROW_j}$	21.59%	$\omega^{I}_{SOE_i,ROW_j}$	31.59%
$\omega^{C}_{ROW_i,ROW_i}$	85%	$\omega^{I}_{ROW_i,ROW_i}$	70%
$\omega^{C}_{ROW_i,SOE_i}$	0.7%	$\omega^{I}_{ROW_i,SOE_i}$	0.7%
$\omega^{C}_{ROW_i,SOE_j}$	0.001%	$\omega^{I}_{ROW_i,SOE_j}$	0.001%
$\omega^{C}_{ROW_i,ROW_j}$	14.3%	$\omega^{I}_{ROW_i,ROW_j}$	29.3%

Table 24: Calibrated Parameters. Investment intensive on imported intermediates. Benchmark calibration.

Variable	Data	Model
TI_{gdp}	0.041%	0.048%
TI_{trade}	0.058%	0.060%
TPS	1.26	1.26
TO_{SOE}	77%	80%
TO_{ROW}	37%	36%
GDP^{SOE}_{share}	6.5%	4.1%
$M^{I}_{share,SOE}$	40%	29%
$M^{I}_{share,ROW}$	40%	38%

Table 25: Targeted Moments. Investment intensive on imported intermediates. Benchmark calibration.

	Model$_{INV}$		Model$_{INV+TFP+Iceberg}$		Data	
$+1_{SD}$ TI_{gdp}	0.4***	0.2*	2.6***	1.6***	3.5***	2.9***
$+1_{SD}$ $Comov_{TPC}$		0.9***		4.0***		4.0***
N	4725	4725	4725	4725	4724	4724

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Coefficients are in percentage points

Table 26: Trade Intensity, Trade-Partner-Synchronization and Comovement. Investment intensive on imported intermediates.

Variable	Data	Model_{INV}	$\text{Model}_{INV+TFP+Iceberg}$
C	1.34	0.32	0.89
I	3.33	3.23	3.36
X	2.31	0.80	2.43
M	2.68	0.77	2.68

Table 27: Standard deviations relative to GDP volatility. Investment intensive in imported intermediates.

Parameter	Value	Parameter	Value
$\omega^C_{SOE_i,SOE_i}$	75%	$\omega^I_{SOE_i,SOE_i}$	50%
$\omega^C_{SOE_i,SOE_j}$	0.025%	$\omega^I_{SOE_i,SOE_j}$	0.025%
$\omega^C_{SOE_i,ROW_i}$	15.8%	$\omega^I_{SOE_i,ROW_i}$	31.6%
$\omega^C_{SOE_i,ROW_j}$	9.17%	$\omega^I_{SOE_i,ROW_j}$	18.37%
$\omega^C_{ROW_i,ROW_i}$	85%	$\omega^I_{ROW_i,ROW_i}$	70%
$\omega^C_{ROW_i,SOE_i}$	0.0%	$\omega^I_{ROW_i,SOE_i}$	0.0%
$\omega^C_{ROW_i,SOE_j}$	4.5%	$\omega^I_{ROW_i,SOE_j}$	4.5%
$\omega^C_{ROW_i,ROW_j}$	10.5%	$\omega^I_{ROW_i,ROW_j}$	25.5%

Table 28: Calibrated Parameters. Investment intensive on imported intermediates + low trade elasticity. Benchmark calibration.

Variable	Data	Model
TI_{gdp}	0.041%	0.043%
TI_{trade}	0.058%	0.052%
TPS	1.26	1.26
TO_{SOE}	77%	84%
TO_{ROW}	37%	36%
GDP^{SOE}_{share}	6.5%	6.7%
$M^{I}_{share,SOE}$	40%	35%
$M^{I}_{share,ROW}$	40%	39%

Table 29: Targeted Moments. Investment intensive on imported intermediates + low trade elasticity. Benchmark calibration.

	Model_{INV+LE}		$\text{Model}_{INV+TFP+Iceberg+LE}$		Data	
$+1_{SD}\ TI_{gdp}$	0.4***	0.1*	3.4***	2.7***	3.5***	2.9***
$+1_{SD}\ Comov_{TPC}$		1.0***		3.4***		4.0***
N	4725	4725	4725	4725	4724	4724

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Coefficients are in percentage points

Table 30: Trade Intensity, Trade-Partner-Synchronization and Comovement. Investment intensive on imported intermediates + Low trade elasticity.

Variable	Data	Model_{INV+LE}	$\text{Model}_{INV+TFP+Iceberg+LE}$
C	1.34	0.36	1.39
I	3.33	0.61	3.23
X	2.31	1.29	2.31
M	2.68	0.62	2.79

Table 31: Standard deviations relative to GDP volatility. Investment intensive in imported intermediates + Low trade elasticity.

Variable	Data	Model
TI_{gdp}	0.041%	0.046%
TO_{SOE}	77%	78%
GDP^{SOE}_{share}	6.4%	6.3%

Table 32: Targeted Moments. Three country model. Benchmark calibration.

Parameter	Value
ω_{SOE_i,SOE_i}	33%
ω_{SOE_i,SOE_j}	0.0135%
ω_{ROW_i,ROW_i}	99%
ω_{ROW_i,SOE_i}	0.5%

Table 33: Calibrated Parameters. Three country model. Benchmark calibration.

	$Model_{3C}$	$TFP_{bias} + Iceberg$
$+1_{SD}\ TI_{gdp}$	0.0	1.7^{***}
N	4725	4725

$^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$

Coefficients are in percentage points

Table 34: Trade Intensity, Trade-Partner-Synchronization and Comovement. Three country model.

Variable	Data	$Model_{3C}$	$TFP_{bias} + Iceberg$
C	1.34	0.25	0.85
I	3.33	2.57	3.40
X	2.31	0.82	2.36
M	2.68	0.29	2.61

Table 35: Standard deviations relative to GDP volatility. Three-Country Model.