The Trade Comovement Puzzle and the Margins of International Trade

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Abstract

Countries that trade more with each other tend to have more strongly correlated business cycles. Yet, traditional international business cycle models predict a much weaker link between trade and business cycle comovement. We propose that fluctuations in the number of varieties embedded in trade flows may drive the observed comovement by increasing the correlation among trading partners' aggregate productivity. Our hypothesis is that business cycles should be more strongly correlated between countries that trade a wider variety of goods. We find empirical support for this hypothesis. After decomposing trade into its extensive and intensive margins, we find that the extensive margin explains most of the trade–productivity and trade–output comovement. This result is striking because the extensive margin accounts for only a fourth of the variability in total trade. We then develop a two-country model with heterogeneous firms, endogenous entry, and fixed export costs, in which the aggregate productivity correlation increases with trade in varieties. A numerical exercise shows that our proposed mechanism increases business cycle synchronization compared with the levels predicted by traditional models.

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1 Introduction

Countries that trade more with each other tend to have more strongly correlated business cycles (Frankel and Rose (1998); Clark and Van Wincoop (2001); Baxter and Kouparitsas (2005); Kose and Yi (2006)). However, traditional international business cycle (IBC) models predict only a weak link between trade and output comovement.[1] Kose and Yi (2006) propose several solutions to what they call the "trade comovement puzzle". In particular, they find that (i) aggregate productivity shocks are also more strongly correlated across countries that trade more with each other and (ii) calibrations of the standard model that account for this fact are able to fully capture the trade–output comovement observed empirically. Yet, the underlying mechanisms that connect trade and productivity comovement remain unexplained.

We hypothesize that fluctuations in the number of goods (or varieties) embedded in trade flows may be one of the forces driving productivity comovement and thereby output comovement. Indeed, research has shown that low-frequency fluctuations of trade in varieties can explain differences in aggregate productivity growth across countries (Broda, Greenfield, and Weinstein (2006); Goldberg, Khandelwal, Pavcnik, and Topalova (2010); Santacreu (2014)). One interpretation of these findings is that technology is embedded in new goods created through innovation.[2] Under autarky, a country's productivity depends only on domestic technology. With international trade, however, productivity depends also on foreign technologies embedded in imported goods.[3] Thus trade in varieties involves the international diffusion of technologies, which enables countries to benefit from each others' innovations. Ghironi and Melitz (2005) analyze the effect of high-frequency fluctuations in the extensive margin of trade on real aggregate variables. These authors report that when trade flows vary, either across countries or within a country over time, so does the number of goods embodied in those trade flows. Based on this premise, our hypothesis is that business cycles are more strongly correlated for countries that trade a wider variety (though not necessarily a greater quantity) of goods.[4]

[1] In the standard IBC model (Backus, Kydland, and Kehoe (1995)), which is driven by productivity shocks, two opposing forces determine the trade–output comovement. First, more trade leads to more synchronization by increasing the demand for foreign products (*demand complementarity* effect). Second, greater integration induces a stronger reallocation effect toward the most productive country, lessening synchronization (*resource-shifting* effect). When markets are complete, the latter effect dominates. In addition to these standard channels, a third channel—the *terms of trade* effect—has an ambiguous sign. An economy experiencing a positive productivity shock benefits from lower prices and so increases its market share relative to other economies, which reduces business cycle synchronization. Yet foreign economies also benefit from cheaper imports, which increases synchronization. Which effect dominates depends on the elasticity of substitution between domestic or foreign intermediate goods as well as on the share of imported intermediate goods in the foreign economies.

[2] Burstein and Melitz (2011) show how innovative activities at the firm level amplify productivity differences between exporters and nonexporters.

[3] Goldberg, Khandelwal, Pavcnik, and Topalova (2009) and Goldberg, Khandelwal, Pavcnik, and Topalova (2010) study Indias's (1991) trade liberalization and show that imports of varieties generate static and dynamic gains from trade while increasing productivity at the plant level.

[4] Both theoretical and empirical work have highlighted how the number of goods embedded in trade flows varies with the business cycle. Ghironi and Melitz (2005) and Alessandria and Choi (2007) argue that the extensive margin of trade should not be ignored when studying trade flows. There is empirical evidence for endogenous fluctuations in available US domestic varieties (Ghironi and Melitz (2007)). Other papers that document new varieties being introduced in the US economy in conjunction with the business cycle include Axarloglou (2003), Bernard, Jensen, Redding, and Schott (2007), and Broda and Weinstein (2007).

We proceed in three steps. First, we find empirical support for this hypothesis. We update the trade–output and trade–productivity comovement regressions and find results in line with the literature. We then decompose trade intensity into its extensive and intensive margins. We find that the former explains most of the trade–productivity and trade–output comovement while the latter plays only a marginal role. These results hold both at high and at medium frequencies.[5] In particular we find that, while holding the *intensive* margin constant, a doubling of the median extensive margin of trade is associated with an increase in the bilateral productivity correlation of about 0.06 and in the bilateral gross domestic product (GDP) correlation of about 0.059. When we hold the *extensive* margin constant, in contrast, doubling the median intensive margin of trade is associated with a decrease in the bilateral productivity correlation of about 0.01 and an increase of the bilateral GDP correlation of about 0.003. These estimates are statistically significant only for the extensive margin of trade. Our finding that the extensive margin explains most of the trade–productivity and trade–output comovement is striking because that margin accounts for only a fourth of the variability of bilateral trade intensity observed in the data. This suggests that countries trading a higher number of products (a higher level of the extensive margin)—and not more of each product (a higher level of the intensive margin)—exhibit a greater amount of aggregate productivity comovement and output comovement.

Second, we illustrate our empirical results with a well-established model that explains how shocks to aggregate productivity generate movements in the extensive margin that affect output comovement across pairs of countries. In this model, the higher is the steady-state level of the extensive margin between two countries, the stronger is the effect of productivity shocks on the comovement of business cycles through fluctuations in that margin. We build upon Ghironi and Melitz (2005) and Alessandria and Choi (2007) to develop a two-country IBC model with the following additional features.[6] First, there is capital and an endogenous labor supply. Second, there is trade in differentiated intermediate goods (varieties).[7] Third, the dynamics of "welfare–based" aggregate productivity are mainly driven, at both low and high frequencies, by the number and average productivity of domestic and foreign varieties; this is the mechanism we propose to explain the trade comovement puzzle.[8] Fourth, variations in trade are induced by iceberg transport costs (which affect mainly the intensive margin of trade) and

[5] Comin and Gertler (2006) show that there are strong procyclical movements in embodied technological change, research and development (R&D), and aggregate productivity over the medium term; there is also strong comovement between output and embedded technological change at both high and medium frequencies. These authors argue that the strong medium-term procyclicality of aggregate productivity can be explained by endogenous productivity. The idea is to introduce mechanisms by which investments in resources lead to greater future productivity.

[6] Kose and Yi (2006) argue that, in a two-country model, one of the countries would be the rest of the world and so the model would overstate the impact of one country on the other; hence, a three-country model is needed to accommodate the third-country effect. Although we agree that this is the right approach when calibrating to a particular pair of countries, our paper focuses on whether the mechanism is stronger for pairs of countries with tighter trade linkages. As will become clearer in the quantitative exercise, we show that pairs of countries with stronger trade linkages have more strongly correlated aggregate productivity and output.

[7] During the past decade, the structure of international trade has shifted toward intermediate and capital goods: 78% of total trade corresponds to capital (14%) and intermediate inputs (64%), and only 22% corresponds to consumption goods. A similar decomposition into consumption, capital, and intermediate goods is obtained when one considers the number of goods traded rather than trade flows.

[8] In Appendix 5 we provide evidence of high-frequency movements in the extensive margin of trade that track closely the high-frequency movements in aggregate productivity and GDP. There we focus on the case of the United States and China.

the fixed export costs associated with entry regulations (which affect mainly the extensive margin) . In each country, a firm produces a nontraded final good using domestic and foreign varieties. Production involves "love of variety" à la Ethier (1982), so production efficiency (i.e., aggregate productivity) increases with the number and average productivity of varieties used. Intermediate producers are heterogeneous in productivity and face sunk costs of entry into the domestic market and fixed costs of serving the foreign market. In the model, each firm is associated with a different variety. Forward-looking firms formulate entry and export decisions based on their expected future profits. Only a subset of the most productive firms serves the foreign market–a fact that generates variations in the extensive margin of trade across pairs of countries. Exogenous shocks to aggregate productivity alter the composition and average productivity of domestic and foreign varieties in each country. We consider only those productivity shocks that are uncorrelated across countries while focusing on the correlation between the endogenous component of countries' aggregate productivity.

Two channels strengthen the correlation of GDP growth rates between trading partners. The first channel is the traditional demand–supply spillover effect, which is present in standard IBC models but quantitatively too small to explain the trade–output comovement observed in the data. A second (albeit less direct) channel results from entry, at business cycle frequencies, into domestic and foreign markets. Following a positive transitory shock to domestic aggregate productivity, domestic final producers increase their demand for foreign intermediate goods, which in turn increases foreign output; this is the standard demand–supply channel. In addition, however, higher productivity induces entry into both domestic and foreign markets. Indeed, the country experiencing a positive productivity shock exports varieties, each of which has a higher average productivity, and these exports increase each trading partner's endogenous aggregate productivity. Higher aggregate productivity increases output both directly through the production function and indirectly by increasing the demand for intermediate goods even more, which amplifies the demand–supply channel present in the standard IBC model. The strength of the endogenous productivity effect is higher when export fixed costs are lower. An important prediction of our model—one that allows us to illustrate our empirical results—is that countries with higher steady-state levels of the extensive margin also exhibit greater propagation of shocks due to changes in this margin. In other words, the importance of the extensive margin is evident not only at the steady-state level but also with respect to the transmission of shocks across countries. We describe the empirical evidence that establishes this result. In particular, we show that pairs of countries with a higher extensive margin (as measured by the number of traded varieties) exhibit a greater variability in this margin and that this is true at different frequencies.

Third, we conduct a quantitative analysis to illustrate the main mechanisms of the model. Toward this end, we first use impulse response functions to analyze how trade in varieties amplifies the effect of an exogenous productivity shock to one country on the output growth of its trading partners. Then, we simulate the model for artificial pairs of countries that differ in their iceberg transport costs and in their fixed export costs. We compute the correlations among output growth, aggregate productivity growth, and average trade intensity; we then reproduce the same exercise as in our empirical analysis. This exercise allows us to recover the trade–output and the trade–productivity coefficients implied by the model, which we compare with the coefficients implied by the data. We find that adding heterogeneous firms and fixed costs to the standard IBC model improves significantly the trade–output and trade–productivity coefficients in comparison with the standard model.

Taken together, our results suggest that (i) much of the trade–productivity and trade–output comovement can be explained by the extensive (but not the intensive) margin of trade and (ii) the international transmission of shocks through trade in varieties is a plausible explanation for these relationships.

Several strands of the literature have tackled the trade comovement puzzle. Kose and Yi (2006) document that productivity shocks are more strongly correlated across countries that trade more with each other. Other researchers emphasize the role of intermediate inputs in increasing plant-level productivity after a trade liberalization (e.g., Goldberget al. 2009, 2010; Kugler and Verhoogen (2009); Manova and Zhang (2012)). Juvenal and Santos Monteiro (2010) find that cross-country correlations in technology constitute one of the main drivers of the trade comovement puzzle. The main innovations in our paper are disentangling the effects of the extensive and intensive margins on the comovement of productivity growth and output growth and proposing a mechanism to explain the importance of the extensive margin of trade.

As Kose and Yi (2006) point out, the puzzle addressed in this paper differs from standard puzzles in the IBC literature (e.g., the output and consumption puzzles). In that literature, the correlation puzzle concerns the inability of standard IBC models to generate a ranking of cross-country output and consumption correlations that matches the data. The trade comovement problem concerns the inability of these models to generate a strong change in output correlations from changes in bilateral trade intensity.

Another strand of the literature studies the role of vertical linkages, both empirically (Burstein, Kurz, and Tesar (2008); Di Giovanni and Levchenko (2009); Ng (2010); Johnson (2014)) and theoretically (Arkolakis and Ramanarayanan (2009)). Much as in our paper, that research emphasizes the amplifying effect of traded intermediate goods. However, the amplification reported by these authors is driven by the multistage nature of production, whereas here it is driven by fluctuations in the extensive margin of trade.

Drozd and Nosal (2008) argue that a low elasticity of substitution between domestic and foreign intermediate goods (at business cycle frequencies) can explain, in part, the trade–output comovement. In their model, frictions in the short run generate a low price elasticity that is compatible with the high long-run elasticity of substitution observed in the data. Although that model captures as much as half of the correlation (between trade and output comovement) found in empirical studies, the mechanism by which this occurs has not been well established empirically.

Finally, Alessandria and Choi (2007) and Jaef and Lopez (2014) extend the framework of Ghironi and Melitz (2005) by adding capital and adjustment costs to the high-frequency fluctuations in the extensive margin of trade; they find that the addition of capital dampens the effect of the extensive margin on business cycle comovement. We follow that modeling strategy, but instead of analyzing the model's time-series properties of the model, we examine its cross-sectional properties. Our goal is to determine whether increases in bilateral trade generate an increase in business cycle comovement that is consistent with previous empirical findings. The mechanism that we propose can be viewed as an alternative explanation to complement the empirical and theoretical literature that has addressed the trade comovement puzzle.

Our paper proceeds as follows. Section 2 decomposes bilateral trade intensity into intensive and extensive margins of trade and shows that much of the observed comovement is due to the latter margin. Section 3 presents our model and explains the proposed mechanism, and Section 4 conducts a quantitative analysis. Section 5 concludes.

2 Trade–Output Comovement and the Margins of Trade

In this section, we disentangle the effects of extensive and intensive margins of bilateral trade on both output and aggregate productivity comovement. This approach is a departure from the literature, which investigates only the relationship between total bilateral trade and the comovement of output. We update Frankel and Rose (1998) with respect to a 30-country sample (20 OECD countries and 10 developing countries) spanning the period from 1980Q1 through 2009Q4. This sample accounts for nearly 75% of world GDP and 73% of world trade.[9]

The output data are transformed in three ways: (i) Hodrick–Prescott (HP) filtering of real output (with smoothing parameter 1600); (ii) first-differencing of natural logarithms to calculate the output growth rate; and (iii) band-pass (BP) filtering to remove high-frequency variations (while retaining frequencies between 32 and 116 quarters). The first two transformations capture business cycle frequencies and the third captures medium-term business cycles (Comin and Gertler (2006)). We then calculate the bilateral correlation of real output over six (nonoverlapping) 5-year intervals, between 1980 and 2009, for each of the three resulting measures.[10]

We use bilateral trade data at the 5-digit level of disaggregation (SITC Rev. 3) from the UN Comtrade database and calculate the two margins of trade using the Hummels and Klenow (2005) decomposition. This is the highest level of disaggregation at which data exist for a large sample of countries and a long period of time.[11]

Hummels and Klenow (2005) use the Feenstra and Markusen (1994) methodology to incorporate new varieties into a country's import price index when preferences reflect constant elasticity of substitution (CES). The extensive margin (EM) is defined as a weighted count of country j's imported varieties

[9] The country list is given in Appendix 5 as Table E.1.

[10] Several authors argue that the extensive margin of trade does not vary significantly at high frequencies (see, e.g., Kehoe and Ruhl (2013)). Hence, we follow Comin and Gertler (2006) and remove high-frequency variations in the data.

[11] As a robustness check, we count the number of varieties to obtain the extensive margin of trade (normalized by the number of varieties exported by the rest of the world). The count data represent a particular case of the Hummels and Klenow decomposition in which each variety is assigned the same weight. The two measures yield similar results.

from country i relative to its imported varieties from country k. If i's shipments to j are a subset of k's shipments to j, then the extensive margin is

$$\mathrm{EM}_{ij} = \frac{\sum_{m \in I_{ij}} p_{kjm} x_{kjm}}{\sum_{m \in I} p_{kjm} x_{kjm}}; \tag{1}$$

here $I_{ij} \in I$ is the set of observable varieties for which country i has positive exports to j, and I is the set of all varieties. The reference country k (in this case, the rest of the world) has positive exports to j in all I varieties. The terms p_{kjm} and x_{kjm} are, respectively, the price and quantity of variety m exported by the reference country k to country j.

The intensive margin (IM) similarly compares nominal shipments for country i and country k with respect to a common set of goods:

$$\mathrm{IM}_{ij} = \frac{\sum_{m \in I_{ij}} p_{ijm} x_{ijm}}{\sum_{m \in I_{ij}} p_{kjm} x_{kjm}}. \tag{2}$$

The ratio of country i's exports to country j with respect to country k's exports to country j, which we refer to as overall trade and denote by $\mathrm{O}T_{ij}$, equals the product of the two margins; thus, taking logs yields

$$\log(\mathrm{OT}_{ij}) = \log(\mathrm{EM}_{ij}) + \log(\mathrm{IM}_{ij}). \tag{3}$$

We classify the 5-digit goods into three categories (consumption, intermediate, and capital goods) and then compute the margins of trade for each category for the period 1980–2009. We perform a variance decomposition of the trade intensity into the variability of the intensive and extensive margins of trade; we find that, on average, the intensive margin accounts for nearly 75% of the variation of overall trade. We then regress the correlation of our three measures of output correlation against the logarithm of country i's exports to country j relative to country k's exports to country j while including only intermediate and capital goods[12]:

$$\mathrm{corr}(\tilde{y}_{it}, \tilde{y}_{jt}) = \beta_0 + \beta_{\mathrm{OT}} \log(\mathrm{OT}_{ij,t}) + \varepsilon_{jm,t}. \tag{4}$$

with $\tilde{y}_{it}$representing real output, filtered as mentioned.

We run instrumental variable (IV) regressions using distance as the instrument for overall trade. The results, reported in Table 1, are consistent with those obtained in previous studies: countries that trade more with each other tend to have more strongly correlated output growth.

[12]We include only intermediate and capital goods to capture the notion that the transfer of technology embodied in these types of goods may help explain the business cycle comovement. In the next section, we present a model in which only intermediate and capital goods are traded across countries. Regressions that also include consumption goods deliver similar results.

Table 1: Output correlation and overall trade

HP-filtered output		Output growth		BP-filtered output	
$\text{corr}(y_i^{\text{HP}}, y_j^{\text{HP}})$	Coeff.	$\text{corr}(\Delta y_i, \Delta y_j)$	Coeff.	$\text{corr}(y_i^{\text{BP}}, y_j^{\text{BP}})$	Coeff.
$\log(\text{OT}_{ij})$	0.114***	$\log(\text{OT}_{ij})$	0.066***	$\log(\text{OT}_{ij})$	0.197***
	(0.011)		(0.006)		(0.023)
Constant	0.847***	Constant	0.490***	Constant	1.077***
	(0.051)		(0.029)		(0.104)

Notes: Two-stage least-squares (2SLS) IV regression using log distance as the IV.
Standard errors are reported in parentheses. *** denotes statistical significance at the 1% level.

The next step is to analyze the contribution of each margin of trade to output comovement. We do this via the following regression:

$$\text{corr}(\tilde{y}_{it}, \tilde{y}_{jt}) = \beta_0 + \beta_{\text{EM}} \log(\text{EM}_{ij,t}) + \beta_{\text{IM}} \log(\text{IM}_{ij,t}) + \varepsilon_{ij,t}. \quad (5)$$

Instruments are needed for both margins of trade. We follow Chaney (2008) and Helpman, Melitz, and Rubinstein (2008) in using both entry costs and distance between the two countries as instruments. Our IVs are presumed to be correlated with bilateral trade intensity, but we can assume that they are not influenced by other conditions that affect the bilateral correlation of activity. The idea is that the intensive margin is affected mainly by the iceberg transport cost (a variable cost), whereas the extensive margin is affected mainly by the cost of entering a new market (a fixed cost). We therefore use distance as an instrument for the intensive margin; to instrument the extensive margin, we use country-level data on the regulation costs of firm entry as measured by Djankov, La Porta, Lopez-de Silanes, and Shleifer (2002). These entry costs are measured in terms of their effects on the number of days, the number of legal procedures, and the relative cost (as a percentage of GDP per capita) required for an entrepreneur to start operating a business. Our indicator of pairwise trade costs is constructed by adding the importing and exporting relative cost as a percentage of GDP per capita.[13] One problem with this approach is that entry regulation costs might be correlated with the variable trade cost affected by distance; however, we follow Helpman, Melitz, and Rubinstein (2008) and add country fixed effects to the first-stage regression to show that this is not the case. Furthermore, the first-stage regression results show that our IVs are strong. Table F.2 (in Appendix 5) reports the weak identification test results from the first-stage regressions, which demonstrate the strength of our proposed instruments for each first-stage equation. The adjusted R-squared ranges from 14% to around 40%, which shows that the instruments can explain a sizable share of the variation in our endogenous variables. More importantly, the Cragg–Donald F-statistic exceeds the Stock–Yogo weak identification test critical values by substantial margins at all the conventional sizes; this, too, shows that our instruments are strong. The results are robust to alternative measures of EM and IM.

[13]The bilateral extensive margin between country i and j is computed as the sum of the extensive margins for the two countries i and j. Therefore, the entry regulation cost used as an instrument is bilateral and is computed as the sum of the entry cost for the importer and the exporter; it varies by source and destination but not over time. The same remarks apply to distance, a variable used in the empirical literature as an instrument for trade intensity.

We next run IV regressions of the output comovement on the extensive and intensive margins of trade for all measures of output. We find that the extensive margin has a positive and significant effect on GDP comovement whereas the intensive margin is statistically nonsignificant (see Table 2). The results are stronger for the BP filter. Indeed, the coefficients in this case are double those found with respect to either the HP filter or GDP growth, which indicates that the relationship between business cycle synchronization and international trade is stronger at medium-term frequencies.

There are two main reasons why IVs are required. First, we must deal with the omitted variable problem. For instance, a linked exchange rate policy between trade partners can raise both trade intensity and output correlation. Using instruments will help us identify the effect of trade patterns on output correlation. The second reason for using IVs is that trade data may be recorded with measurement error. If the intensive margin's measurement error is much larger than the extensive margin's error, then a multiple linear regression of GDP correlation on the extensive and intensive margins will result in underestimating the intensive margin's coefficient; using IVs helps correct such a bias. Measurement error in the data could also result in large standard deviations for the estimators. However, as seen in Table 2, this is not a problem in our estimation for two reasons: (i) the standard error of the coefficient for the extensive margin is small; and (ii) even though the standard error of the coefficient for the intensive margin is large relative to the point estimates, the upper bound of the resulting 95% confidence interval for the intensive margin is much lower than the extensive margin's coefficient.

Finally, we address the issue of multicollinearity between the margins of trade. The extensive and intensive margins are indeed positively correlated. But since the correlation is only about 0.43, multicollinearity should not be a concern. We also calculate the variance inflation factor (VIF) and find that it is only 1.25; traditionally, only VIFs of at least 10 are problematic.

Table 2: Output correlation and the margins of trade

HP-filtered output		Output growth		BP-filtered output	
$\text{corr}(y_i^{\text{HP}}, y_j^{\text{HP}})$	Coeff.	$\text{corr}(\Delta y_i, \Delta y_j)$	Coeff.	$\text{corr}(y_i^{\text{BP}}, y_j^{\text{BP}})$	Coeff.
$\log(\text{EM}_{ij})$	0.309***	$\log(\text{EM}_{ij})$	0.196***	$\log(\text{EM}_{ij})$	0.593***
	(0.075)		(0.053)		(0.189)
$\log(\text{IM}_{ij})$	0.031	$\log(\text{IM}_{ij})$	0.011	$\log(\text{IM}_{ij})$	0.028
	(0.035)		(0.025)		(0.091)
Constant	0.644***	Constant	0.354***	Constant	0.662***
	(0.100)		(0.072)		(0.250)

Note: Two-stage least-squares (2SLS) IV regression using log distance as the IV.
Standard errors are reported in parentheses. *** denotes statistical significance at the 1% level.

Next we study the relation between international trade and total factor productivity. Kose and Yi (2006) find that productivity shocks are more strongly correlated across countries that trade more with each other. We calculate aggregate productivity as the Solow residual in a standard Cobb–Douglas production function.

We then test whether countries that trade more with each other have more correlated aggregate productivity. Just as for the case with output data, we transform aggregate productivity in three ways (quarter-to-quarter growth rates, HP-, and BP-filtered productivity) before computing the bilateral correlations during each of the six 5-year intervals.

$$\text{corr}(T\tilde{F}P_{it}, T\tilde{F}P_{jt}) = \beta_0 + \beta_{\text{OT}} \log(\text{OT}_{ij,t}) + \varepsilon_{jm,t}. \tag{6}$$

with $T\tilde{F}P_{it}$representing real output, filtered as mentioned.The results are reported in Table 3 and are consistent with those obtained in Section 2.

Table 3: Aggregate productivity correlation and overall trade

HP-filtered productivity		Productivity growth		BP-filtered productivity	
$\text{corr}(\text{TFP}_i^{\text{HP}}, \text{TFP}_j^{\text{HP}})$	Coeff.	$\text{corr}(\Delta\text{TFP}_i, \Delta\text{TFP}_j)$	Coeff.	$\text{corr}(\text{TFP}_i^{\text{BP}}, \text{TFP}_j^{\text{BP}})$	Coeff.
$\log(\text{OT}_{ij})$	0.055***	$\log(\text{OT}_{ij})$	0.037***	$\log(\text{OT}_{ij})$	0.106***
	(0.009)		(0.006)		(0.013)
Constant	0.453***	Constant	0.308***	Constant	1.029***
	(0.042)		(0.028)		(0.058)

Note: Two-stage least-squares (2SLS) IV regression using log distance as the IV.
Standard errors are reported in parentheses. *** denotes statistical significance at the 1% level.

Finally, we investigate the contribution of the different margins of trade on productivity comovement via the following regression:

$$\text{corr}(\text{T}\tilde{\text{F}}\text{P}_{it}, \text{T}\tilde{\text{F}}\text{P}_{jt}) = \beta_0 + \beta_{\text{EM}} \log(\text{EM}_{ij,t}) + \beta_{IM} \log(\text{IM}_{ij,t}) + \varepsilon_{ij,t}. \tag{7}$$

We find that the extensive margin has a positive and statistically significant effect on the comovement of aggregate productivity but that the intensive margin has a small (negative) effect that is not significant (see Table 4).[14]

[14] Similar results on the effect of trade cost changes on the two margins of trade are obtained by Dutt, Mihov, and Van Zandt (2011) in the context of the World Trade Organization. These authors show that such changes affect the extensive margin of trade almost exclusively and have a negligible (or negative) effect on the intensive margin.

Table 4: Aggregate productivity correlation and the margins of trade

HP-filtered productivity		Productivity growth		BP-filtered productivity	
corr(TFP_i^{HP}, TFP_j^{HP})	Coeff.	corr($\Delta TFP_i, \Delta TFP_j$)	Coeff.	corr(TFP_i^{BP}, TFP_j^{BP})	Coeff.
$\log(EM_{ij})$	0.305***	$\log(EM_{ij})$	0.205***	$\log(EM_{ij})$	0.610***
	(0.076)		(0.056)		(0.119)
$\log(IM_{ij})$	–0.052	$\log(IM_{ij})$	–0.035	$\log(IM_{ij})$	–0.109*
	(0.035)		(0.027)		(0.057)
Constant	0.188*	Constant	0.131*	Constant	0.495***
	(0.099)		(0.078)		(0.160)

Note: Two-stage least-squares (2SLS) IV regression using log distance as the IV.
Standard errors are reported in parentheses. *** (*) denotes statistical significance at the 1% (10%) level.

The intensive margin of trade explains the largest part (75%) of the overall variability in trade intensity. However, the extensive margin of trade explains most of the variability in the pairwise correlation of output growth (80%) and of aggregate productivity growth (57%).[15] As a robustness check, we repeat the regressions of output growth correlation and aggregate productivity correlation on the extensive and intensive margins for various categories of the traded goods—namely, capital, intermediate goods, and nonintermediate (consumption) goods. Tables F.7.1 and F.7.2 report the results. We also performed regressions using the Harmonized System (HS) classification as an alternative to the SITC classification; see Tables F.8.1 and F.8.2. Finally, we analyzed the results for different levels of disaggregation of the trade data (3- and 5-digit codes; see Tables F.9.1 and F.9.2.). Hummels and Klenow (2005) remark that, at lower levels of disaggregation, it is expected that some variety differences will be relegated to the intensive margin of trade. Our results are broadly consistent with that intuition, showing smaller coefficients for EM at the 3-digit level than at the 5-digit level. For all the regressions described so far, coefficients for the extensive margin are both statistically and economically significant; this is in contrast to the insignificant and small coefficients found for the intensive margin.

Taken together, the empirical results reported in this section indicate that countries trading more at the extensive than at the intensive margin have more strongly correlated aggregate productivity growth and also more strongly correlated output growth. These empirical results involve the levels of the margins of trade. A greater level of extensive margin is associated with a greater output growth and aggregate productivity growth synchronization. In the next section, we extend the standard IBC model to account for both margins of trade and then show how the mechanism proposed in the extended model can amplify the effect of a productivity shock on business cycle comovement.

[15] Standard OLS regressions deliver similar results: The effect of the extensive margin is positive and statistically significant whereas the effect of the intensive margin is negative or statistically insignificant.

3 The Model

We build on the work of Ghironi and Melitz (2005) and Alessandria and Choi (2007) in developing a two-country model of heterogeneous firms that face both fixed and variable trade costs; we extend their framework to generate variations in aggregate productivity through the extensive margin of trade. Unlike the original model, in which consumers derive their utility from CES Dixit–Stiglitz preferences, our model treats preferences as a separable function of aggregate consumption and labor (thus allowing for endogenous labor supply) and introduces the CES aggregator on the producer side of the economy. In this sense, we examine the effect of imported intermediate goods on aggregate productivity rather than their effect on welfare.[16] Time is discrete and is indexed by $t = 0, 1, \ldots$. The two countries are Home and Foreign, indexed by $n = H, F$.

3.1 Production and Consumption

In each country, a firm produces a nontraded final good using domestic and foreign intermediate goods (varieties). Production involves a love of variety as in Ethier (1982), so production efficiency (i.e., aggregate productivity) increases with the number and average productivity of varieties used. In this sense, productivity is endogenous. An exogenous productivity shock provides the only source of uncertainty in the model. Each intermediate good is produced by a monopolistically competitive firm using labor and capital. The nontraded final good is then sold to households that consume, supply labor and capital, and save.

3.1.1 Intermediate Production

We extend Ghironi and Melitz (2005)'s model of intermediate production by adding capital and an endogenous labor supply, as in Alessandria and Choi (2007) and Jaef and Lopez (2014). In each country $n = H, F$, the total labor supply (L_{nt}) and total capital supply (K_{nt}) are used by a continuum of monopolistically competitive firms (henceforth, intermediate producers) to produce intermediate goods indexed by $j \in [0, N_{nt}]$, where N_{nt} represents the mass (or, alternatively, the number) of available products. Aggregate productivity is indexed by Z_{nt}; this represents the effectiveness of one unit of Home labor and follows the first-order autoregressive process

$$\log(Z_{nt}) = \rho_n \log(Z_{n,t-1}) + u_{nt}, \tag{8}$$

where $\rho_n \in (0, 1)$ and $u_{nt} \sim N(0, \sigma_u^2)$.

[16]We describe the implications of our modeling choice in Appendix 5.

Firms are heterogeneous in producing goods with different technologies indexed by relative productivity z. A domestic firm with relative productivity z has an aggregate productivity of $Z_{nt}z$. The technology of each intermediate producer is given by the Cobb–Douglas production function

$$y_{nt}(z) = zZ_{nt}k_{nt}(z)^{(1-\alpha)}l_{nt}(z)^{\alpha}, \tag{9}$$

where $\alpha \in (0,1)$ is the labor income share; here $k_{nt}(z)$ and $l_{nt}(z)$ represent, respectively, the capital input and labor input used by intermediate firm z.

Firms choose $k_{nt}(z)$ and $l_{nt}(z)$ to minimize the production cost

$$\omega_{nt}l_{nt}(z) + r^k_{nt}k_{nt}(z),$$

subject to the technology constraint (9). All variables are expressed in real terms. That i, $\omega_{nt} \equiv W_{nt}/P_{nt}$ is the real wage, where W_{nt} is country n's nominal wage and P_{nt} is the price index (to be defined later); and $r^k_{nt} = R^k_{nt}/P_{nt}$ is the real rental price of capital, where R^k_{nt} is the nominal rental price of capital.

The first-order conditions of the intermediate producers are

$$\omega_{nt} = mc_{nt}(z)\alpha\frac{y_{nt}(z)}{l_{nt}(z)}, \tag{10}$$

$$r^k_{nt} = mc_{nt}(z)(1-\alpha)\frac{y_{nt}(z)}{k_{nt}(z)}; \tag{11}$$

here $mc_{nt}(z)$ is the real marginal cost of producing one unit of an intermediate good by a firm with productivity z. The expression for $mc_t(z)$ is

$$mc_{nt}(z) = \frac{1}{zZ_{nt}}\left(\frac{\omega_{nt}}{\alpha}\right)^{\alpha}\left(\frac{r^k_{nt}}{1-\alpha}\right)^{1-\alpha}. \tag{12}$$

Note that the marginal cost for each firm is identical except for the idiosyncratic productivity z.

As in Melitz (2003), firms prior to entry are identical and must incur sunk costs (to enter the market) of f_E effective labor units, given by $\omega_{nt}f_E/Z_{nt}$ units of the final good. We view these costs as product development costs or fixed costs of innovation. Upon entry, firms draw their productivity level z from a common distribution $G(z)$ with support on $[z_{\min},\infty)$; thereafter, the relative productivity level remains fixed. All firms produce in every period until they are hit with an exogenous death shock $\delta \in (0,1)$ that is independent of the firm's productivity level.

Intermediate producers can serve both their domestic and export markets. Exporting is costly. We consider two types of trade costs: an iceberg transport cost $\tau \geq 1$ that affects mainly the intensive margin of trade; and a fixed entry cost f_X, which is measured in units of effective labor, that affects mainly the extensive margin of trade. In real terms, the fixed costs are $\omega_{nt}f_X/Z_{nt}$ and are paid period by period. For a multicountry model the fixed costs would be bilateral, and we could interpret them as entry regulation costs (Helpman, Melitz, and Rubinstein (2008)) or as the costs of adapting a product to the foreign market's specifications, establishing networks for marketing and distribution, and learning about bureaucratic and administrative procedures in the new market (Alessandria and Choi (2007)).

All firms take as given the demand by the final producer in each country $n = H, F$ and then set a price that reflects a constant markup over marginal cost. Prices may differ across countries because markets are segmented owing to the iceberg transport cost τ for products shipped to the foreign market. Let p^D_{nt} and p^X_{nt} denote, respectively, the nominal domestic and export prices of a firm in country n. Prices, in real terms (relative to the price index in the destination market), are then given by

$$\rho^D_{nt} = \frac{\theta}{\theta-1} mc_{nt}(z), \quad \text{and} \quad \rho^F_{nt} = Q_t^{-1} \frac{\theta}{\theta-1} mc_{nt}(z)\tau; \tag{13}$$

here $Q_t \equiv \frac{e_t P_t^*}{P_t}$ is the real exchange rate and $\frac{\theta}{\theta-1}$ is the constant markup (with θ to be defined shortly).

Given the fixed export costs, firms with low productivity levels z may decide not to export in any given period. Firms decompose their total profits $\pi_{nt}(z)$ into what they earn in the domestic market $\pi^D_{nt}(z)$ and from export sales $\pi^X_{nt}(z)$. The total profits in countries n at time t are thus given by

$$\pi_{nt}(z) = \pi^D_{nt}(z) + I^x_{nt}(z)\pi^X_{nt}(z) \tag{14}$$

with $I^x_{nt}(z) = 1$ if firm z exports and 0 otherwise.

In every period there is a mass N^D_{nt} of domestic firms producing in country n. Among these firms, $N^X_{nt} = (1 - G(z^X_{nt}))N^D_{nt}$ sell their product to the foreign market. A firm exports as long as its productivity remains above the cutoff level $z^X_{nt} = \inf\{z : \pi^X_{nt}(z) > 0\}$.

3.1.2 Final Production

In each country $n = H, F$, a perfectly competitive firm (henceforth, final producer) uses a composite of traded intermediate goods—both domestic and foreign—to produce a nontraded final good according to the CES production function

$$Y_{nt} = \left(\int_{z\in\Omega_t} (y_{nt}(z))^{(\theta-1)/\theta} dz \right)^{\theta/(\theta-1)}, \tag{15}$$

where Ω_t is the set of available intermediate goods (both domestic and foreign) at time t, and $\theta > 1$ is the symmetric elasticity of substitution across intermediate goods. The CES component introduces a love-of-variety effect: When expenditures $y_{nt}(z)$ are held constant, using a wider range of varieties corresponds to increased productivity (Ethier 1982).

The final producer chooses $y_{nt}(z)$ to maximize its profit:

$$\Pi_{nt} = P_{nt}Y_{nt} - \int_{z\in\Omega_t} p_{nt}(z)y_{nt}(z)\,dz; \tag{16}$$

here P_{nt} is the price index for the final good and takes the form

$$P_{nt} = \left(\int_{z\in\Omega_t} (p_{nt}(z))^{1-\theta}\,dz\right)^{1/(1-\theta)}. \tag{17}$$

Observe that the price index faced by the final producer is decreasing in the number of varieties.

The demand by the final producer of each intermediate good is

$$y_{nt}(z) = \left(\frac{p_{nt}(z)}{P_{nt}}\right)^{-\theta} Y_{nt}. \tag{18}$$

3.1.3 Households

In each country n, a representative household consumes the final good, supplies labor and capital, and saves. The household maximizes its lifetime expected utility function,

$$U_t = E_t \sum_{s=t}^{\infty} \beta^s \left(\frac{C_{ns}^{\mu}(1-L_{ns})^{1-\mu}}{1-\gamma}\right)^{1-\gamma}, \tag{19}$$

subject to the budget constraint

$$B_{nt+1} + Q_t B_{n't+1} + \frac{\eta}{2}B_{nt+1}^2 + \frac{\eta}{2}Q_t B_{n't+1}^2 + C_{nt} + I_{nt} =$$

$$= \omega_{nt}L_{nt} + r_{nt}^k K_{nt} + \Pi_{nt}^T + R_{nt}B_{nt} + Q_t R_{n't}B_{n't} + T_{nt} \tag{20}$$

for $n \neq n'$ and $n,n' = \{H,F\}$. Here C_{nt} is consumption; $\beta \in (0,1)$ is the discount factor; γ is the intertemporal elasticity of substitution; μ is the share of consumption in the household's utility; ω_{nt} is the real wage; I_{nt} is investment; Π_{nt}^T are the total profits of all firms in country n, to be defined in detail later; B_{nt+1} are holdings of home bonds and $B_{n't+1}$are holdings of foreign bonds; $\frac{\eta}{2}B_{nt+1}^2$ is the cost of adjusting holdings of home bonds and $\frac{\eta}{2}B_{n't+1}^2$ is the cost of adjusting holdings of foreign bonds (in units of foreign consumption); T_{nt} is the fee rebate, taken as given by the household and equal to $\frac{\eta}{2}B_{nt+1}^2 + \frac{\eta}{2}Q_t B_{n't+1}^2$ in equilibrium; and R_{nt} is the risk-free rate of return.

The household's decision problem is to choose consumption, labor and capital supply, and domestic and foreign bonds to maximize (19) subject to (20).

The law of motion for capital is

$$I_{nt} = K_{nt+1} - (1-\delta_k)K_t, \tag{21}$$

where $\delta_k \in (0,1)$ is the rate of depreciation of capital.

The first-order conditions of the consumers are

$$\frac{1-\mu}{\mu} C_{nt} = \omega_{nt}(1-L_{nt}); \tag{22}$$

$$\left(\frac{C_{nt}}{C_{nt+1}}\right)^{-1} \left(\frac{C_{nt}^{\mu}(1-L_{nt})^{1-\mu}}{C_{nt+1}^{\mu}(1-L_{nt+1})^{1-\mu}}\right)^{1-\gamma} = \beta(r_{nt+1}^{k} + (1-\delta_k)). \tag{23}$$

$$(1+\eta B_{nt+1})C_{nt}^{-1}\left(C_{nt}^{\mu}(1-L_{nt})^{1-\mu}\right)^{1-\gamma} = \beta C_{nt+1}^{-1}\left(C_{nt+1}^{\mu}(1-L_{nt+1})^{1-\mu}\right)^{1-\gamma} R_{nt+1}, \tag{24}$$

$$(1+\eta B_{n't+1})C_{nt}^{-1}\left(C_{nt}^{\mu}(1-L_{nt})^{1-\mu}\right)^{1-\gamma} = \beta C_{nt+1}^{-1}\left(C_{nt+1}^{\mu}(1-L_{nt+1})^{1-\mu}\right)^{1-\gamma} R_{nt+1}. \tag{25}$$

3.2 Firm Entry and Exit and the Export Decision

In every period there is an unbounded mass of prospective entrants in both countries. Entrants are forward looking and maximize profits $\pi_{nt}(z) = \pi_{nt}^{D}(z) + I_{nt}^{x}(z)\pi_{nt}^{X}(z)$. All these profits are expressed in real terms in units of the final production good:

$$\pi_{nt}^{D}(z) = \frac{1}{\theta}\left(\rho_{nt}^{D}(z)\right)^{1-\theta} Y_{nt}; \tag{26}$$

$$\pi_{nt}^{X}(z) = \begin{cases} (Q_t/\theta)\left(\rho_{nt}^{X}(z)\right)^{1-\theta} Y_{n't} - \omega_{nt} f_{Xt}/Z_{nt} & \text{if firm } z \text{ exports,} \\ 0 & \text{otherwise.} \end{cases} \tag{27}$$

Once again, $n' \neq n$.

As in Melitz (2003), we define the average productivity levels that allow us to summarize all the information on the productivity distributions that is relevant for the macroeconomic variables. Thus we write

$$\tilde{z}_D = \left[\int_{z_{\min}}^{\infty} z^{\theta-1} dG(z)\right]^{1/(\theta-1)} \tag{28}$$

and

$$\tilde{z}_{Xt} = \frac{1}{1-G(z_{Xt})}\left[\int_{z_{Xt}}^{\infty} z^{\theta-1} dG(z)\right]^{1/(\theta-1)}. \tag{29}$$

Prospective entrants in period t compute the present discounted value of their expected stream of profits:

$$\tilde{v}_{nt} = E_t \sum_{s=t+1}^{\infty} [\beta(1-\delta)]^{s-t} \tilde{d}_{ns}. \tag{30}$$

Entry occurs until the average firm value $\tilde{v}_t$ is equal to the entry cost. The free-entry condition is

$$\tilde{v}_{nt} = \frac{\omega_{nt} f_E}{Z_{nt}}. \tag{31}$$

We assume that entrants at time t do not begin producing until time $t+1$. Therefore, the number of domestically produced varieties is given by

$$N_{nt}^D = (1-\delta)(N_{n,t-1}^D + N_{n,t-1}^E), \tag{32}$$

and the total number of varieties available for final production in country n in every period t is

$$N_{nt} = N_{nt}^D + N_{nt}^X.$$

The budget constraint is now

$$B_{nt+1} + Q_t B_{n't+1} + C_{nt} + I_{nt} = \omega_{nt} L_{nt} + r_{nt}^k K_{nt} + \tilde{\Pi}_{nt}^T + R_{nt} B_{nt} + Q_t R_{n't} B_{n't}, \tag{33}$$

where $\tilde{\Pi}_{nt}^T = \left(\tilde{d}_{nt} + \tilde{v}_{nt}\right) N_{nt}^D x_{nt} - \tilde{v}_{nt} N_{nt} x_{n,t+1}$. Households in each country hold two types of assets: (i) shares in a mutual fund of domestic firms and (ii) domestic and foreign risk-free bonds. We use x_t to denote the share in the mutual fund of Home firms held by the representative home household entering period t.

3.3 Parameterization of Productivity Draws

Productivity is assumed to be Pareto distributed with lower bound $z_{\min}$ and shape parameter $k > \theta - 1$; thus, $G(z) = 1 - (z_{\min}/z)^k$. From this assumption we obtain the average domestic and export cutoffs,

$$\tilde{z}_n^D = v z_{\min} \tag{34}$$

and

$$\tilde{z}^X_{nt} = v z^X_{nt}, \tag{35}$$

where $v = \left[\frac{k}{k-(\theta-1)}\right]^{1/(\theta-1)}$. The fraction of exported intermediate goods is

$$\frac{N^X_{nt}}{N^D_{nt}} = z^k_{\min}\left(\tilde{z}^X_{nt}\right)^{-k}\left(\frac{k}{k-(\theta-1)}\right)^{k/(\theta-1)}. \tag{36}$$

Observe that, with all else held constant, the number of exported varieties is increasing in the extent of domestic entry and is decreasing in the average export cutoff value.

3.4 Aggregate Accounting and Closing the Open Economy

In equilibrium

$$B_{nt+1} + B^*_{nt+1} = 0, \tag{37}$$

$$B_{n't+1} + B^*_{n't+1} = 0. \tag{38}$$

The current account is defined as

$$CA_{nt} = B_{nt+1} - B_{nt} + Q_t(B_{n't+1} - B_{n't}). \tag{39}$$

Combining the domestic and foreign aggregate budget constraints, we have an equilibrium version of trade balance

$$CA_{nt} + Q_t CA_{n't} = 0. \tag{40}$$

An equivalent equation to the trade balance condition is

$$B_{nt+1} + Q_t B_{n't+1} =$$

$$= R_{nt}B_{nt} + Q_t R_{n't}B_{n't} + \frac{1}{2}(\omega_{nt}L_{nt} + r^k_{nt}K_{nt} - Q_t(\omega_{n't}L_{n't} + r^k_{n't}K_{n't}))+$$

$$+\frac{1}{2}(N^D_{nt}\tilde{d}_{nt} - Q_t N^D_{n't}\tilde{d}_{n't}) - \frac{1}{2}(N^E_{nt}\tilde{v}_{nt} - N^E_{n't}\tilde{v}_{n't}) - \frac{1}{2}(C_{nt} + I_{nt} - Q_t(C_{n't} + I_{n't})). \tag{41}$$

3.5 Market Clearing

The market clearing conditions for labor and capital are, respectively,

$$L_{nt} = N_{nt}^{D}\left(\frac{r_{nt}^{k}\alpha}{\omega_{nt}(1-\alpha)}\right)^{1-\alpha}\left(\left(r_{nt}^{k}\right)^{(1-\alpha)}(\omega_{nt})^{\alpha}\frac{\theta}{\theta-1}A\right)^{-\theta}Z_{nt}^{\theta-1}$$

$$\left(\left(\tilde{z}_{nt}^{D}\right)^{\theta-1}Y_{nt}+\frac{N_{nt}^{x}}{N_{nt}^{D}}\left(\tilde{z}_{nt}^{x}\right)^{\theta-1}\tau_{t}^{1-\theta}Q_{t}^{\theta}Y_{n't}\right)+N_{nt}^{E}\frac{f_{n}^{E}}{Z_{nt}}+N_{nt}^{x}\frac{f_{n}^{x}}{Z_{nt}} \tag{42}$$

$$K_{nt} = N_{nt}^{D}\left(\frac{\omega_{nt}(1-\alpha)}{r_{nt}^{k}\alpha}\right)^{\alpha}\left(\left(r_{nt}^{k}\right)^{(1-\alpha)}(\omega_{nt})^{\alpha}\frac{\theta}{\theta-1}A\right)^{-\theta}Z_{nt}^{\theta-1}$$
$$\left(\left(\tilde{z}_{nt}^{D}\right)^{\theta-1}Y_{nt}+\frac{N_{nt}^{x}}{N_{nt}^{D}}\left(\tilde{z}_{nt}^{x}\right)^{\theta-1}\tau_{t}^{1-\theta}Q_{t}^{\theta}Y_{n't}\right), \tag{43}$$

where $A \equiv \left(\frac{1}{\alpha}\right)^{\alpha}\left(\frac{1}{1-\alpha}\right)^{1-\alpha}$.

The final good in each country is used for consumption and investment,

$$Y_{nt} = C_{nt} + I_{nt}. \tag{44}$$

The demand for domestic and foreign varieties is equal to the supply:

$$\tilde{y}_{nt} = \tilde{y}_{nt}^{D} + \tilde{y}_{nt}^{X}, \tag{45}$$

where

$$\begin{aligned}\tilde{y}_{nt}^{D} &= N_{nt}^{D}\left(\tilde{\rho}_{nt}^{D}\right)^{-\theta}Y_{nt},\\ \tilde{y}_{nt}^{X} &= N_{nt}^{X}\left(\tilde{\rho}_{nt}^{X}Q_{t}\right)^{-\theta}Y_{n't}.\end{aligned}$$

Analogous equalities hold for the foreign economy.

3.6 Equilibrium

For all $n = \{H, F\}$, a general symmetric equilibrium in this economy is defined as consisting of an exogenous stochastic sequence $\{Z_{nt}\}$, an initial vector $\{Z_{n0}, N_{n0}^{D}, K_{n0}, B_{n0}\}$, a set of parameters $\{\theta, \delta, \delta_k, \alpha, \beta, z_{\min}, \tau, \mu, f_E, f_X, \eta\}$ that are common across countries, a set of parameters $\{\rho_n\}$ that differ across countries, an aggregate sequence of prices and wages $\{Q_t, P_{nt}, \omega_{nt}, r_{nt}^{k}, r_{nt}\}_{t=0}^{\infty}$, a set of prices $\{\tilde{\rho}_{nt}^{D}, \tilde{\rho}_{nt}^{X}\}_{t=0}^{\infty}$ for intermediate goods, a sequence of aggregate quantities $\{Y_{nt}, I_{nt}, B_{nt}, \tilde{y}_{nt}\}$, quantities of intermediate goods $\{\tilde{y}_{nt}^{D}, \tilde{y}_{nt}^{X}\}_{t=0}^{\infty}$, a number of intermediate goods $\{N_{n,t}^{E}, N_{nt}^{X}\}_{t=0}^{\infty}$, domestic and export cutoff values $\{\tilde{z}_n^D, \tilde{z}_{nt}^X\}_{t=0}^{\infty}$, sequences of profits and value $\{\Pi_{nt}, \tilde{d}_{nt}, \tilde{v}_{nt}\}_{t=0}^{\infty}$, and laws of motion $\{N_{nt}^D, Z_{n,t+1}\}$ such that the following conditions hold. (The model equations are given in Appendix 5.)

- The state variables satisfy the laws of motion.
- The endogenous variables solve the producer and household problems.
- Feasibility is satisfied by the market-clearing conditions.
- Prices are such that markets clear.

We focus on a stationary equilibrium that consists of stationary decision rules and pricing rules that are functions of the economy's state. This state is completely described by the distribution of each individual intermediate producer state variable (z) and of each productivity shock Z_{nt}.

3.7 The Mechanism

In this section, we explain how our model generates the endogenous comovement of aggregate productivity growth across countries. We analyze the formula for "welfare–based productivity", which is obtained as a CES aggregate of domestic and foreign intermediate goods from equation (14), to focus on the effect of the extensive margin of trade. Using the average firm variables (28) and (29), we show that aggregate productivity in our model has two components—one exogenous and one endogenous. The exogenous component is determined by the exogenous aggregate productivity shock Z_{nt}. The endogenous component depends on: (i) the number of intermediate goods used for final production, both domestic N_{nt}^D and foreign N_{nt}^X; (ii) the average productivity of each of these intermediate goods, respectively, $\tilde{z}_n^D$ and $\tilde{z}_{nt}^X$; (iii) relative prices as derived from the relative marginal cost $\frac{mc_{nt}/Z_{nt}}{mc_{n't}/Z_{n't}}$, the real exchange rate Q_t, and the iceberg transport cost τ; and (iv) the elasticity of substitution θ between domestic and foreign goods. Factors (i) and (ii) correspond to the extensive margin of trade, and (iii) corresponds to the intensive margin of trade. Factor (iv) affects both margins.[17] Thus, the average productivity, A_{nt}, in country $n, n' = \{H, F\}$ can be written as

$$A_{nt} = \left(Z_{nt}^{\theta-1} \left[N_{nt}^D \left(\tilde{z}_{nt}^D\right)^{\theta-1} + N_{n't}^x \left(\tilde{z}_{n't}^x\right)^{\theta-1} \tau^{1-\theta} \left(\frac{mc_{nt}/Z_{nt}}{mc_{n't}/Z_{n't}} \right) \right] \right) \left(\frac{L_{nt}^p}{L_{nt}} \right)^{\alpha}. \tag{46}$$

The mechanism that we propose in the model to reproduce the trade–output comovement works as follows. A positive transitory aggregate productivity shock in the Home economy (i.e., an increase in Z_{nt}) generates a demand–supply spillover effect whereby domestic final producers demand more foreign intermediate goods, increasing output in the Foreign economy. This is the channel present in

[17]See Appendix 5 for the derivation.

the standard IBC model, but we know from Kose and Yi (2006) that it alone cannot explain the trade–output comovement observed in the data. Hence, our model incorporates an additional channel that increases comovement across the trading partners. The positive aggregate shock induces entry in the domestic market because expected future profits of the potential entrants increase (i.e., the domestic economy becomes more attractive to new businesses). First, via the law of motion (32), there is an increase in $N^D_{H,t}$ that increases the domestic component of productivity in the Home economy. Second, there is an increase in the number of exported varieties of the economy experiencing this positive productivity shock, which increases the endogenous component of productivity in the Foreign economy. When we study the transitional dynamics of "welfare–based productivity", in addition to the effect of the extensive margin of trade, we need to take into account the effect of exogenous productivity shocks, Z_{nt}, on the factors of production (as in equation 46). In the transition, beyond the effect of trade in varieties on productivity (factors (i) and (ii), respectively), there is also (iii) the effect of relative prices, which in our model is influenced mainly by the ratio of marginal costs. The relative marginal cost of Home with respect to Foreign (in units of effective labor) moves in favor of the Domestic economy upon impact, but it reverses after a few quarters, which implies that Home producers end up demanding more Foreign intermediate goods and fewer Home goods (which are now more expensive). This tends to increase output in the Foreign economy and therefore increases comovement. This channel operates through the intensive margin of trade.

The international transmission effect is stronger the lower is the fixed export cost between the two countries. Low fixed export costs increase the steady-state value of "welfare–based productivity" that is explained by the extensive margin, which in turn amplifies the transition effects of a positive productivity shock. One should bear in mind that the effect of endogenous productivity on final output is both direct (through the production function) and indirect (through a higher demand for intermediate goods that amplifies the demand–supply channel present in the standard IBC model).

4 Simulation and Quantitative Analysis

In this section, we conduct a quantitative analysis to illustrate the model's mechanisms. First, we use impulse response functions to analyze how trade in varieties amplifies the effect of a positive domestic productivity shock on the output growth of the country's trading partner. In this exercise, we look at the time-series implications of the model. Second, we create a dataset with artificial pairs of countries that behave as in our model from Section 3. We allow them to differ in terms of three parameters: (i) the iceberg transport cost; (ii) the fixed cost of exports; and (iii) the elasticity of substitution between domestic and foreign goods. The steady state is symmetric within each pair of countries but asymmetric across pairs of countries, varying along with parameters (i)–(iii). We then compute the correlation of output growth, productivity growth, and average trade intensity and reproduce the regressions from Section 2 on this dataset. We thereby recover the trade–productivity and trade–output coefficients implied by our model, which are compared with the coefficients derived from the data and from the standard IBC model. The extensive margin is computed as the number of varieties traded across countries, which corresponds to our empirical analysis in Section 2 (robustness exercise in Appendix 5.).

4.1 Measurement: Data and Model

Here we discuss how we map the measure of GDP from the model to the one computed in the data. We use the previous revision of NIPA for GDP, in which R&D was not capitalized, and thus entry costs are not included in investment. Here, GDP is computed as value added (value added of final production and value of all intermediate goods that are produced by the domestic intermediate producers that sell in the domestic country and abroad (exports)). Because in our model output is produced with intermediate goods, we use the double deflation method, as in Burstein and Cravino (forthcoming), in which gross output and intermediate goods are deflated with their own deflator (that is, their own producer price index [PPI]). The expression for real GDP growth is

$$RGDP_{it} = \frac{P_{it}Y_{it}}{PPI_{it}} - \frac{\sum_{n\neq i} N_{int} x_{int} P_{it}}{PPI_{it}^{m}} + \frac{\sum_{n\neq i} N_{nit} x_{nit} P_{nt}}{PPI_{it}^{x}} \tag{47}$$

where PPI_{it} is the final goods producer's PPI, and PPI_{it}^{m} and PPI_{it}^{x} are the PPIs of imports and exports, respectively. The growth rate of real GDP is computed using a price index that is the ratio of prices in two subsequent time periods. The details on how we compute the real GDP growth rate using the price indices are explained in Appendix 5.

We now derive an expression for aggregate productivity that is consistent with the one reported by statistical agencies, which we refer to as measured aggregate productivity. This is the variable used in our empirical analysis in Section 2 and the one reported in our quantitative analysis of the model. This measure is important because some of the margins that affect "welfare–based productivity" (such as the extensive margin, as shown in Section 3.7) are not directly reflected in measured productivity. Measured productivity growth (which we call ΔTFP, to be consistent with our empirical analysis) is

$$\Delta TFP_{it} = \Delta \text{RGDP}_{it} - \alpha \Delta L_{it} - (1-\alpha)\Delta K_{it} \tag{48}$$

4.2 Simulation

We start by simulating a symmetric version of our model at a quarterly frequency. We log-linearize the system of equilibrium conditions under the unique symmetric steady state (see Ghironi and Melitz (2005)). The simulation is not a full-fledged calibration but rather a quantitative exercise meant to illustrate the main mechanisms of the model. It is designed as a reasonable benchmark, and the model's behavior is robust to small deviations from this benchmark. To the extent possible, we use steady-state restrictions to pin down parameter values; otherwise, we borrow estimates from the literature (see Table 5). The discount factor β is calibrated to 0.99, which implies an annual steady-state real interest rate of 4%. The intertemporal elasticity of consumption is calibrated to $\gamma = 2$ and the share of consumption in the utility, μ, to 0.38. The size of the exogenous death shock is set to $\delta = 0.025$, which matches the 10% of U.S. jobs destroyed annually. We set the elasticity of substitution between domestic and foreign goods, θ, to 2.8. This implies that the parameter of the Pareto distribution is $k = 2.4$. Estimates of θ in the trade and industrial organization literature range between 3 and 10, and the value differs across goods—as shown by Broda, Greenfield, and Weinstein (2006), who report lower elasticities for goods that are more differentiated. Macroeconomic studies typically find a value of 2 for this parameter. We allow θ to vary in our quantitative exercise. The depreciation rate is set to $\delta_k = 0.025$, and we set $\alpha = 0.7$. The value for the cost of adjustment in international bond holding, η, is set to a small number so that asset holdings will be stationary. Finally, we set the iceberg transport cost to $\tau = 1.5$ but allow it to vary in our experiments. The fixed costs are calibrated as in Ghironi and Melitz (2005) to match the 21% proportion of exporting plants (Bernard, Eaton, Jensen, and Kortum (2003)). This calibration implies that f_X is 23.5% of the present value of the entry cost, although we allow f_X to vary in our experiments.

The aggregate shock is calibrated as in Backus, Kydland, and Kehoe (1995) and Ghironi and Melitz (2005), while using a persistence parameter $\rho = 0.9$. We assume exogenous productivity shocks to be uncorrelated across countries, so that all the correlation in productivity growth is driven by our endogenous mechanism. We thereby establish a lower bound for trade–productivity and trade–output comovement.

Table 5: Calibrated parameters

Parameter	Value	Description
β	0.99	Discount factor
μ	0.38	Share consumption in utility
γ	2.00	Intertemporal elasticity of consumption
η	0.0025	Bond adjustment cost
δ	0.025	Death shock
δ_k	0.025	Depreciation rate
α	0.70	Share of labor in final output
θ	2.80	Elasticity of substitution
$z_{\min}$	1.00	Productivity distribution
k	$\theta - 0.4$	Pareto parameter
τ	[1.2, 1.5]	Iceberg transport cost
f_E	1.00	Fixed entry cost
f_X	[0.235, 0.5]	Fixed export cost
ρ	0.90	Persistence of productivity shock

4.3 Second Moments

In this section, we compute the second moments of trade intensity in the simulated model—as well as the extensive and intensive margins of trade— and compare these values with those characterizing the empirical data. We focus on these variables because they are the novel features of our model. Taking the United States as the exporter, we aggregate all other sample countries as the "rest of the world". We then compute the corresponding trade intensity and margins of trade for these two groups. The results are displayed in Table 6. The model does a good job of reproducing the standard deviation of the variables related to the trade flows (extensive and intensive margins of trade and trade intensity).

Table 6: Second moments

Standard deviation	Data	Model
Extensive margin	0.78	0.60
Intensive margin	1.78	2.44
Trade intensity	2.10	2.87

Finally, we compute the variance decomposition of total trade from the simulated data. Recall from Section 2 that, in the data, the extensive margin accounts for one-fourth of the trade intensity. Table 7 shows that the simulated model generates similar magnitudes.

Table 7: Decomposition of trade margins

Decomposition	Data	Model
Extensive margin	27	20
Intensive margin	73	80
Trade intensity	100	100

Our calibrated model yields reasonable predictions for the extensive and intensive margins of trade that are consistent with the data reported in Section 2. Also, we calibrate the parameters so that the steady-state import share is around 27%.

4.4 Quantitative Analysis

Our numerical experiments consist mostly of varying two parameters: the iceberg transport cost τ, which affects mainly the intensive margin of trade, and the fixed cost f_X, which affect mainly the extensive margin of trade.

4.4.1 Impulse Response Functions: A Positive Productivity Shock at Home

Here we consider a positive productivity shock at Home and then analyze its effect on Foreign's output and measured aggregate productivity for the standard IBC model and then for our model with different values of the fixed cost, f_X. We simulate the three versions so that the steady-state import share is 27%. The impulse responses to a 1% standard deviation productivity shock are shown in Figures 1–3 (the x-axis units are quarters). Figure 1: A) compares the standard IBC model (dashed line) with our extended model, which accounts for an extensive margin of trade (solid line). The figure shows that, in the extreme case of no extensive margin (the IBC model), a positive productivity shock at Home has a negative effect on the real GDP of Foreign. With an extensive margin, however, the productivity shock at Home increases output in Foreign via the international transmission channel. In Figure 1: B) we show that this effect is stronger for lower fixed costs.[18]

The details are as follows. A positive productivity shock at Home increases its final output and hence the demand for intermediate goods (both domestic and foreign), thereby increasing final output in Foreign. This is the traditional demand–supply spillover channel, which is also present in the model without fixed costs. As Figure 1: A) shows, this channel alone cannot generate the right comovement. When heterogeneous firms and fixed entry costs are introduced (solid and dashed lines in Figure 1: B)), a new channel reinforces the spillover effect: Higher final output at Home increases entry in the domestic market because the value of creating a new firm is now higher. New intermediate goods are then introduced into the Home market, increasing Home's final producers' efficiency of production via the love-of-variety effect and thus boosting final output in that country even further. The international transmission channel is at play here: Goods developed in a country are eventually exported to its trading partners. Foreign then benefits from a greater number of goods and a greater extensive margin of trade. Again, the effect is stronger when the fixed cost is lower. The reason is that lower fixed export costs translate into a higher steady-state extensive margin of trade. As a result, productivity shocks have a greater impact on the extensive margin at business cycle frequencies. For a lower steady-state extensive margin of trade productivity shocks have a greater impact on the intensive margin of trade. What the IRF analysis shows is that, if the increase in trade intensity is dominated by an increase in the extensive margin of trade (rather than by an increase in the intensive margin of trade), the comovement of output growth across pairs of countries (and also of aggregate productivity growth) will be stronger. Thus productivity shocks originating in one country propagate internationally, an effect that is amplified by the international transmission channel.

[18]The IBC model does not correspond to a particular parameterization of our model, since the two are not nested. We specify the IBC model as the standard RBC model (Kose and Yi (2006)) without an extensive margin of trade and then calibrate the trade parameters so that the steady-state import share in all cases is 27%. It would be a version of our model, where the decisions of entry are eliminated.

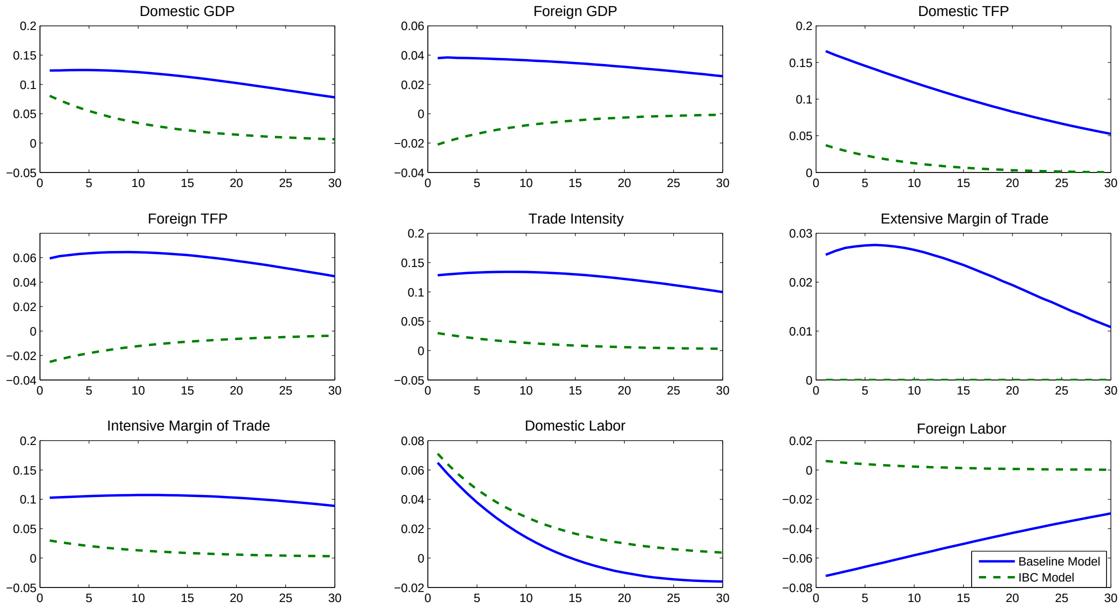

Figure 1: A) Impulse Response Function to Domestic Productivity Shock (IBC vs Baseline models)

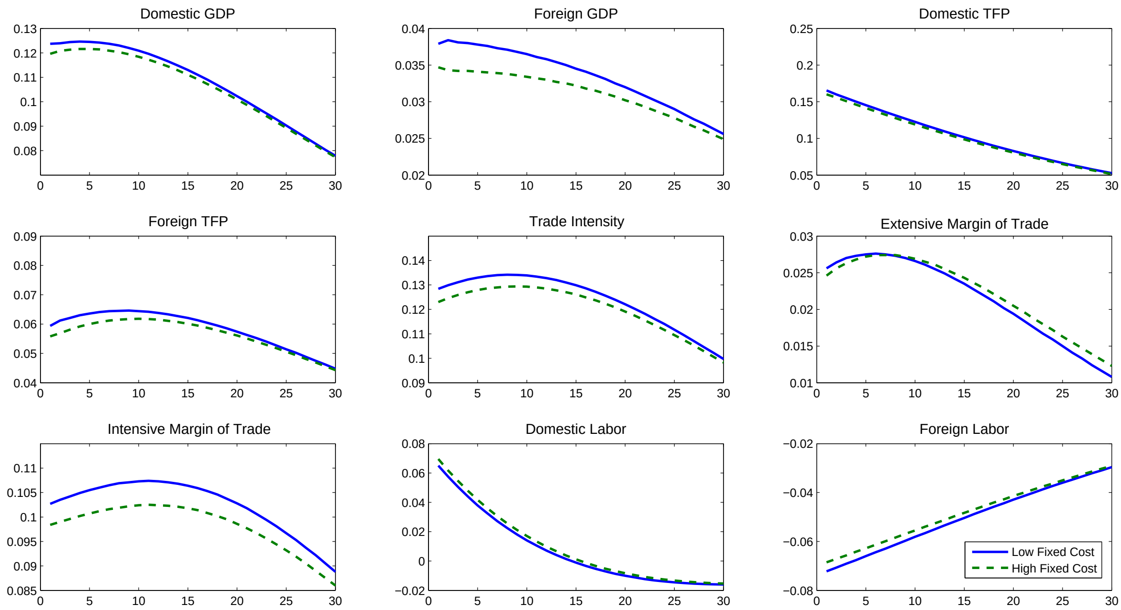

Figure 1: B) Impulse Response Function to Domestic Productivity Shock (varying f_x)

Figure 2 shows the effect of a positive productivity shock at Home on the same variables as in Figure 1: B) but for different values of the iceberg transport cost. The results show that the amplification effect of our proposed mechanism is higher for lower transport costs. We can thus generate variations in the extensive margin of trade through changes in both variable and fixed costs.

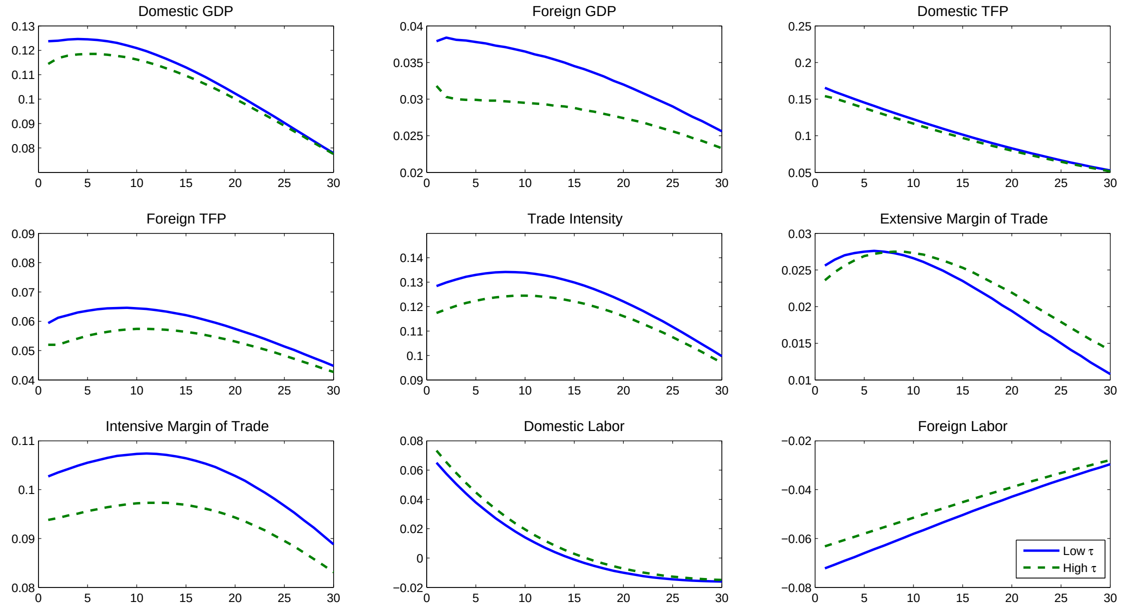

Figure 2: Impulse Response Function to Domestic Productivity Shock (varying τ)

Because we are considering a transitory (albeit persistent) productivity shock, all the variables eventually return to their steady-state values. The effect of the productivity shock is more persistent for lower fixed costs of exports. The reason is that the increase in the expected present discounted value of future profits is then stronger, which amplifies the effect of the extensive margin, as mentioned in Section 3.7.

4.4.2 The Trade–Output and Trade–Productivity Coefficients

Here we simulate the model for artificial pairs of countries with varied iceberg transport costs, fixed costs of export, and elasticity of substitution between domestic and foreign goods. First, we suppose each country encounters a transitory productivity shock that is uncorrelated across countries. Next, we compute the correlations among output growth, productivity growth, and average trade intensity; we then repeat the regressions performed in Section 2 for each value of the elasticity of substitution θ. We shall report our results for 2.8. Our aim is to generate substantial variation in the extensive and intensive margins of trade by varying the model's relevant parameters. The extensive margin is defined as the sum of exported and imported varieties, which is consistent with the measure used in our empirical estimation when examining count data. We compare the results from our model with those based on the standard IBC model. In our simulated data, the fraction of exporters varies between 2.3% and 53% while the extensive margin of trade explains from 20% to 40% of the variability of trade intensity; these values are consistent with what we find in the sample data. The fixed export costs vary between 15% (as in Ghironi and Melitz (2005) and 50%, and the iceberg transport costs vary between 1.5 and 1.7. With this calibration, we obtain an import share between 10% and 30%, as it is consistent with the data. This procedure implies that the steady state is symmetric within each pair of countries, whereas asymmetries arise across pairs of countries in response to variations in the fixed and variable trade costs and in the elasticity of substitution between domestic and foreign goods; that is, we allow each pair of countries to vary in terms of fixed and iceberg transport costs while holding constant the elasticity of substitution. These results establish a lower bound for the empirical coefficient, given that we have assumed throughout the analysis that productivity shocks are uncorrelated across countries.

The standard IBC model does not explicitly address the extensive margin of trade. Yet because this margin (as demonstrated in Section 2) accounts for most of the trade–output comovement in the data, that model fails to capture the quantitative effect of international trade on the synchronization of business cycles. In contrast, by explicitly modeling the extensive margin of trade, we are able to explain a significant part of this coefficient. Our model yields a trade–output coefficient of 0.040 and a trade–productivity coefficient of 0.030 when GDP is measured as the production of the final good and deflated using the welfare-based price index, which captures the effect of fluctuations in the extensive marginb of trade. In contrast to the IBC model, which predicts a negative coefficient, our model with an extensive margin of trade improves the standard results both qualitatively and quantitatively. In the data, these values are 0.067 and 0.036. Finally, and to be consistent with the mesures used by the statistical agencies, we derive the same coefficients using the measured real GDP growth and measured aggregate productivity growth, deflated with the double deflator method described in Section 4.1. The trade–output and trade–productivity coefficients are lower than when the welfare–based price index is used, albeit positive. In this case, the extensive margin of trade plays a lower role in increasing measured productivity, hence the lower effect. Therefore, our model improves significantly the standard IBC model that predicts a negative coefficient, even when we use the double deflator method to compute the real GDP growth. This simple quantitative exercise illustrates how a model that introduces variations in both the extensive and intensive margins of trade can help us explain the correlation between international trade and the comovement of business cycles, and it represents an improvement over the standard IBC model.[19]

Table 8: Implied trade–output and trade–productivity comovement coefficient

f_x	Trade–output coefficient	Trade–Productivity coefficient
Model (welfare-based)	0.040^{**}	0.030^{**}
Model (measured)	0.012^{**}	0.008^{**}
IBC	< 0	< 0
Data	**0.0670**	**0.036**

Note: (**) indicates statistical significance at the 5% level

4.4.3 "Welfare–based" Versus "Measured" Variables

Finally, in order to understand what drives the differences between the second and third rows of Table 8, we perform two numerical exercises and compare the effect of international trade on; (i) the

[19]In another paper, we are working on a full-fledged calibration of a multicountry model with the same features of our current model.

comovement of real output growth deflated with the welfare-based price index, and (ii) the measured real ouput growth deflated as in the statistical agencies (see Appendix 5 for the details).

First, we perform impulse response functions to look at the response of both measures of real GDP growth to a positive domestic productivity shock. Then, we generate a table with the implied trade–output coefficients for both measures of real output growth and for different values of the elasticity of substitution and the fixed costs of exports.

The impulse response analysis is done for a fixed cost of $f_x = 0.25$, as in our baseline calibration. The results are displayed in Figure 3. We show that a positive domestic productivity shock increases both domestic and foreign real output when the elasticity of substitution is sufficiently low, i.e around $\theta = 2.8$ or $\theta = 2.9$. The increase in foreign output is larger when output is deflated using the welfare-based price index rather than the method that is consistent with statistical agencies. These differences between the two measures are more pronounced for higher values of the elasticity of substitution. When $\theta > 3.1$, the welfare-based real output in the foreign economy increases (although much less than for lower values), but measured output decreases upon impact. These results suggest that the positive correlation between domestic and foreign real output growth may become negative for higher values of the elasticity of substitution when we use the measure reported by the statistical agencies. However, values of the elasticity of substitution in the range [2,3] can generate positive correlations even when using the proper deflator. Those values are also consistent with estimates of the elasticity of substitution found in the empirical literature.

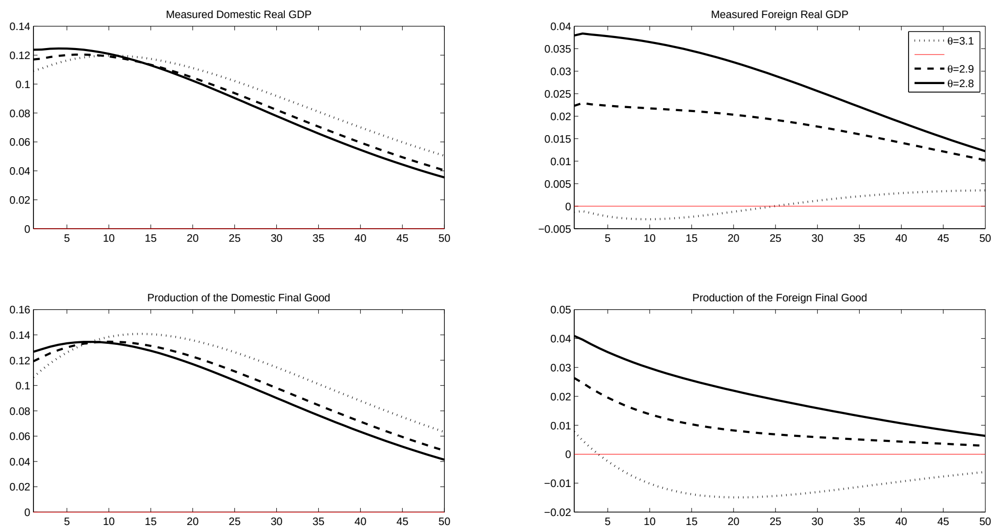

Figure 3: Impulse responses to a positive domestic productivity shock

Next, we compute the increase in the real output growth correlation when the iceberg transport cost decreases from $\tau = 1.9$ to $\tau = 1.5$. We do this for two values of the elasticity of substitution ($\theta = 2.8$ and $\theta = 3.1$) and two values of the fixed costs of exports ($f_x = 0.25$ and $f_x = 0.35$).

	$\theta = 2.8$		$\theta = 3.1$	
	$f_x = 0.25$	$f_x = 0.35$	$f_x = 0.25$	$f_x = 0.35$
Real GDP growth (welfare–based)	0.0791	0.0746	0.0856	0.0780
Real GDP growth (measured)	0.0237	0.0195	-0.0395	-0.0380

Table 9: Change in output correlation

Consistent with the impulse response analysis, the results in Table 9 show that the increase is always higher for the welfare-based measure of real GDP growth than for the statistical measure. The correlation increase is larger for lower values of the elasticity of substitution and lower fixed cost of exports. These differences are mainly driven by the extensive margin of trade. Interestingly the coefficient becomes negative when $\theta > 3.1$, which is also consistent with the impulse response functions.

Table 10 shows the implied Frankel and Rose coefficients, computed as the ratio of the increase in output correlation (i.e., the numbers in Table 9) to the increase in the trade intensity that results from the decrease in the iceberg transport cost. The results are consistent with those in Table 9.

	$\theta = 2.8$		$\theta = 3.1$	
	$f_x = 0.25$	$f_x = 0.35$	$f_x = 0.25$	$f_x = 0.35$
Real GDP growth (welfare–based)	0.0484	0.0376	0.0191	0.0168
Real GDP growth (measured)	0.0145	0.0098	-0.0018	-0.0019

Table 10: Frankel and Rose Coefficients

These results suggest that the mechanism proposed in our model improves the results of the standard IBC model, especially for lower values of the elasticity of substitution between intermediate goods, even when we consider properly deflated real output growth and aggregate productivity. For higher values of the elasticity of substuitution, this is no longer the case, since some of the margins that affect "welfare–based productivity" (such as the extensive margin, as shown in Section 3.7) are not directly reflected in measured productivity.

5 Conclusion

We show that fluctuations in the number of varieties embedded in trade flows may help explain the so-called trade comovement puzzle. Countries that trade more at the extensive margin have more correlated aggregate productivity growth and, in turn, more strongly correlated output growth. Standard models, which do not account for the extensive margin of trade, miss an important channel through which international trade may drive business cycle synchronization. We use previous empirical findings to develop a two-country model with productivity shocks, heterogeneous firms, and fixed costs. We then show, for reasonable parameter values, that our proposed mechanism improves substantially the standard IBC results and more nearly approaches the trade–output coefficient reported in empirical studies. This is a significant improvement over the standard IBC model, which predicts a practically negligible effect of trade on output comovement.

Our empirical results focus on levels of the extensive margin: Countries that trade a wider set of varieties have more strongly correlated business cycles. Our model better replicates the empirical findings because higher steady-state levels of that margin (which correspond to higher levels of extensive margin in our empirical analysis) amplify the effect of productivity shocks on the comovement of output and productivity growth. We show empirically that this is the case in our data: Pairs of countries that trade more varieties (higher extensive margin) exhibit greater variability in that margin.

This analysis has abstracted from a number of important issues. These include the calibration of a full-blown model (for a sample of OECD and emerging countries) to data on R&D, productivity, and trade in varieties. Such a calibration would enable us to disentangle the effect of three different mechanisms proposed in the literature: vertical linkages, elasticity of substitution between domestic and foreign goods, and technological diffusion. Doing so would require building a multicountry general equilibrium model and obtaining measures for the margins of trade that correspond exactly to those used in the empirical analysis. We leave these issues for future research.

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Appendix A: Model Equations

In this appendix, we list the equations that define the symmetric equilibrium described in Section 3.6.

The endogenous variables in this model are (for the domestic country and the real exchange rate)

$$\left\{N^D_{nt}, \tilde{\rho}^D_{nt}, N^x_{nt}, \tilde{\rho}^x_{nt}, \tilde{d}_{nt}, \tilde{v}_{nt}, \tilde{d}^x_{nt}, \tilde{d}^D_{nt}, \tilde{z}^x_{nt}, N^E_{nt}, C_{nt}, B_{nt}, B_{n't}, I_{nt}, R_{nt}, r^k_{nt}, \omega_{nt}, L_{nt}, K_{nt}, Y_{nt}, Q_t\right\}.$$

Here, we give the expressions for the domestic country; analogous expressions apply to the foreign economy.

1. Price index:

$$1 = N^D_{nt}\left(\tilde{\rho}^D_{nt}\right)^{1-\theta} + N^x_{n't}\left(\tilde{\rho}^x_{n't}\right)^{1-\theta}.$$

2. Profits:

$$\tilde{d}_{nt} = \tilde{d}^D_{nt} + \frac{N^x_{nt}}{N^D_{nt}}\tilde{d}^x_{nt}.$$

3. Free entry:

$$\tilde{v}_t = \omega_{nt}\frac{f_E}{Z_{nt}}.$$

4. Zero profit export cut-off:
$$\tilde{d}^x_{nt} = \omega_{nt}\frac{f_X}{Z_{nt}}\frac{\theta-1}{k-(\theta-1)}.$$

5. Share of exporting firms:

$$\frac{N^x_{nt}}{N^D_{nt}} = z^k_{min}(z^x_{nt})^{-k}\left[\frac{k}{k-(\theta-1)}\right]^{\frac{k}{\theta-1}}.$$

6. Number of firms:
$$N^D_{nt} = (1-\delta)(N^D_{nt-1}+N^E_{nt-1}).$$

7. Euler equations (shares):

$$\tilde{v}_t = \beta(1-\delta)\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}(\tilde{v}_{t+1}+\tilde{d}_{t+1})\right].$$

8. Euler equation (Home bonds):

$$C^{-\gamma}_{nt}(1+\eta B_{nt+1}) = \beta R_{nt+1}C^{-\gamma}_{nt+1}.$$

9. Euler equation (Foreign bonds):

$$C^{-\gamma}_{nt}(1+\eta B_{n't+1}) = \beta R_{n't+1}\left(\frac{Q_{t+1}}{Q_t}\right)C^{-\gamma}_{nt+1}.$$

10. Bond market clearing:
$$B_{nt+1}+B^*_{nt+1} = 0.$$

11. Capital market clearing:
$$K_{nt} =$$
$$= N^D_{nt}\left(\frac{\omega_{nt}(1-\alpha)}{r^k_{nt}\alpha}\right)^{\alpha}\left(\left(r^k_{nt}\right)^{(1-\alpha)}(\omega_{nt})^{\alpha}\frac{\theta}{\theta-1}A\right)^{-\theta}Z^{\theta-1}_{nt}\left(\left(\tilde{z}^D_{nt}\right)^{\theta-1}Y_{nt}+\frac{N^x_{nt}}{N^D_{nt}}(\tilde{z}^x_{nt})^{\theta-1}\tau_t^{1-\theta}Q^{\theta}_tY_{n't}\right).$$

12. Labor market clearing:
$$L_{nt} =$$
$$= N^D_{nt}\left(\frac{r^k_{nt}\alpha}{\omega_{nt}(1-\alpha)}\right)^{1-\alpha}\left(\left(r^k_{nt}\right)^{(1-\alpha)}(\omega_{nt})^{\alpha}\frac{\theta}{\theta-1}A\right)^{-\theta}Z^{\theta-1}_{nt}\left(\left(\tilde{z}^D_{nt}\right)^{\theta-1}Y_{nt}+\frac{N^x_{nt}}{N^D_{nt}}(\tilde{z}^x_{nt})^{\theta-1}\tau_t^{1-\theta}Q^{\theta}_tY_{n't}\right)+$$
$$+N^E_{nt}\frac{f^E_n}{Z_{nt}}+N^x_{nt}\frac{f^x_n}{Z_{nt}}.$$

13. Closing the open economy:

$$B_{nt+1} + Q_t B_{n't+1} = R_{nt} B_{nt} + Q_t R_{n't} B_{n't} + \frac{1}{2}(\omega_{nt} L_{nt} + r^k_{nt} K_{nt} - Q_t(\omega_{n't} L_{n't} + r^k_{n't} K_{n't})) +$$

$$+ \frac{1}{2}(N^D_{nt} \tilde{d}_{nt} - Q_t N^D_{n't} \tilde{d}_{n't}) - \frac{1}{2}(N^E_{nt} \tilde{v}_{nt} - N^E_{n't} \tilde{v}_{n't}) - \frac{1}{2}(C_{nt} + I_{nt} - Q_t(C_{n't} + I_{n't})).$$

14. Law of motion for capital:

$$I_{nt} = K_{nt+1} - (1 - \delta_k) K_{nt}.$$

15. Final good clearing condition:

$$Y_{nt} = C_{nt} + I_{nt}.$$

16. Domestic profits:

$$\tilde{d}^D_{nt} = \frac{1}{\theta} \left(\tilde{\rho}^D_{nt}\right)^{1-\theta} Y_{nt}.$$

17. Domestic prices of intermediate goods:

$$\tilde{\rho}^D_{nt} = \frac{\theta}{\theta - 1} \left(\frac{\omega_{nt}}{\alpha}\right)^{\alpha} \left(\frac{r^k_{nt}}{1 - \alpha}\right)^{1-\alpha} \frac{1}{\tilde{z}^D_n Z_{nt}}.$$

18. First order condition for labor-consumption

$$L^{\psi}_{nt} = \omega_{nt} C^{-\gamma}_{nt}.$$

19. Prices of foreign goods:

$$\tilde{\rho}^x_{nt} = \tau_t Q_t^{-1} \tilde{\rho}^D_{nt}.$$

20. First order condition for capital:

$$\left(\frac{C_{nt}}{C_{nt+1}}\right)^{-\gamma} = \beta(r^k_{nt+1} + (1 - \delta_k)).$$

21. Profits of exporters:

$$\tilde{d}^x_{nt} = \frac{Q_t}{\theta} \left(\tilde{\rho}^x_{nt}\right)^{1-\theta} Y_{n't} - \omega_{nt} \frac{f_X}{Z_{nt}}.$$

22. Shock process:

$$\log(Z_{nt}) = \rho_n \log(Z_{n,t-1}) + u_{nt}.$$

Appendix B: Dixit–Stiglitz Preferences Versus the Ethier Production Function

We consider two different preference structures that yield different predictions regarding the effects of imported varieties. First, we assume Dixit–Stiglitz preferences; this enables predictions about the effect of imported varieties in terms of welfare. Second, we consider a CES final production a la Ethier, which yields predictions in terms of total factor productivity.

Consumers with Dixit–Stiglitz preferences derive utility from the domestic and foreign intermediate goods that they aggregate according to a CES utility function. The economy features firms that produce for the domestic market and firms that produce for export markets. Firms differ in their productivity and use labor according to a production function with constant returns to scale. GDP in this economy is the sum of the production of firms selling to the domestic market and that of firms selling to the foreign market:

$$GDP_t = N_t^d y_t^d + N_t^x y_t^x; \tag{49}$$

here $N_t^d$and N_t^x are the number of firms selling in the domestic and export markets, respectively, and y_t^d and y_t^x are the average sales of the respective firms. From the CES utility function, we obtain

$$y_t^d = \left(\frac{p_t^d}{P_t}\right)^{\theta-1} P_t C_t,$$

$$y_t^x = \left(\frac{p_t^x \tau}{P_t^*}\right)^{\theta-1} P_t^* C_t^*.$$

From the budget constraint it follows that

$$C_t + I_t = \omega_t L_t + r_t^k K_t = mc_t Y_t,$$

and the "expenditure approach" definition of GDP yields

$$GDP_t = Y_t + X_t - M_t.$$

Trade balance in this economy implies that

$$GDP_t = Y_t.$$

Now we need a measure of aggregate productivity:

$$log(TFP_t) = log(Y_t) - \alpha log(L_t) - (1-\alpha) log(K_t).$$

In this economy, then, aggregate productivity corresponds to the real marginal cost. Now we can combine the definition of GDP with the demand for domestic and intermediate goods:

$$GDP_t = N_t^d \left(\frac{p_t^d}{P_t}\right)^{-(\theta-1)} P_t Y_t + N_t^x \left(\frac{p_t^x \tau}{P_t^*}\right)^{-(\theta-1)} P_t^* Y_t^*,$$

$$GDP_t = N_t^d \left(\frac{mc_t}{z_t^d Z_t}\right)^{-(\theta-1)} P_t Y_t + N_t^x \left(\frac{mc_t \tau}{z_t^x Z_t P_t^*/P_t}\right)^{-(\theta-1)} P_t^* Y_t^*,$$

$$GDP_t = P_t Y_t \left(N_t^d \left(\frac{mc_t}{z_t^d Z_t}\right)^{-(\theta-1)} + N_t^x \left(\frac{mc_t \tau Q_t}{z_t^x Z_t}\right)^{-(\theta-1)} \frac{P_t^* Y_t^*}{P_t Y_t}\right).$$

where $Q_t = P_t/P_t^*$. Since $GDP_t = P_t Y_t$, it follows that

$$1 = \left(N_t^d \left(\frac{mc_t}{z_t^d Z_t}\right)^{-(\theta-1)} + N_t^x \left(\frac{mc\omega\tau Q_t}{z_t^x Z_t}\right)^{-(\theta-1)} \frac{P_t^* Y_t^*}{P_t Y_t}\right).$$

If we move the term for wages to outside the parentheses, then rearranging yields the following sequence:

$$1 = \left(N_t^d \left(z_t^d Z_t\right)^{\theta-1} + N_t^x \left(z_t^x Z_t\right)^{\theta-1} \frac{P_t^* Y_t^*}{P_t Y_t}\right) \omega_t^{1-\theta},$$

$$mc_t^{\theta-1} = \left(N_t^d \left(z_t^d Z_t\right)^{\theta-1} + N_t^x \left(z_t^x Z_t\right)^{\theta-1} \frac{P_t^* Y_t^*}{P_t Y_t}\right),$$

$$mc_t = TFP_t = \left(N_t^d \left(z_t^d Z_t\right)^{\theta-1} + N_t^x \left(z_t^x Z_t\right)^{\theta-1} \frac{P_t^* Y_t^*}{P_t Y_t}\right)^{1/(\theta-1)}.$$

The aggregate productivity in this economy is an average of the productivity of the domestic producers and the productivity of the exporters, and the efficiency of imports has implications only in terms of welfare.

With an Ethier production function, consumers derive utility from a final output that is produced by aggregating domestic and foreign intermediate goods according to a CES production function. Once again, labor is the only factor of production. Thus, we have

$$Y_t = \left(N_t^d \left(y_t^d\right)^{(\theta-1)/\theta} + N_t^m \left(y_t^m\right)^{(\theta-1)/\theta}\right)^{\theta/(\theta-1)}.$$

From the market clearing of final goods it follows that

$$Y_{nt} = C_{nt} + I_{nt}.$$

If we use the expenditure approach to define GDP, then

$$GDP_{nt} = C_{nt} + I_{nt} + X_{nt} - M_{nt}.$$

When the two preceding expressions are combined, the results is

$$GDP_{nt} = Y_{nt} + X_{nt} - M_{nt}.$$

If we use the output approach to define GDP, then

$$GDP_{nt} = N^D_{nt} y^D_{nt} + N^x_{nt} y^x_{nt} = N^D_{nt} y^D_{nt} + X_{nt}.$$

The expression for the expenditures of the final producers allows us to derive

$$Y_{nt} = N^D_{nt} y^D_{nt} + N^D_{n't} y^D_{n't} = N^D_{nt} y^D_{nt} + M_{nt}.$$

Given both the domestic and foreign demand for intermediate goods, we have

$$1 = N^D_{nt} (\rho^D_{nt}(\tilde{z}^D_{nt}))^{1-\theta} + N^x_{n't} (\rho^x_{nt}(\tilde{z}^x_{n't}))^{1-\theta}.$$

Now, using the expressions for prices of intermediate goods, we obtain

$$1 = \left[\left(\frac{\omega_{nt}}{\alpha}\right)^{\alpha} \left(\frac{r^k_{nt}}{1-\alpha}\right)^{1-\alpha} \right]^{1-\theta} \left(\frac{\theta}{\theta-1}\right)^{1-\theta} \tag{50}$$

and so

$$Z^{\theta-1}_{nt} \left[N^D_{nt} \left(\tilde{z}^D_{nt}\right)^{\theta-1} + N^x_{n't} \left(\tilde{z}^x_{n'x}\right)^{\theta-1} \tau_t^{1-\theta} Q_t^{\theta-1} \left(\frac{\omega_{n't}}{\omega_{nt}}\right)^{\alpha} \left(\frac{r^k_{n't}}{r^k_{nt}}\right)^{1-\alpha} \right]$$

Next we need an expression for aggregate productivity in this economy. The idea is for the economy's total production to be given by the total production of intermediate goods. That total production is a Cobb–Douglas function of capital and labor; from which we can derive both GDP and aggregate productivity. GDP reflects the production of intermediate goods, not the production of the final good; hence, we can use the income approach to derive the following expression for GDP:

$$GDP_{nt} = \omega_{nt} L_{nt} + r^k_{nt} K_{nt} = mc_{nt} Y_{nt}.$$

From this equality it follows that

$$TFP_{nt} = \left(\frac{\theta}{\theta-1}\right) \left(\frac{\omega_{nt}}{\alpha}\right)^{\alpha} \left(\frac{r^k_{nt}}{1-\alpha}\right)^{1-\alpha}.$$

Equation(50) and the previous expression yield

$$TFP_{nt} =$$

$$= \left(Z_{nt}^{\theta-1} \left[N_{nt}^{D} \left(\tilde{z}_{nt}^{D} \right)^{\theta-1} + N_{n't}^{x} \left(\tilde{z}_{n'x}^{x} \right)^{\theta-1} \tau_t^{1-\theta} Q_t^{\theta-1} \left(\frac{\omega_{n't}}{\omega_{nt}} \right)^{\alpha} \left(\frac{r_{n't}^{k}}{r_{nt}^{k}} \right)^{1-\alpha} \right] \right)^{\frac{1}{\theta-1}} . \tag{51}$$

We can summarize our claims as follows. With Dixit–Stiglitz preferences, the effect of imported varieties is on welfare, and aggregate productivity depends on the productivity of domestic and exporters. With an Ethier production function, the effect of importers is on productivity.

Appendix C: Computing Real GDP using the Double Deflation Method

We follow Burstein and Cravino (forthcoming) to derive an expression for the real GDP that is consistent with the one measured in the statistical agencies. Real GDP is computed as the real value added created in a country:

$$RGDP_{it} = RealVA_{it} =$$

$$\left[\text{Gross Production}/PPI_{it} - \text{Int. Goods (domestic)}/PPI_{it}^{d} - \text{Int. Goods (imports)}/PPI_{it}^{m} \right] +$$

$$+ \left[\text{Int. Goods (domestic)}/PPI_{it}^{d} + \text{Int. Goods (exports)}/PPI_{it}^{x} \right],$$

with PPI_{it}, PPI_{it}^{d}, PPI_{it}^{x} and PPI_{it}^{m} denoting the producer price index of final producers, domestic intermediate producers selling in the domestic and export markets, and foreign intermediate producers importing goods. Canceling terms becomes

$$RGDP_{it} = \text{Gross Production}/PPI_{it} -$$

$$-\text{Int. Goods (imports)}/PPI_{it}^{m} + \text{Int. Goods (exports)}/PPI_{it}^{x}$$

Now, using the notation of our model,

$$RGDP_{it} = \frac{P_{it}Y_{it}}{PPI_{it}} - \frac{\sum_{n \neq i} N_{int} P_{int} X_{int}}{PPI_{it}^{m}} + \frac{\sum_{n \neq i} N_{nit} P_{nit} X_{nit}}{PPI_{it}^{x}}$$

We follow the procedure of the BEA to define a price deflator between two periods as a weighted chained price. In the context of our model, we define

$$\frac{PPI_{it}}{PPI_{i,t-1}} = \frac{N_{i0}^{d} p_{i0}^{d}(\tilde{z}_i^{d}) q_{i0}^{d}(\tilde{z}_i^{d})}{Y_{i0}} \frac{p_{it}^{d}(\tilde{z}_i^{d})}{p_{i,t-1}^{d}(\tilde{z}_i^{d})} + \frac{N_{i'0}^{x} p_{i'0}^{x}(\tilde{z}_{i'}^{x}) q_{i'0}^{x}(\tilde{z}_{i'}^{x})}{Y_{i0}} \frac{p_{i't}^{x}(\tilde{z}_{i'}^{x})}{p_{i',t-1}^{x}(\tilde{z}_{i'}^{x})}$$

, where the first term of the summation in the right hand side corresponds to the price of the domestic intermediate goods that are sold in the domestic market and the second term corresponds to the price of the imported intermediate goods from country i' (which in our two country world is equal to the exports of country i'). We follow the notation from Ghironi and Melitz (2005).

This expression is derived after assuming a Pareto distribution for the productivity of the intermediate producers. In that case, we can express everything as a function of an average firm producing with an average productivity $\tilde{z}$. In other words,

$$\int_{j=0}^{N_{nt}} p_{njt} q_{njt} dj = N_{nt} p_{nt}(\tilde{z}) q_{nt}(\tilde{z})$$

with N_{nt} the number of intermediate producers in country n, $p_{nt}(\tilde{z})$ the price of the average intermediate producer $\tilde{z}$ (all prices are expressed relative to the price of the final good producer, P_{nt}), and $q_{nt}(\tilde{z})$ the supply of each intermediate producer $\tilde{z}$. Hereafter, prices and quantities are derived for the average firm with productivity $\tilde{z}$. To simplify notation, we do not express every variable as a function of the average productivity $\tilde{z}$. We consider $t = 0$ to be the steady-state of the economy. Therefore, the expression for the price deflator above becomes

$$\frac{PPI_{it}}{PPI_{i,t-1}} = \frac{N_{i0}^d p_{it}^d q_{i0}^d}{Y_{i0}} \frac{p_{it}^d}{p_{i,t-1}^d} + \frac{N_{i'0}^x p_{i'0}^x q_{i'0}^x}{Y_{i0}} \frac{p_{i't}^x}{p_{i',t-1}^x}$$

and the rest of expressions are expressed in a similar way:

$$\frac{PPI_{it}^x}{PPI_{it-1}^x} = \frac{p_{it}^x}{p_{i,t-1}^x}$$

$$\frac{PPI_{it}^m}{PPI_{it-1}^m} = \frac{p_{i't}^x}{p_{i',t-1}^x}$$

We can use these price deflators to compute the real GDP by taking a first order Taylor expansion of the real GDP deflated with the double deflator method

$$RGDP_{it} = \frac{P_{it} Y_{it}}{PPI_{it}} + \frac{X_{it}}{PPI_{it}^x} - \frac{M_{it}}{PPI_{it}^m}$$

To calculate the growth rate of the real GDP of the economy, we compute the first order approximation using the following formulation. Consider the expression

$$y_t = f(x_t)$$

A first order Taylor expansion is computed as

$$\bar{Y} \hat{y}_t = f'(\bar{X}) \bar{X} \hat{x}_t$$

with $\bar{Y}$ and $\bar{X}$ the steady state value of y_t and x_t and $\hat{y}_t = log\left(\frac{y_t}{\bar{Y}}\right)$ the log-linear deviation of y_t with respect to its steady-state value.

We use the first order conditions for the demand of intermediate goods to understand how the elasticity of substitution θ and the number of intermediate goods N has an effect on the formula for GDP. From the model,

$$\frac{N_{it}^d p_{it}^d q_{it}^d}{Y_{it}} = N_{it}^d \left(p_{it}^d\right)^{1-\theta}.$$

Therefore, using the general formula for the first-order Taylor expansion for $A_{it} = \frac{N_{i0}^d p_{i0}^d q_{i0}^d}{Y_{i0}} \frac{p_{it}^d}{p_{i,t-1}^d}$, we obtain

$$\hat{a}_{it} = \frac{\bar{N}^d \bar{p}^d \bar{q}^d}{\bar{Y}}(\hat{p}_{it}^d - \hat{p}_{it-1}^d).$$

Note: In steady state there is no growth and therefore $\bar{p}_{it} = \bar{p}_{i,t-1} = \bar{p}_i$.

The chained method is used to compute the growth rate of GDP. We loglinearize the following expression

$$RGDP_{it} = \frac{P_{it} Y_{it}}{PPI_{it}} + \frac{X_{it}}{PPI_{it}^x} - \frac{M_{it}}{PPI_{it}^m},$$

with $X_{it} = N_{it}^x p_{it}^x q_{it}^x$ and $M_{it} = N_{i't}^x p_{i't}^x q_{i't}^x$.

In steady state $\bar{X}_i = \bar{M}_i = N^x p^x q^x$ and $P\bar{P}I_i^m = P\bar{P}I_i^x$. Then, $R\bar{G}DP_i = \frac{\bar{Y}_i}{P\bar{P}I_i/\bar{P}_i}$. From now on we express the steady state variables in capital letters and without a time-subscript or a country)subscript since all countries are symmetric in steady-state. We express every price and price deflator relative to the price index P_{it}.

We obtain

$$R\bar{G}DP * dlog(RGDP_{it}) = \frac{\bar{Y}_i}{P\bar{P}I_i/\bar{P}_i} * (dlogY_{it} - dlogPPI_{it}) +$$

$$+\frac{\bar{X}_i}{P\bar{P}I_i^x} * (dlogX_{it} - dlogPPI_{it}^x) - \frac{\bar{M}_i}{P\bar{P}I_i^m} * (dlogM_{it} - dlogPPI_{it}^m)$$

and using the steady-state relationship, we obtain:

$$dlog(RGDP_{it}) = (dlogY_{it} - dlogPPI_{it}) + \frac{N^x p^x q^x}{Y} \frac{PPI}{PPI^x}(dlogX_{it} - dlogPPI_{it}^x) -$$

$$-\frac{N^x p^x q^x}{Y} \frac{PPI}{PPI^m}(dlogM_{it} - dlogPPI_{it}^m)$$

with the price indices being:

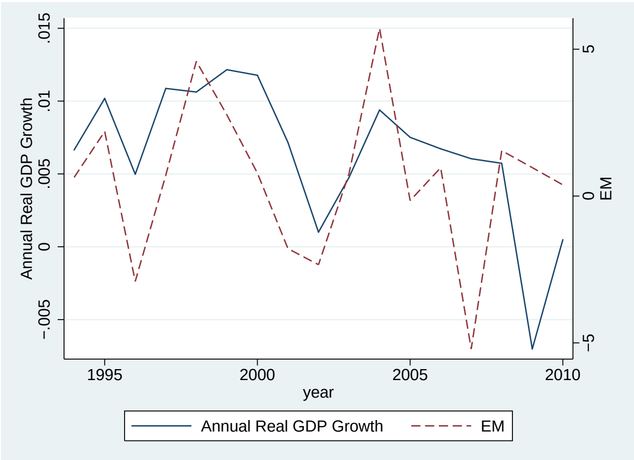
$$dlogPPI_{it} = \frac{N^d p^d q^d}{Y}(p_{it}^d - p_{it-1}^d) + \frac{N^x p^x q^x}{Y}(p_{i't}^x - p_{i't-1}^x)$$

$$dlogPPI_{it}^x = (p_{i't}^x - p_{i't-1}^x)$$

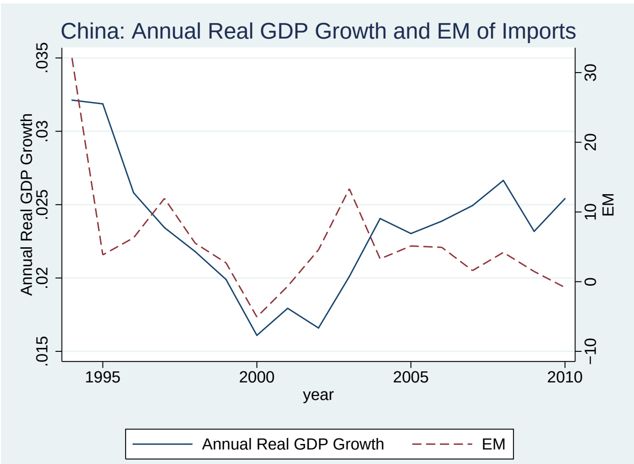
$$dlogPPI_{it}^m = (p_{it}^x - p_{it-1}^x)$$

Appendix D: Comovement of Output (Productivity, respectively) Growth and the Extensive Margin of Trade

As Ghironi and Melitz (2005) show, if firm entry decisions are endogenous then the extensive margin of trade varies at business cycle frequencies—and this serves as an important channel for propagating domestic shocks to foreign countries. The variation in extensive margin serves as an additional channel for strengthening the demand–supply spillover effect. Here we show that, in our sample imported varieties fluctuate at business cycle frequencies. Figures D.1 and D.2 plot (respectively) the real GDP growth and the aggregate productivity growth against changes in the extensive margin of trade for the United States and China (as computed by Broda, Greenfield, and Weinstein (2006).

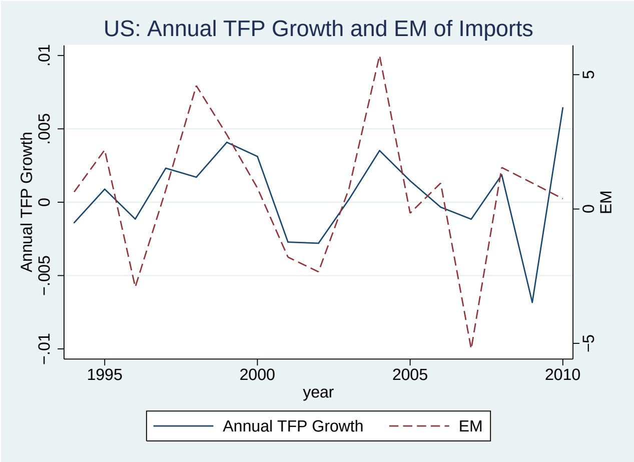


(a) United States

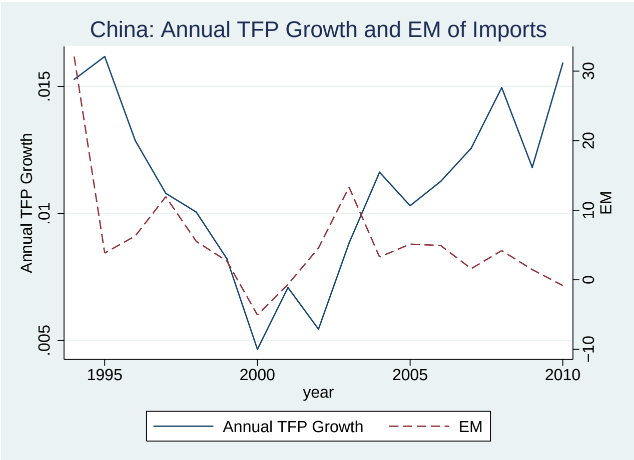


(b) China

Figure D.1: Annual Real GDP Growth and Extensive Margin of Imports



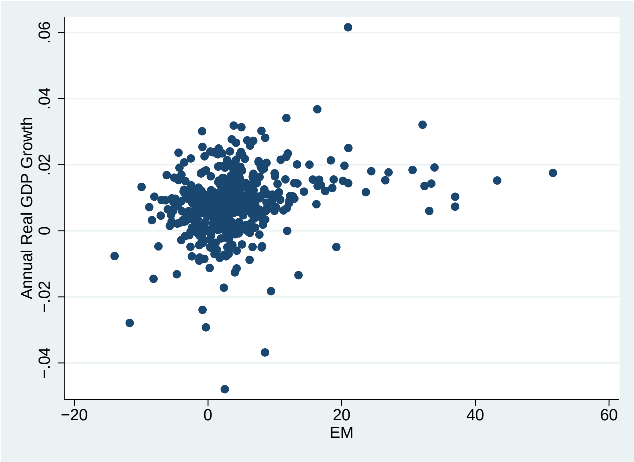
(a) United States



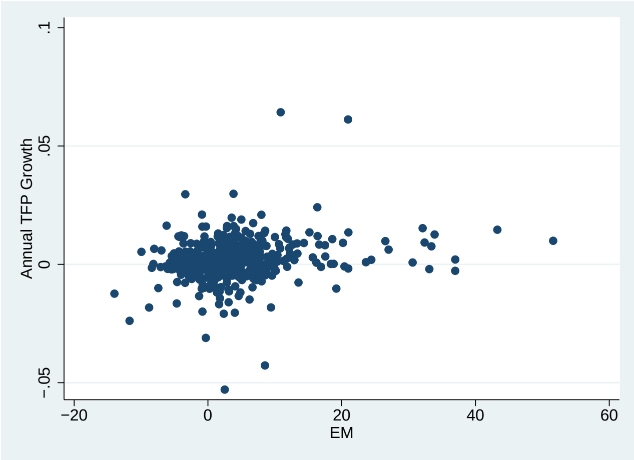
(b) China

Figure D.2: Annual Aggregate Productivity Growth and Extensive Margin of Imports

In Figure D.3, we show that there is a positive relationship between growth in both (i) GDP and (ii) aggregate productivity and the changes in extensive margin of trade across countries.



(a) GDP Growth



(b) Aggregtae Productivity Growth

Figure D.3: Annual Real GDP and Aggregate Productivity Growth versus Extensive Margin of Imports

Appendix E: Country list

Table E.1: Country list

Developed countries	Developing countries
Australia	Argentina
Austria	Brazil
Canada	China
Denmark	Hong Kong, SAR
Germany	India
Finland	Indonesia
France	Korea
Greece	Malaysia
Ireland	Philippines
Italy	Singapore
Japan	
Netherlands	
New Zealand	
Norway	
Portugal	
Spain	
Sweden	
Switzerland	
United Kingdom	
United States	

Source: U.N. classification.

Appendix F: Additional Tables

F.1 Summary Statistics

Table F.1A: Trade and output correlations

Descriptive statistics	Bilateral trade intensity	HP-filtered GDP correlation	Log first-differenced GDP correlation	BP-filtered GDP correlation
Median	0.0035	0.40	0.16	0.39
Minimum	0	−0.89	−0.71	−1
Maximum	0.1976	0.99	0.96	1
Standard deviation	0.0157	0.47	0.30	0.77

Table F.1B: Trade and output correlations (OECD countries prior to 2000)

Descriptive statistics	Bilateral trade intensity	HP-filtered GDP correlation	Log first-differenced GDP correlation	BP-filtered GDP correlation
Median	0.0053	0.36	0.15	0.86
Minimum	0.0003	−0.85	−0.53	−1
Maximum	0.1607	0.98	0.87	1
Standard deviation	0.0179	0.42	0.25	0.72

F.2 Weak IV Tests

Table F.2: Weak identification test

Endog. regressor	Instrument	Cragg–Donald Wald F-stat.	Adj. R^2	Stock–Yogo critical values	
$\log(w_{ij})$	log distance	8186.56	0.38	10% max. IV size	16.38
				15% max. IV size	8.96
$\log(\mathrm{O}T_{ij})$	log distance	2850.20	0.17	20% max. IV size	6.66
				25% max. IV size	5.53
$\log(\mathrm{E}M_{ij})$,	log distance and	193.27	0.16	10% max. IV size	7.03
$\log(\mathrm{I}M_{ij})$	log of entry cost		0.14	15% max. IV size	4.58
Using count data:				20% max. IV size	3.95
$\log(\mathrm{E}M_{ij})$	log distance and	89.63	0.221		
$\log(\mathrm{I}M_{ij})$	log of entry cost		0.14	25% max. IV size	3.63

F.3 Using Count Data

Table F.3.1: Output correlation with EM and IM using count data

HP-filtered output		Output growth		BP-filtered output	
corr(y_i^{hp}, y_j^{hp})	Coef.	corr($\Delta y_i, \Delta y_j$)	Coef.	corr(y_i^{bp},y_j^{bp})	Coeff.
log(EM_{ij})	0.348***	log(EM_{ij})	0.229***	log(EM_{ij})	0.701***
	(0.063)		(0.041)		(0.108)
log(IM_{ij})	–0.067	log(IM_{ij})	–0.063	log(IM_{ij})	–0.201*
	(0.056)		(0.036)		(0.095)
Constant	1.528***	Constant	0.954***	Constant	2.502***
	(0.166)		(0.108)		(0.284)

Notes: 2SLS IV regression using log distance and log of entry costs as the IVs;
Extensive and intensive margin are calculated as count data.
*** (resp., *) denotes statistical significance at the 1% (resp., 10%) level

Table F.3.2: Productivity correlation with EM and IM using count data

HP-filtered productivity		Productivity growth		BP-filtered productivity	
corr(tfp_i^{hp},tfp_j^{hp})	Coeff.	corr($\Delta tfp_i, \Delta tfp_j$)	Coeff.	corr(tfp_i^{bp},tfp_j^{bp})	Coeff.
log(EM_{ij})	0.362***	log(EM_{ij})	0.241***	log(EM_{ij})	0.744***
	(0.061)		(0.041)		(0.100)
log(IM_{ij})	−0.197***	log(IM_{ij})	−0.133***	log(IM_{ij})	−0.415***
	(0.054)		(0.036)		(0.088)
Constant	1.303***	Constant	0.867***	Constant	2.759***
	(0.162)		(0.107)		(0.262)

Notes: 2SLS IV regression using log distance and log of entry costs as the IVs;
Extensive and intensive margin are calculated as count data.
*** denotes statistical significance at the 1% level.

F.4 Correlation Results When EM and IM Are Measured Using Both Imports and Exports

Table F.4.1: Output Correlation with EM and IM Using Hummels–Klenow Decomposition

HP-filtered output		Output growth		BP-filtered output	
corr(y_i^{hp},y_j^{hp})	Coeff.	corr($\Delta y_i, \Delta y_j$)	Coeff.	corr(y_i^{bp},y_j^{bp})	Coeff.
log(EM_{ij}) +log(EM_{ji})	0.155***	log(EM_{ij}) +log(EM_{ji})	0.098***	log(EM_{ij}) +log(EM_{ji})	0.296***
	(0.029)		(0.018)		(0.049)
log(IM_{ij}) +log(IM_{ji})	0.016	log(IM_{ij}) +log(IM_{ji})	0.006	log(IM_{ij}) +log(IM_{ji})	0.014
	(0.014)		(0.009)		(0.024)
Constant	0.644***	Constant	0.354***	Constant	0.662***
	(0.080)		(0.051)		(0.136)

Notes: 2SLS IV regression using log distance and log of entry as IVs;
standard errors are reported in parentheses. *** denotes statistical significance at the 1% level.

Table F.4.2: Productivity Correlation with EM and IM Using Hummels–Klenow Decomposition

HP-filtered productivity		Productivity growth		BP-filtered productivity	
corr(tfp_i^{hp},tfp_j^{hp})	Coeff.	corr($\Delta tfp_i, \Delta tfp_j$)	Coeff.	corr(tfp_i^{bp},tfp_j^{bp})	Coeff.
log(EM_{ij}) + log(EM_{ji})	0.138***	log(EM_{ij}) + log(EM_{ji})	0.091***	log(EM_{ij}) + log(EM_{ji})	0.279***
	(0.025)		(0.017)		(0.042)
log(IM_{ij}) + log(IM_{ji})	–0.021	log(IM_{ij}) + log(IM_{ji})	–0.013	log(IM_{ij}) + log(IM_{ji})	–0.042*
	(0.012)		(0.008)		(0.021)
Constant	0.215**	Constant	0.154**	Constant	0.568***
	(0.071)		(0.047)		(0.118)

Notes: 2SLS IV regression using log distance and log of entry as IVs;
standard errors are reported in parentheses. *** (**, *resp.) denotes statistical significance at the 1% (5%, 10% resp.) level.

Table F.4.3: Output Correlation with EM and IM Using Count Data

HP-filtered output		Output growth		BP-filtered output	
$\text{corr}(y_i^{hp}, y_j^{hp})$	Coeff.	$\text{corr}(\Delta y_i, \Delta y_j)$	Coeff.	$\text{corr}(y_i^{bp}, y_j^{bp})$	Coeff.
$\log(\text{E}M_{ij})$ $+\log(\text{E}M_{ji})$	0.355***	$\log(\text{E}M_{ij})$ $+\log(\text{E}M_{ji})$	0.237**	$\log(\text{E}M_{ij})$ $+\log(\text{E}M_{ji})$	0.736***
	(0.106)		(0.073)		(0.194)
$\log(\text{I}M_{ij})$ $+\log(\text{I}M_{ji})$	−0.216*	$\log(\text{I}M_{ij})$ $+\log(\text{I}M_{ji})$	−0.157*	$\log(\text{I}M_{ij})$ $+\log(\text{I}M_{ji})$	−0.495*
	(0.108)		(0.074)		(0.197)
Constant	2.097***	Constant	1.340***	Constant	3.731***
	(0.440)		(0.301)		(0.805)

Notes: 2SLS IV regression using log distance and log of entry as IVs;
standard errors are reported in parentheses. *** (**, *resp.) denotes statistical significance at the 1% (5%, 10% resp.) level.

Table F.4.4: Productivity Correlation with EM and IM Using Count Data

HP-filtered productivity		Productivity growth		BP-filtered productivity	
$\text{corr}(tfp_i^{hp}, tfp_j^{hp})$	Coeff.	$\text{corr}(\Delta tfp_i, \Delta tfp_j)$	Coeff.	$\text{corr}(tfp_i^{bp}, tfp_j^{bp})$	Coeff.
$\log(\text{E}M_{ij})$ $+\log(\text{E}M_{ji})$	0.365**	$\log(\text{E}M_{ij})$ $+\log(\text{E}M_{ji})$	0.249**	$\log(\text{E}M_{ij})$ $+\log(\text{E}M_{ji})$	0.793***
	(0.118)		(0.080)		(0.221)
$\log(\text{I}M_{ij})$ $+\log(\text{I}M_{ji})$	−0.298*	$\log(\text{I}M_{ij})$ $+\log(\text{I}M_{ji})$	−0.205*	$\log(\text{I}M_{ij})$ $+\log(\text{I}M_{ji})$	−0.660**
	(0.120)		(0.081)		(0.224)
Constant	1.870***	Constant	1.269***	Constant	4.095***
	(0.488)		(0.331)		(0.914)

Notes: 2SLS IV regression using log distance and log of entry as IVs;
standard errors are reported in parentheses. *** (**, *resp.) denotes statistical significance at the 1% (5%, 10% resp.) level.

F.5 Using Different Measures of Trade Intensity

Table F.5.1: Output correlation with trade intensity as normalized by GDP

HP-filtered output		Output growth		BP-filtered output	
corr(y_i^{hp}, y_j^{hp})	Coeff.	corr($\Delta y_i, \Delta y_j$)	Coeff.	corr(y_i^{bp}, y_j^{bp})	Coeff.
$\log(w_{ij})$	0.123***	$\log(w_{ij})$	0.071***	$\log(w_{ij})$	0.213***
	(0.006)		(0.004)		(0.010)
Constant	0.977***	Constant	0.565***	Constant	1.304***
	(0.030)		(0.019)		(0.055)

Notes: The table reports results of a 2SLS regression using log distance as the IV; standard errors are reported in parentheses. *** denotes statistical significance at the 1% level. Trade intensity is measured as $w^2_{ijt} = (X_{ij,t} + M_{ij,t})/(GDP_{it} + GDP_{jt})$.

Table F.5.2: Productivity correlation with trade intensity as normalized by GDP

HP-filtered productivity		Productivity growth		BP-filtered productivity	
corr(tfp_i^{hp}, tfp_j^{hp})	Coeff.	corr($\Delta tfp_i, \Delta tfp_j$)	Coeff.	corr(tfp_i^{bp}, tfp_j^{bp})	Coeff.
$\log(w_{ij})$	0.057***	$\log(w_{ij})$	0.038***	$\log(w_{ij})$	0.117***
	(0.005)		(0.003)		(0.008)
Constant	0.510***	Constant	0.349***	Constant	1.164***
	(0.027)		(0.018)		(0.044)

Notes: The table reports results of a 2SLS regression using log distance as the IV; standard errors are reported in parentheses. *** denotes statistical significance at the 1% level. Trade intensity is measured as $w^2_{ijt} = (X_{ij,t} + M_{ij,t})/(GDP_{it} + GDP_{jt})$.

F.6 Using the Full Sample (1985–2009)

Table F.6.1: Output correlation with trade intensity

HP-filtered output		Output growth		BP-filtered output	
corr(y_i^{hp}, y_j^{hp})	Coeff.	corr($\Delta y_i, \Delta y_j$)	Coeff.	corr(y_i^{bp}, y_j^{bp})	Coeff.
log(w_{ij})	0.186***	log(w_{ij})	0.121***	log(w_{ij})	0.220***
	(0.011)		(0.007)		(0.020)
Constant	1.331***	Constant	0.845***	Constant	1.363***
	(0.060)		(0.037)		(0.111)

Notes: The table reports results of a 2SLS IV regression using log distance as the IV; standard errors are reported in parentheses. *** denotes statistical significance at the 1% level. Trade intensity is normalized by total bilateral trade and averaged over the period 1985–2009; bilateral correlations are calculated for the full sample (1985–2009).

Table F.6.2: Productivity correlation with trade intensity

HP-filtered output		Output growth		BP-filtered output	
corr(tfp_i^{hp}, tfp_j^{hp})	Coeff.	corr($\Delta tfp_i, \Delta tfp_j$)	Coeff.	corr(tfp_i^{bp}, tfp_j^{bp})	Coeff.
log(w_{ij})	0.091***	log(w_{ij})	0.064***	log(w_{ij})	0.108***
	(0.011)		(0.008)		(0.014)
Constant	1.306***	Constant	1.196***	Constant	1.431***
	(0.063)		(0.045)		(0.079)

Notes: The table reports results of a 2SLS IV regression using log distance as theIV; standard errors are reported in parentheses. *** denotes statistical significance at the 1% level. Trade intensity is normalized by total bilateral trade and averaged over the period 1985–2009; bilateral correlations are calculated for the full sample (1985–2009).

Table F.6.3: Output correlation with EM and IM using Hummels–Klenow decomposition

HP-filtered output		Output growth		BP-filtered output	
corr(y_i^{hp},y_j^{hp})	Coeff.	corr($\Delta y_i, \Delta y_j$)	Coeff.	corr(y_i^{bp},y_j^{bp})	Coeff.
log(EM_{ij})	0.232***	log(EM_{ij})	0.167***	log(EM_{ij})	0.205**
	(0.035)		(0.023)		(0.063)
log(IM_{ij})	0.009	log(IM_{ij})	−0.001	log(IM_{ij})	0.040
	(0.017)		(0.011)		(0.031)
Constant	0.662***	Constant	0.375***	Constant	0.721***
	(0.099)		(0.065)		(0.176)

Notes: The table reports the results of a 2SLS IV regression using log distance and log of entry costs as IVs; standard errors are reported in parentheses. *** (resp., **) denotes statistical significance at the 1% (resp., 5%) level. Trade intensity is normalized by total bilateral trade and averaged over the period 1985–2009; bilateral correlations are calculated for the full sample (1985–2009).

Table F.6.4: Productivity correlation with EM and IM using Hummels–Klenow decomposition

HP-filtered productivity		Productivity growth		BP-filtered productivity	
corr(tfp_i^{hp},tfp_j^{hp})	Coeff.	corr($\Delta tfp_i, \Delta tfp_j$)	Coeff.	corr(tfp_i^{bp},tfp_j^{bp})	Coeff.
log(EM_{ij})	0.266***	log(EM_{ij})	0.211***	log(EM_{ij})	0.244***
	(0.035)		(0.026)		(0.041)
log(IM_{ij})	−0.062***	log(IM_{ij})	−0.053***	log(IM_{ij})	−0.042*
	(0.017)		(0.013)		(0.020)
Constant	0.651***	Constant	0.686***	Constant	0.808***
	(0.098)		(0.074)		(0.114)

Notes: The table reports the results of a 2SLS IV regression using log distance and log of entry costs as IVs; standard errors are reported in parentheses. *** (resp., **) denotes statistical significance at the 1% (resp., 5%) level. Trade intensity is normalized by total bilateral trade and averaged over the period 1985–2009; bilateral correlations are calculated for the full sample (1985–2009).

F.7 Different Categories of Traded Goods

Table F.7.1: Output correlation with EM and IM by types of goods

Consumption		Capital		Intermediates	
corr(y_i^{hp}, y_j^{hp})	Coeff.	corr(y_i^{hp}, y_j^{hp})	Coeff.	corr(y_i^{hp}, y_j^{hp})	Coeff.
log(EM_{ij})	0.436***	log(EM_{ij})	0.230*	log(EM_{ij})	0.362***
	(0.119)		(0.134)		(0.109)
log(IM_{ij})	–0.009	log(IM_{ij})	0.079	log(IM_{ij})	0.001
	(0.038)		(0.064)		(0.042)
Constant	0.527***	Constant	0.863***	Constant	0.562***
	(0.118)		(0.241)		(0.124)

Notes: The table reports results of a 2SLS IV regression using lof distance and log of entry costs as the IVs; standard errors are reported in parentheses. *** (resp., *) denotes statistical significance at the 1% (resp., 5%). Extensive and intensive margins are calculates as count data.

Table F.7.2: Productivity correlation with EM and IM by types of goods

Consumption		Capital		Intermediates	
corr(tfp_i^{hp}, tfp_j^{hp})	Coeff.	corr(tfp_i^{hp}, tfp_j^{hp})	Coeff.	corr(tfp_i^{hp}, tfp_j^{hp})	Coeff.
log(EM_{ij})	0.329***	log(EM_{ij})	0.291**	log(EM_{ij})	0.311***
	(0.114)		(0.149)		(0.116)
log(IM_{ij})	−0.050	log(IM_{ij})	−0.042	log(IM_{ij})	−0.059
	(0.043)		(0.072)		(0.051)
Constant	0.184	Constant	0.213	Constant	0.174
	(0.132)		(0.219)		(0.144)

Notes: The table reports results of a 2SLS IV regression using lof distance and log of entry costs as the IVs; standard errors are reported in parentheses. *** (resp., *) denotes statistical significance at the 1% (resp., 5%). Extensive and intensive margins are calculates as count data.

F.8 Using Harmonized System Classification Code

Table F.8.1: Output correlation with EM and IM using HS classification

HP-filtered output		Output growth		BP-filtered output	
corr(y_i^{hp}, y_j^{hp})	Coeff.	corr($\Delta y_i, \Delta y_j$)	Coeff.	corr(y_i^{bp}, y_j^{bp})	Coeff.
log(EM_{ij})	0.398***	log(EM_{ij})	0.244***	log(EM_{ij})	0.742***
	(0.067)		(0.047)		(0.166)
log(IM_{ij})	0.009	log(IM_{ij})	−0.003	log(IM_{ij})	0.015
	(0.033)		(0.245)		(0.086)
Constant	0.608***	Constant	0.326***	Constant	0.570**
	(0.094)		(0.072)		(0.241)

Notes: The table reports results of a 2SLS IV regression using log distance and log entry costs as IVs;
standard errors are reported in parentheses. *** (resp., **) denotes statistical significance at the 1% (resp., 5%) level.

Table F.8.2: Productivity correlation with EM and IM using HS classification and Hummels–Klenow decomposition

HP-filtered productivity		Productivity growth		BP-filtered productivity	
corr(tfp_i^{hp}, tfp_j^{hp})	Coeff.	corr($\Delta tfp_i, \Delta tfp_j$)	Coeff.	corr(tfp_i^{bp}, tfp_j^{bp})	Coeff.
log(EM_{ij})	0.330***	log(EM_{ij})	0.218***	log(EM_{ij})	0.638***
	(0.067)		(0.048)		(0.103)
log(IM_{ij})	−0.061	log(IM_{ij})	−0.043	log(IM_{ij})	−0.130**
	(0.033)		(0.026)		(0.054)
Constant	0.172	Constant	0.107	Constant	0.422*
	(0.097)		(0.075)		(0.154)

Notes: The table reports results of a 2SLS IV regression using log distance and log entry costs as IVs;
standard errors are reported in parentheses. *** (resp., ** and *) denotes statistical significance at the 1% (resp., 5% and 10%) level.

F.9 Using Data at a Less Disaggregated Level

Table F.9.1: Output correlation with EM and IM at the 3-digit level

HP-filtered output		Output growth		BP-filtered output	
corr(y_i^{hp}, y_j^{hp})	Coeff.	corr($\Delta y_i, \Delta y_j$)	Coeff.	corr(y_i^{bp}, y_j^{bp})	Coeff.
log(EM_{ij})	0.274***	log(EM_{ij})	0.165***	log(EM_{ij})	0.500***
	(0.035)		(0.024)		(0.086)
log(IM_{ij})	–0.015	log(IM_{ij})	–0.018	log(IM_{ij})	-0-.061
	(0.038)		(0.028)		(0.098)
Constant	–0.135	Constant	–0.146	Constant	–0.874
	(0.260)		(0.192)		(0.674)

Notes: The table reports results for a 2SLS IV regression using log distance and log of entry costs as IVs; standard errors are reported in parentheses. *** denotes statistical significance at the 1% level. Extensive and intensive margins are calculated as count data.

Table F.9.2: Productivity correlation with EM and IM at the 3-digit level

HP-filtered productivity		Productivity growth		BP-filtered productivity	
corr(tfp_i^{hp}, tfp_j^{hp})	Coeff.	corr($\Delta tfp_i, \Delta tfp_j$)	Coeff.	corr(tfp_i^{bp}, tfp_j^{bp})	Coeff.
log(EM_{ij})	0.205***	log(EM_{ij})	0.135***	log(EM_{ij})	0.392***
	(0.035)		(0.024)		(0.050)
log(IM_{ij})	–0.085**	log(IM_{ij})	–0.059**	log(IM_{ij})	–0.177***
	(0.038)		(0.029)		(0.060)
Constant	–0.574**	Constant	–0.391**	Constant	–1.044**
	(0.261)		(0.197)		(0.408)

Notes: The table reports results for a 2SLS IV regression using log distance and log of entry costs as IVs; standard errors are reported in parentheses. *** (resp., **) denotes statistical significance at the 1% (resp., 5%) level. Extensive and intensive margins are calculated as count data.

Appendix G: Data Sources

For OECD countries, real GDP data are from the OECD quarterly national account database (series name: VOBARSA, millions of national currency, volume estimates, OECD reference year, annual levels, seasonally adjusted). For the other countries, the quarterly real GDP data are from the IMF International Financial Statistics (IFS; GDP volume series, 2005 = 100). For earlier sample periods, quarterly data are not available for some emerging economies. In such cases we interpolate an annual index (also from IFS) while assuming that real GDP is constant in each quarter of any given year. As a robustness check, we perform regressions using shorter sample periods during which quarterly GDP data are available for all economies; the results (available upon request) are consistent with those obtained for the full sample.

There are a total of 2,610 observations (435 country pairs, corresponding to 30 countries and 6 time periods). To account for possible measurement error, we also calculate pairwise output correlations for the entire sample period. The results (available upon request) are similar.

The bilateral trade data used to calculate trade intensity are obtained from the IMF's Direction of Trade Statistics dataset.

The nominal GDP data (annual index in national currency) are collected from IMF IFS. Because the trade data are in US dollars (USD), we use the official exchange rate (period average; when that rate is not available, the market exchange rate is used) to transform the nominal GDP in national currency into USD-denominated data. The international trade data are collected at an annual frequency. We calculate bilateral trade intensity for each year and then take natural logarithms. To match the frequency of bilateral output correlations, we take the average of the trade intensity in each of the six subsamples.

For each country i,

$$\log(z_{it}) = \log(y_{it}) - \alpha \log(n_{it}) - (1-\alpha)\log(k_{it});$$

here z_{it} denotes the aggregate productivity, y_{it} the real income, n_{it} the total employment, and k_{it} the real physical capital stock. We take the gross fixed capital formation (GFCF) data from IFS and take the employment index from IFS and the OECD database. For OECD countries, the GFCF data are given by a series named VOBARSA (millions of national currency, volume estimates, OECD reference year, annual levels, seasonally adjusted); the employment data are from the OECD Labour Force Statistics (MEI, Main Economic Indicators) dataset (all persons, index OECD base year 2005 = 100, seasonally adjusted). For other countries, data are from the IFS database. The GFCF data are deflated by a GDP deflator (2005 = 100, also from the IFS database) to obtain the real capital formation data. For countries and periods when quarterly data are not available, we interpolate the annual index while assuming a constant volume every quarter within a year. As a robustness check, we exclude the periods when quarterly data are not available; this does not affect our results.

Physical capital is constructed using the perpetual inventory method with a constant quarterly depreciation of 2.5% and assuming that the initial capital stock is zero. We follow the literature in setting α, the labor share of income in GDP, to 0.64 for all countries.[20]

Appendix H: Adjustment Costs and Higher–Frequency Fluctuations in the Extensive Margin

In our model, countries with higher steady-state levels of the extensive margin also exhibit a stronger propagation through changes in this margin. In other words, the importance of the extensive margin can be seen both at the steady-state level and with respect to the transmission of shocks across countries. The details of the transmission mechanism involve EM variations not only at the steady-state level but also in response to shocks; however, these variations are comparable in our model.

We now provide additional evidence that the extensive margin does move at business cycles frequencies, a crucial assumption in our model. The evidence we present confirms that the extensive margin changes at business cycle frequencies and that such change is related to the EM's steady-state level, a correlation that is predicted by our model. We present evidence that this is the case, that the extensive changes over business cycle frequencies and that this change is related to the steady-state level of the extensive margin, a correlation that is also present in our model. We proceed in two steps. First, we compute 1-year, 5-year, and 10-year growth rates of this margin for our sample of countries; we do this for exports, imports, and bilateral trade. We find that the extensive margin exhibits more change at lower frequencies (5 and 10 years) than at higher frequencies (1 year), as summarized in Table 9.

Table H.1.: Growth rate of extensive margin (average for all countries)

Growth EM	1-year	5-years	10-years
Exports	0.03	0.13	0.25
Imports	0.01	0.08	0.15
Bilateral	0.02	0.13	0.25

When we move from a 5-year to a 10-year frequency, the growth rate of the extensive margin doubles in all three cases (exports, imports, and bilateral trade). When we move from 1-year to a 5-year frequency, the growth rate increases by a factor of 6 in the case of exports and bilateral trade and by a factor of 8 in the case of imports.

Second, we compute the variance of the extensive margin of trade in our sample at 5-year, 10-year, and 20-year frequencies. To eliminate units, we calculate the variance at the 5-year and 10-year frequencies with respect to the variance at the 20-year frequency (we obtain similar results if instead we normalize using the variance of trade intensity). Then we compare the variance so calculated with

[20] As a robustness check, we also calculate aggregate productivity for emerging markets while setting $\alpha = 0.5$; this does not affect our results.

the levels of the extensive margin and with the correlation of GDP growth across pairs of countries. We observe three interesting facts: (i) The extensive margin varies at both high and low frequencies (Table H.1. shows this in terms of growth rates, and we also see it by computing the variance for the extensive margin at different frequencies). (ii) There is a positive correlation between the level and the variability of the extensive margin: Higher EMs for country pairs are also more volatile (the correlation is about 0.3), and (iii) There is a positive correlation between the correlation of output growth and the EM volatility, and there are no significant differences in this correlation for different frequencies (see Tables H.2. and H.3.). Result (i) is evidence that the extensive margin in our data moves at business cycle frequencies. Result (ii) is an indirect test that the mechanism stipulated by our model is consistent with what we observe in the data—namely, that in pairs of countries with a higher extensive margin, this margin also fluctuates more. Finally, result (iii) shows that these higher fluctuations are key to explaining the comovement of business cycles across pairs of countries.

Table H.2.: Output correlation with 5-year EM variability

$corr(\Delta y_i, \Delta y_j)$	Coeff.
5-year variance	0.175***
	(0.038)
Constant	0.126***
	(0.017)

Notes: Standard errors are reported in parentheses.
*** denotes statistical significance at the 1% level.

Table H.3.: Output correlation with 10-year EM variability

$corr(\Delta y_i, \Delta y_j)$	Coeff.
10-year Variance	0.151***
	(0.035)
Constant	0.106***
	(0.021)

Notes: Standard errors are reported in parentheses.
*** denotes statistical significance at the 1% level.

Appendix I: The Trade–Output Comovement Relationship Revisited

In this Appendix, we study the relationship between bilateral trade intensity and bilateral correlation of real output in terms of GDP.

We first update the Frankel and Rose (1998) regression for a 30-country sample (20 OECD countries and 10 developing countries) spanning the period from 1980:Q1 through 2009:Q4. This sample accounts for nearly 75% of world GDP and 73% of world trade.[21]

[21] The country list is given in Appendix 5 as Table E.1.

The output data are transformed in three ways: (i) Hodrick–Prescott (HP) filtering of real GDP (with smoothing parameter 1600); (ii) first-differencing of natural logarithms to calculate the output growth rate; and (iii) band-pass (BP) filtering to remove high-frequency variations (while retaining frequencies between 32 and 116 quarters). The first two transformations capture business cycle frequencies; the third captures medium-term business cycles (Comin and Gertler (2006)).

We then calculate the bilateral correlation of real GDP over six (nonoverlapping) 5-year intervals, between 1980 and 2009, for each of the resulting three measures. As a measure of bilateral trade intensity, we consider two alternatives. The first one is based solely on international trade data:

$$w_{ijt} = \frac{X_{ij,t} + M_{ij,t}}{X_{it} + X_{jt} + M_{it} + M_{jt}},$$

where $X_{ij,t}$ and $M_{ij,t}$ denote (respectively) bilateral nominal exports and imports between country i and country j during period t and where X_{it} and (resp., M_{it}) denotes country i's aggregate nominal exports to (resp., imports from) all countries. The second measure is

$$w_{ijt} = \frac{X_{ij,t} + M_{ij,t}}{y_{it} + y_{jt}},$$

where y_{it} is the nominal GDP of country i at time t. Our results are robust to using either of these measures of bilateral trade intensity.

For the three measures of output (growth rates, HP filter, and BP filter), we run the following regression:

$$\text{corr}(\Delta y_{it}, \Delta y_{jt}) = \beta_0 + \beta_1 \log(w_{ijt}) + \varepsilon_{ijt},$$

where $\text{corr}(\Delta y_{it}, \Delta y_{jt})$ is the correlation of output growth rates between countries i and j over each subsample period t.

Table I.1. reports the results for the trade–output comovement regression using distance as an IV. We find that a doubling of the trade intensity leads to an increase in correlation of 0.02 for output growth (0.04 for HP-filtered output and 0.07 for BP-filtered output); the coefficients are statistically significant for all three measures of output. These results are broadly consistent with the literature and are robust to the inclusion of IVs.[22]

[22] All tables report standard errors clustered by country pairs. Standard errors clustered by exporters and importers (two-way cluster) are slightly higher, but all our results still hold. Adding either period-specific or country-specific "fixed effect" controls (or both) also has no effect on our results.

Table I.1.: Output correlation with trade intensity

HP-filtered output		Output growth		BP-filtered output	
$\text{corr}(y_i^{HP}, y_j^{HP})$	Coeff.	$\text{corr}(\Delta y_i, \Delta y_j)$	Coeff.	$\text{corr}(y_i^{BP}, y_j^{BP})$	Coeff.
$\log(w_{ij})$	0.139***	$\log(w_{ij})$	0.081***	$\log(w_{ij})$	0.240***
	(0.012)		(0.007)		(0.026)
Constant	1.095***	Constant	0.634***	Constant	1.506***
	(0.070)		(0.041)		(0.142)

Notes: The table reports results of a 2SLS IV regression using log distance as the IV; standard errors are reported in parentheses. *** denotes statistical significance at the 1% level.

Next we study the relation between international trade and TFP. Kose and Yi (2006) find that productivity shocks are more correlated across countries that trade more with each other. We calculate aggregate productivity as the Solow residual in a standard Cobb–Douglas production function.

We then test whether countries that trade more with each other have more correlated aggregate productivity. As we did with the output data, we transform aggregate productivity in three ways (quarter-to-quarter growth rates, HP- and BP-filtered productivity) before computing the bilateral correlations of aggregate productivity during each of the six 5-year intervals. Next we run the following regression for the three measures of aggregate productivity:

$$\text{corr}(T\tilde{F}P_{it}, T\tilde{F}P_{jt}) = \beta_0 + \beta_1 \log(w_{ijt}) + \varepsilon_{ijt}.$$

Table I.2. reports the results. There is a positive and significant relationship between bilateral trade intensity and productivity comovement. These results are consistent with the literature and are robust to the inclusion of IVs.[23] This finding indicates that understanding the trade–output comovement relationship requires that we understand the drivers of the trade–productivity comovement relationship.

Table I.2.: Aggregate productivity correlation with trade intensity

HP-filtered productivity		Productivity growth		BP-filtered productivity	
$\text{corr}(\text{TFP}_i^{HP}, \text{TFP}_j^{HP})$	Coeff.	$\text{corr}(\Delta\text{TFP}_i, \Delta\text{TFP}_j)$	Coeff.	$\text{corr}(\text{TFP}_i^{BP}, \text{TFP}_j^{BP})$	Coeff.
$\log(w_{ij})$	0.066***	$\log(w_{ij})$	0.045***	$\log(w_{ij})$	0.128***
	(0.011)		(0.007)		(0.016)
Constant	0.571***	Constant	0.391***	Constant	1.255***
	(0.061)		(0.042)		(0.087)

Notes: The table reports results of a 2SLS IV regression using log distance as the IV; standard errors are reported in parentheses. *** denotes statistical significance at the 1% level.

Our results, which are in accord with the empirical literature, suggest that countries trading more with each other tend to have not only more correlated business cycles but also more correlated productivity growth.

[23]Drozd and Nosal (2008) obtain similar results.