Supplementary Appendix: Value Added and Productivity Linkages Across Countries

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François de Soyres*
Federal Reserve Board

Alexandre Gaillard†
Toulouse School of Economics

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*Email: francois.m.desoyres@frb.gov; Corresponding author. The views in this paper are solely the responsibility of the authors and should not necessarily be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System.

†Email: alexandre.gaillard@tse-fr.eu.

A Empirical Appendix

A.1 Data source

Trade Comovement Puzzle Unless explicitly stated, we focus the empirical analysis on 40 OECD countries and major emerging markets, which account for around 90% of world GDP.[1] Our bilateral trade flows data come from Johnson and Noguera (2017) who separated between final and intermediate goods for 42 countries between 1970 and 2009. According to their data appendix A.2, they construct their data as follows. For bilateral goods trade, they use the NBER-UN Database for 1970-2000 and the CEPII BACI Database for 1995-2009. This data is reported on a commodity-basis. They assign commodities to end uses and industries using existing correspondences from the World Bank. To assign commodities to end uses, they use correspondences between SITC (Revision 2) 4-digit or HS (1996 Revision) 6-digit commodities and the BEC end use classifications. To assign commodities to industries, they use correspondences between SITC and HS categories and ISIC (Revision 2) industries. GDP data comes from the 9th Penn World Tables. We use the output-side real GDP at chained PPPs (variable *rgdpo*), to compare relative productive capacity across countries and over time.[2] We also use OECD data and quarterly based price GDP data in some robustness checks. In total, we have 630 country-pairs appearing 4 times and 190 pairs appearing 2 times (both in the case of 10 years time windows), leading to a dataset with a total of 2900 observations.

[1]The list of countries is: Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Russia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Thailand, Turkey, United Kingdom, United States and Vietnam.

[2]We drop Romania and South Africa from their sample because of lack of GDP series in the Penn World Tables. Moreover, in Johnson and Noguera (2017)'s data for Russia starts only in 1990 while data for Estonia, Slovak Republic, Slovenia and Czech Republic start only in 1993. All country-pairs involving one of those five countries appears only two times in the case of 10 years time-windows and cannot be used at all in the case of 20 years time-windows.

A.2 Summary statistics

Table 1 shows the summary statistics of the data used throughout the empirical investigations, either in the core paper or in this online appendix.

Table. 1. Summary statistics

Statistic	Min	Max	Mean	Pctl(25)	Median	Pctl(75)	N	St. Dev.
log_inx_tot_trade	−19.280	−2.430	−7.768	−8.838	−7.583	−6.486	2,900	2.004
log_inx_int_trade	−19.945	−2.869	−8.314	−9.360	−8.132	−7.007	2,900	2.025
log_inx_fin_trade	−20.003	−3.468	−8.759	−9.874	−8.522	−7.368	2,900	2.100
corr_GDP_HP	−0.933	0.973	0.277	0.003	0.327	0.592	2,900	0.396
corr_GDP_BK	−0.928	0.961	0.280	0.013	0.330	0.592	2,900	0.387
corr_GDP_FD	−0.976	0.978	0.253	−0.023	0.293	0.554	2,900	0.388
third_tot	0.090	0.942	0.528	0.400	0.534	0.665	2,900	0.173
sector_ex	0.023	0.722	0.307	0.211	0.294	0.390	2,520	0.133
index_C_claims_2	0.00000	1.431	0.035	0.001	0.003	0.011	1,030	0.122
index_TOT_FDI	−0.002	0.012	0.0004	0.00001	0.0001	0.0003	783	0.001
SITC_sector	0.081	0.806	0.452	0.344	0.451	0.557	2,900	0.145

A.3 Trade Comovement Slope

In this section, we conduct additional robustness checks and show that our main empirical results concerning the trade co-movement slope are robust to alternative specifications, sample selection and time period. We start by providing in Figure 1 scatter-plots relating GDP co-movomenets and trade intensity for each time windows. In each time-windows, their is a positive relationship between the two variables. Therefore, the main analysis consists in disentangling effects coming from unobserved heterogeneity (common borders, same language etc.) and specific time effect (the global rise in GDP correlation through time).

A.3.1 Trade comovement slope with financial controls

We provide additional robustness of the trade comovement slope using financial controls. To this effect, we construct two additional variables capturing the financial interconnection between every country-pairs. First, we construct an index of financial integration (FI) using Foreign Direct Investment (FDI) data, as follows: $FI_{ijt} = \frac{FDI_{i\to j,t}+FDI_{j\to i,t}}{GDP_{it}+GDP_{jt}}$. Second, we use the total bilateral cross-border claims (including bank and non-bank sectors for all maturities) from the consolidated banking statistics from the Bank for International Settlement to construct an index of financial proximity (FP) between a country i and j: $FP_{ijt} = \frac{C_{i\to j,t}+C_{j\to i,t}}{GDP_{it}+GDP_{jt}}$, where here $C_{i\to j,t}$ refers to total cross-border claims from country i to country j.

Figure 1. Bilateral trade intensity and GDP correlation (HP-filter) for the four time windows from 1970 to 2009. Blue: 1970-1979, Red: 1980-1989, Green: 1990-1999, Orange: 2000-2009.

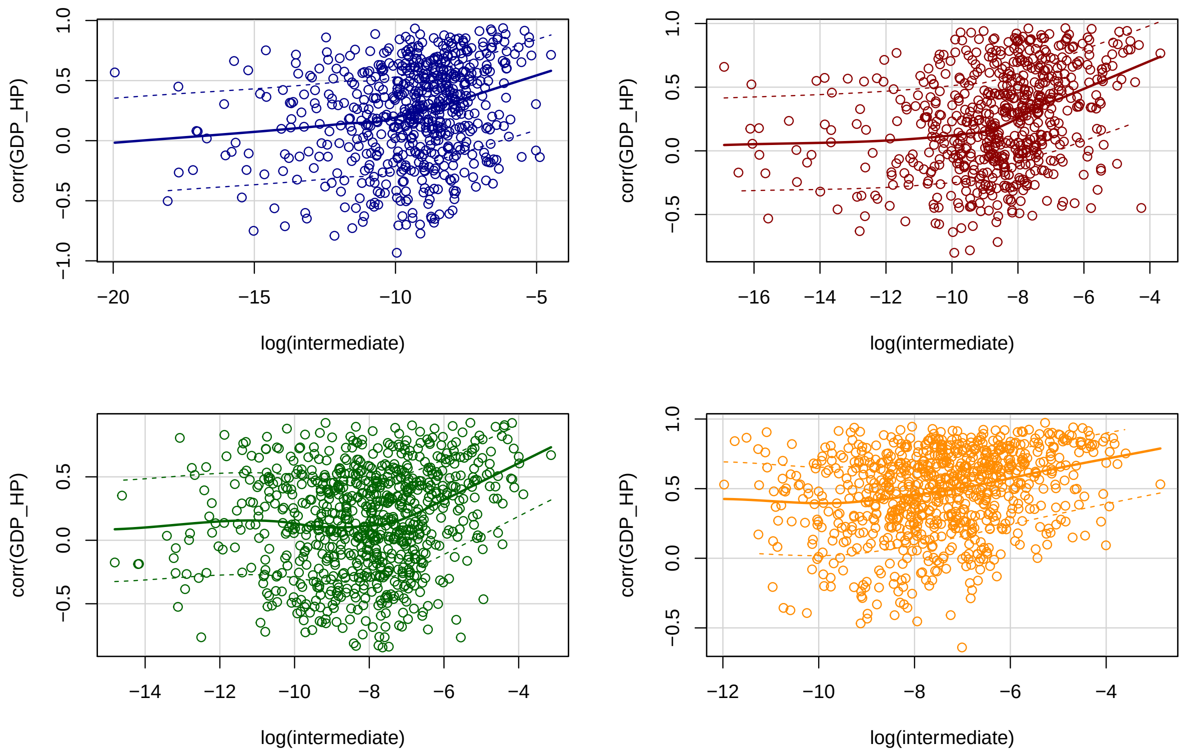


Table 2 summarizes the results with financial controls. Except for the specification using correlation of first difference GDP together with financial proximity index, the results are shown to be robust to the inclusion of financial controls. Using a larger sample including high and low income countries, World Bank (2019) show consistent findings.

A.3.2 Robustness: excluding EU and USSR country-pairs, alternative time windows and time periods

We conduct three sets of analysis concerning our main empirical findings that trade in intermediate inputs is associated with more GDP correlation while trade in final goods is not.

(i). In table 3, we first provides additional results of the main regressions ((1) and (2) in the main paper) with 20 years time windows and fixed effects. The results confirm the robustness of our findings under alternative time windows. Using this dataset, we find a significant trade in inputs co-movement slope using HP filter or first difference.

(ii). In table 4 we run the same empirical analysis with fixed effects but we exclude country-pairs with two countries in the 2000 European Union, while in table 5 we exclude USSR

Table. 2. Trade - GDP correlation, Disaggregated trade, controls with financial variables

	Corr GDP$^{\text{HP filter}}$				Corr ΔGDP			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(\text{Trade}^{\text{input}})$	0.170^{***}	0.177^{***}	0.298^{***}	0.312^{***}	0.067	0.074	0.202^{*}	0.186^{*}
	(0.065)	(0.063)	(0.097)	(0.095)	(0.075)	(0.074)	(0.104)	(0.098)
$\ln(\text{Trade}^{\text{final}})$	-0.006	-0.048	-0.367^{***}	-0.351^{***}	0.074	0.036	-0.340^{***}	-0.316^{***}
	(0.057)	(0.057)	(0.092)	(0.094)	(0.063)	(0.067)	(0.093)	(0.095)
ln(FP)		0.039^{**}				0.027		
		(0.016)				(0.019)		
ln(FI)				-0.022				-0.036^{*}
				(0.020)				(0.021)
$third_{country}$		0.322		-0.319		0.400		0.429
		(0.301)		(0.502)		(0.330)		(0.612)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Window FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
EU + USSR dum.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,030	1,030	728	728	1,030	1,030	728	728
R^2	0.425	0.432	0.440	0.443	0.343	0.347	0.350	0.355

Notes: *p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation. SE clustered on country-pairs.

Table. 3. Trade - GDP correlation using 20 years time windows

	Corr GDP$^{\text{HP filter}}$					Corr ΔGDP				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\ln(\text{Trade}^{\text{total}})$	0.047^{***}	0.019^{*}				0.016^{**}	0.017			
	(0.007)	(0.011)				(0.007)	(0.013)			
$\ln(\text{Trade}^{\text{input}})$			0.056^{*}	0.074^{**}	0.081^{**}			0.070^{**}	0.074^{**}	0.079^{**}
			(0.033)	(0.033)	(0.033)			(0.030)	(0.031)	(0.031)
$\ln(\text{Trade}^{\text{final}})$			-0.005	-0.054	-0.063^{*}			-0.047^{*}	-0.057^{*}	-0.063^{**}
			(0.029)	(0.034)	(0.034)			(0.026)	(0.031)	(0.031)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		
Time Window FE	No	Yes	No	Yes	No	Yes	No	Yes		
EU + URSS dum.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		
N	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450
R^2	0.058	0.068	0.061	0.075	0.103	0.009	0.009	0.017	0.017	0.032

Notes: *p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation.

countries. This is motivated by the fact that the European Union (or trade unions) have made correlated policies to improve trade each other, which may influence the correlation between trade intensity and GDP correlation. Perhaps surprisingly, dropping country-pairs in the European Union from the sample increases the correlation between trade in intermediate goods and GDP comovement. We find a similar conclusion when excluding USSR countries.

(iii). In table 6, we focus only on the three first time windows that cover the period from 1970 to 1999. In that case, we still find a significant trade co-movement slope, with a larger effect of trade intensity on GDP comovement.[3]

Table. 4. Trade and GDP correlation with 10 years time windows - no EU country-pairs

	Corr $GDP^{\text{HP filter}}$				Corr ΔGDP			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(\text{Trade}^{\text{input}})$	0.056^{**}	0.066^{***}	0.067^{***}	0.067^{***}	0.049^{**}	0.047^{*}	0.048^{**}	0.046^{*}
	(0.026)	(0.025)	(0.026)	(0.025)	(0.024)	(0.024)	(0.024)	(0.024)
$\ln(\text{Trade}^{\text{final}})$	0.005	-0.043^{*}	-0.051^{**}	-0.050^{*}	-0.005	-0.020	-0.030	-0.028
	(0.023)	(0.025)	(0.026)	(0.026)	(0.021)	(0.024)	(0.024)	(0.024)
$sector_{prox}$				-0.107				-0.253
				(0.161)				(0.158)
$third_{country}$			0.326^{**}	0.332^{**}			0.354^{**}	0.366^{**}
			(0.161)	(0.162)			(0.147)	(0.147)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Window FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
URSS dum.	No	Yes	Yes	Yes	No	Yes	Yes	Yes
N	2,280	2,280	2,280	2,280	2,280	2,280	2,280	2,280
R^2	0.044	0.173	0.178	0.178	0.022	0.143	0.149	0.150

Notes: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$. In parenthesis: std. deviation.

A.3.3 Robustness: sector composition

In table 7 we show the results of an analysis where the index of similarity in sectoral composition is constructed using first the ISIC classification (columns (2) and (5)) and then using the SITC 4-digits classification (columns (3) and (6)). The sample size is not exactly similar as in the main text but results are robust to this specification.

We then use the data from the World Development Indicators (WDI) of the World Bank to construct our index of proximity in sectoral composition. We use the share in value added of

[3]Notice that findings for the points (ii) and (iii) are also valid using FD.

Table. 5. Trade and GDP correlation with 10 years time windows - no USSR countries

	Corr $GDP^{\text{HP filter}}$				Corr ΔGDP			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(\text{Trade}^{\text{input}})$	0.064^{**}	0.066^{**}	0.073^{***}	0.072^{***}	0.063^{***}	0.055^{**}	0.066^{***}	0.061^{**}
	(0.027)	(0.027)	(0.027)	(0.027)	(0.025)	(0.025)	(0.025)	(0.025)
$\ln(\text{Trade}^{\text{final}})$	-0.006	-0.020	-0.043	-0.042	-0.020	-0.007	-0.031	-0.026
	(0.024)	(0.027)	(0.027)	(0.027)	(0.022)	(0.025)	(0.026)	(0.026)
$sector_{prox}$				-0.064				-0.302^{*}
				(0.160)				(0.154)
$third_{country}$			0.307^{*}	0.310^{*}			0.361^{**}	0.374^{**}
			(0.164)	(0.165)			(0.150)	(0.151)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Window FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
URSS dum.	No	Yes	Yes	Yes	No	Yes	Yes	Yes
N	2,244	2,244	2,244	2,244	2,244	2,244	2,244	2,244
R^2	0.037	0.143	0.165	0.165	0.020	0.132	0.151	0.154
Notes:	*p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation.							

Table. 6. Trade and GDP correlation with 10 years time windows - first three time windows

	Corr $GDP^{\text{HP filter}}$				Corr ΔGDP			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(\text{Trade}^{\text{input}})$	0.081^{***}	0.062^{**}	0.071^{**}	0.079^{***}	0.067^{**}	0.034	0.046	0.055^{*}
	(0.030)	(0.028)	(0.028)	(0.028)	(0.030)	(0.029)	(0.029)	(0.029)
$\ln(\text{Trade}^{\text{final}})$	0.014	-0.034	-0.052^{*}	-0.061^{**}	0.001	-0.006	-0.025	-0.034
	(0.026)	(0.028)	(0.029)	(0.029)	(0.026)	(0.029)	(0.030)	(0.030)
$sector_{prox}$				0.677^{***}				0.679^{***}
				(0.170)				(0.173)
$third_{country}$			0.255	0.208			0.337^{*}	0.289^{*}
			(0.174)	(0.170)			(0.174)	(0.171)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Window FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
URSS dum.	No	Yes	Yes	Yes	No	Yes	Yes	Yes
N	2,270	2,270	2,270	2,270	2,270	2,270	2,270	2,270
R^2	0.068	0.222	0.250	0.258	0.033	0.189	0.221	0.229
Notes:	*p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation.							

Table. 7. Trade - GDP correlation with controls for sectoral composition

	Corr $GDP^{HP\ filter}$			Corr ΔGDP		
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(Trade^{input})$	0.057^{**}	0.059^{**}	0.058^{**}	0.044^{*}	0.043^{*}	0.043^{*}
	(0.026)	(0.026)	(0.026)	(0.024)	(0.024)	(0.024)
$\ln(Trade^{final})$	-0.036	-0.045^{*}	-0.045^{*}	-0.018	-0.025	-0.027
	(0.025)	(0.026)	(0.026)	(0.024)	(0.024)	(0.024)
$sector_{prox}$		0.042	-0.058		-0.376^{**}	-0.219^{**}
		(0.181)	(0.115)		(0.175)	(0.110)
$third_{country}$		0.272^{*}	0.282^{*}		0.369^{**}	0.391^{***}
		(0.154)	(0.156)		(0.144)	(0.146)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Window FE	Yes	Yes	Yes	Yes	Yes	Yes
EU + URSS dum.	Yes	Yes	Yes	Yes	Yes	Yes
N	2,520	2,520	2,520	2,520	2,520	2,520
R^2	0.143	0.144	0.145	0.126	0.132	0.132

Notes: *p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation.

main sectors: service and agricultural sectors and we decompose manufacturing sectors into 7 main sub-sectors.[4] We then compute the following index:

$$index\_sector_{ij} = 1 - \frac{1}{2}\sum_{k}\left|share\_GDP_i^k - share\_GDP_j^k\right| \tag{1}$$

where k refers to a particular sector. Pairs of country with very similar sectoral composition have an index close to 1, while countries that completely specialize in different sectors would have an index of 0.

Results are gathered in table 8 and show a positive relationship between trade intensity in inputs and GDP comovement, with a similar magnitude when controlling for third index and sectoral composition. Note that the sample size is drastically reduced when using this data. Results are not significant with this sub-sample using HP-filtered data.

A.3.4 Robustness: log(mean) regressions

In the main text, we constructed the index of trade proximity by taking, for each time window, the average of the log-proximity observed every year. Alternatively, instead of taking the "*mean of log proximity*", we could take the "*log of mean proximity*". We show in table 9 the results using the log transformation on the average trade intensities within each time-windows. As

[4]This includes textile, industry, machinery, chemical, high-tech, food and tabacco, other. Data are available here: `https://databank.worldbank.org/data/source/`.

Table. 8. Trade - GDP correlation with controls for sectoral composition using World Bank data

	Corr GDP$^{\text{HP filter}}$			Corr ΔGDP		
	(1)	(2)	(3)	(4)	(5)	(6)
ln(Trade$^{\text{input}}$)	0.090	0.092	0.088	0.158***	0.164***	0.167***
	(0.059)	(0.060)	(0.056)	(0.055)	(0.054)	(0.053)
ln(Trade$^{\text{final}}$)	0.046	−0.019	−0.044	−0.086*	−0.127**	−0.142***
	(0.047)	(0.049)	(0.047)	(0.046)	(0.052)	(0.052)
$sector_{prox}$			1.587***			0.393
			(0.432)			(0.459)
$third_{country}$			0.954**			0.796*
			(0.422)			(0.469)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Window FE	Yes	Yes	Yes	Yes	Yes	Yes
EU + URSS dum.	Yes	Yes	Yes	Yes	Yes	Yes
N	1,291	1,291	1,291	1,291	1,291	1,291
R^2	0.253	0.292	0.314	0.233	0.283	0.289
Notes:	*p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation.					

compared to results in the paper, the R^2 is slightly lowered. Moreover, notice that given the median increase in trade intensities in intermediate inputs of 5.76 and the estimates reported in column (2), the implied increase in GDP correlation is $log(5.76) * 0.052 = 0.091$, very similar to the case with "*mean of log proximity*" reported in the core paper.

Table. 9. Trade and GDP correlation with 10 years time windows - Trade Proximity constructed as log(mean) (*as opposed to mean(log)*)

	Corr GDP$^{\text{HP filter}}$				Corr ΔGDP			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln(Trade$^{\text{input}}$)	0.044*	0.052**	0.051**	0.052**	0.028	0.036*	0.036*	0.034
	(0.023)	(0.023)	(0.023)	(0.023)	(0.022)	(0.022)	(0.022)	(0.022)
ln(Trade$^{\text{final}}$)	−0.027	−0.034	−0.044*	−0.044*	−0.010	−0.017	−0.029	−0.027
	(0.022)	(0.023)	(0.023)	(0.023)	(0.021)	(0.022)	(0.022)	(0.022)
$sector_{prox}$				0.086				−0.251*
				(0.146)				(0.139)
$third_{country}$			0.337**	0.334**			0.442***	0.450***
			(0.149)	(0.150)			(0.141)	(0.141)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Window FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
URSS + EU dum.	No	Yes	Yes	Yes	No	Yes	Yes	Yes
N	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900
R^2	0.153	0.166	0.169	0.169	0.139	0.151	0.156	0.157
Notes:	*p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation.							

A.3.5 Robustness: alternative bilateral trade data

We also use the STAN Bilateral Trade Database by Industry and End-Use data (BTDIxE).[5] BTDIxE consists of values of imports and exports of goods, broken down by end-use categories. Estimates are expressed in nominal terms, in current US dollars for all OECD member countries. The trade flows are divided into capital goods, intermediate inputs and consumption. For the sake of comparison with the results in the main text, we first group the capital and intermediate goods together and create the index of trade proximity as explained in the main text. Due to data availability, we use the data from 1995 to 2014 which allows us to create four time windows of 5 years each (tables 10 and 11). With 20 countries, the dataset contains 190 pairs, for a total of 760 observations with four time windows. The tables below present the robustness results using both the HP filter (for business cycle frequencies) and then the Baxter and King filter (for medium term frequencies).

Table. 10. Trade and HP-Filtered GDP - STAN database (1995 to 2014)

	dependent variable: corr(GDP_i^{HP},GDP_j^{HP})					
	(1)	(2)	(3)	(4)	(5)	(6)
ln(Trade)	0.064***		-0.009		0.103	
	(5.94)		(-0.14)		(1.53)	
ln($\text{Trade}^{\text{input}}$)		0.044*		0.146*		0.209**
		(1.88)		(1.77)		(2.59)
ln($\text{Trade}^{\text{final}}$)		0.021		-0.152*		-0.107
		(1.06)		(-2.04)		(-1.39)
Country-Pair FE	no	no	yes	yes	yes	yes
Time Trend	no	no	no	no	yes	yes
N	760					

t stat. in parentheses

[5] See at http://www.oecd.org/trade/bilateraltradeingoodsbyindustryandend-usecategory.htm.

Table. 11. Trade and BK-Filtered GDP - STAN database (1995 to 2014)

	dependent variable: corr(GDP_i^{BK},GDP_j^{BK})					
	(1)	(2)	(3)	(4)	(5)	(6)
ln(Trade)	0.075***		0.433***		0.397**	
	(5.23)		(3.86)		(3.16)	
ln($\text{Trade}^{\text{input}}$)		0.115***		0.562***		0.538***
		(3.71)		(3.71)		(3.60)
ln($\text{Trade}^{\text{final}}$)		-0.036		-0.106		-0.122
		(-1.32)		(-0.76)		(-0.83)
Country-Pair FE	no	no	yes	yes	yes	yes
Time Trend	no	no	no	no	yes	yes
N	760					

t stat. in parentheses.

A.4 Trade and GDP components

To better understand the source of the positive association between GDP comovement and trade, we now propose a simple refinement to the empirical analysis performed so far.

We decompose GDP fluctuations into changes in factor supply (labor and capital) and variations of the Solow Residual (SR). A natural question to ask is: if trade is associated with higher GDP correlation, is it also associated with higher synchronization of labor and/or capital movements? This is an important question because its answer should guide our theoretical construction. For example, Johnson (2014) notes that, in a perfectly competitive framework with constant returns to scale, "*real value added depends on productivity and factor inputs alone*". In his framework, when the correlation of technology shocks across countries is independent of trade, then the trade-GDP comovement slope can only be generated by an increased correlation of factor supply.

However, in a framework where the Solow Residual does not only fluctuate due to changes in technology, one should not only focus on the comovement in factor supply. Indeed, as discussed in the core paper, a key element in solving the Trade Comovement Puzzle lies in our recognition that real GDP fluctuations are not restricted to movements in technology, labor and capital.

We examine this issue by running two sets of regressions. We first investigate the relationship between trade and factor supply synchronization. Denoting Corr L_{ijt} and Corr I_{ijt} the correlation of labor and investment between countries i and j at time t, we estimate:

$$\text{Corr L}_{ijt} = \beta_1 \ln(\text{Trade}_{ijt}^{\text{input}}) + \beta_2 \ln(\text{Trade}_{ijt}^{\text{final}}) + \text{controls}_{ijt} + \text{CP}_{ij} + \text{TW}_t + \epsilon_{ijt} \quad (2)$$

$$\text{Corr I}_{ijt} = \beta_1 \ln(\text{Trade}_{ijt}^{\text{input}}) + \beta_2 \ln(\text{Trade}_{ijt}^{\text{final}}) + \text{controls}_{ijt} + \text{CP}_{ij} + \text{TW}_t + \epsilon_{ijt} \quad (3)$$

Second, we construct the Solow Residual for each country as: $SR_{it} = log(RGDP_{it}) - \alpha log(K_{it}) - (1-\alpha)\, log(L_{it})$, with $\alpha = 1/3$. We then compute all country-pair correlations of Solow Residuals for each time window.[6] In line with previous specifications, we estimate:

$$\text{Corr SR}_{ijt} = \beta_1 \ln(\text{Trade}_{ijt}^{\text{input}}) + \beta_2 \ln(\text{Trade}_{ijt}^{\text{final}}) + \text{controls}_{ijt} + \text{CP}_{ij} + \text{TW}_t + \epsilon_{ijt} \quad (4)$$

Table. 12. Trade and SR, K and L correlation with 10 years time windows

	Corr $SR^{\text{HP filter}}$	Corr $I^{\text{HP filter}}$	Corr $L^{\text{HP filter}}$
	(1)	(2)	(3)
$\ln(\text{Trade}^{\text{input}})$	0.059^{**}	0.057^{**}	0.022
	(0.026)	(0.026)	(0.026)
$\ln(\text{Trade}^{\text{final}})$	-0.034	-0.114^{***}	-0.056^{**}
	(0.025)	(0.027)	(0.027)
CP + TW FE	Yes	Yes	Yes
Third country	Yes	Yes	Yes
URSS + EU dum.	Yes	Yes	Yes
N	2,367	2,367	2,367
R^2	0.212	0.262	0.114

Notes: *p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation. SE clustered on country-pairs. SR is computed using PWT 9.1, with $SR = log(rgdpna) - \alpha log(rkna) - (1-\alpha)log(emp)$ and $\alpha = 0.33$. Results are robust to the use of $rnna$ and various values of α. Compared to table **??**, sample is reduced due to lack of observations. Investment I is computed using PWT 9.1 using capital investment in structure, machinery, transport and other investment. We deflate investments using their corresponding price index.

Results in table 15 reveal two key insights for the relationship between trade and real GDP synchronization. First, looking at columns (3), we note that higher trade integration in intermediate inputs is not associated with an increase in labor comovement. We acknowledge that using total employment as a proxy for labor supply is subject to a number of limitations, with issues regarding differences in skills and un-observable hours worked for example. However, this absence of increase in total employment correlation for country-pairs increasing their trade links suggests that models where GDP synchronization is achieved by inducing a strong labor supply reaction to a foreign shock is likely to be at odds with the data. Second, looking

[6]Capital stock and labor are measured using the variable *rkna* and *emp* in the PWT 9.1.

at columns (1) to (2), we note that trade in intermediate inputs is significantly associated with the synchronization of Solow Residual and capital stocks.

Once again, it is important to remember that our panel specifications are not intended to use information about the *level* of GDP comovement across countries, but rather to account for the *change* in GDP comovement when countries are more integrated through trade. Hence, although the *level* of factor supply synchronization is high in the data (as discussed in appendix C.3), this synchronization does not seem to systematically increase with trade proximity. As a result, we argue that an important part of the high value of the observed trade-comovement slope comes from an increase in the synchronization of the Solow Residual, which can arise from a synchronization of aggregate profits.

A.5 Alternative measure of SR correlation

In this robustness, the Solow Residual in the data is constructed using the PWT9.1 using the variables of real GDP (*rgdpo*), real capital stock (*rnna*), total employment (*emp*) and the index of human capital per employee (*hc*), such that: $SR_{ij} = log(rgdpo) - \alpha log(rnna) - (1 - \alpha)log(emp * hc)$, with $\alpha = 1/3$. With this method, we can compute the SR for up to 592 country-pairs over 4 time-windows. Complete results of the trade-SR comovement slope are shown in table 13, where point estimates are positive and significant for intermediate inputs. Results hold for both HP-filter and first difference.

Table. 13. Trade and SR correlation with 10 years time windows, alternative measure

	Corr $SR^{\text{HP filter}}$			Corr ΔSR		
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(\text{Trade}^{\text{total}})$	0.010			0.013		
	(0.012)			(0.012)		
$\ln(\text{Trade}^{\text{input}})$		0.055^{**}	0.066^{***}		0.054^{**}	0.064^{***}
		(0.025)	(0.025)		(0.025)	(0.024)
$\ln(\text{Trade}^{\text{final}})$		-0.044^{*}	-0.044^{*}		-0.040^{*}	-0.040^{*}
		(0.024)	(0.024)		(0.024)	(0.024)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Window FE	Yes	Yes	Yes	Yes	Yes	Yes
URSS + EU dum.	No	No	Yes	No	No	Yes
N	2,367	2,367	2,367	2,367	2,367	2,367
R^2	0.213	0.215	0.235	0.208	0.210	0.228

Notes: *p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation. SE clustered on country-pairs.

Finally, table 14 shows that our results concerning the slope with respect to SR, I and L are somewhat robust to the use of first difference and the use of BK filter. We point out however that the slope with respect to investment and trade in intermediate inputs turns to be not significant using those two filtering procedures.

Table. 14. Trade and SR, I and L correlation with 10 years time windows - Disaggregated trade

	Corr ΔSR	Corr ΔI	Corr ΔL	Corr SR$^{\text{BK filter}}$	Corr I$^{\text{BK filter}}$	Corr L$^{\text{BK filter}}$
	(1)	(2)	(3)	(4)	(5)	(6)
ln(Trade$^{\text{input}}$)	0.044*	0.024	0.001	0.049*	0.009	0.010
	(0.024)	(0.028)	(0.024)	(0.027)	(0.034)	(0.025)
ln(Trade$^{\text{final}}$)	−0.025	−0.140***	−0.011	−0.034	−0.101***	−0.039
	(0.022)	(0.029)	(0.025)	(0.025)	(0.033)	(0.027)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Window FE	Yes	Yes	Yes	Yes	Yes	Yes
Third country	Yes	Yes	Yes	Yes	Yes	Yes
URSS + EU dum.	Yes	Yes	Yes	Yes	Yes	Yes
N	2,367	2,367	2,367	2,367	2,367	2,367
R^2	0.196	0.159	0.132	0.213	0.187	0.125
Notes:	*p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation. SE clustered on country-pairs.					

A.6 The role of the Extensive Margin

A.6.1 EM-IM decomposition using firm-level data

We now use the Exporter Dynamics Database (EDD) from the World Bank and test whether a change in the number of exporters (EM) and a change in the average value added per exporter (IM) are correlated with changes in real GDP comovement. This database provides measures of micro-characteristics of the export sector; number of exporters (their size and growth), their dynamics in terms of entry, exit and survival, and the average unit prices of the products they trade, across 70 countries from 1997 to 2014. Over this time period, we average real GDP (transformed with log and HP-filter) correlations between country-pairs at quarterly frequency over 3 time-windows of 5 years, starting in 1997-Q1.[7] Due to the lack of coverage of the EDD, we use the only reported information of a reference country within a country-pair as direct measure for the EM and the IM.[8] Unfortunately, it is not possible to distinguish trade in intermediate goods and trade in final goods.

We measure the EM using the number of new exporters net of exiting firms between country i and country j, normalized by the total number of exporters. For the IM, we use the

[7]Unfortunately, OECD real GDP at quarterly frequency is not available for all the countries. We therefore reduce the sample. Further details regarding our sample are provided in the online appendix A.1 and robustness exercises are conducted in the online appendix A.4.

[8]For instance, the database contains information about exports from Belgium to many destinations, but there is no information about Belgium's imports. It is therefore not possible to compute symmetric measures.

natural logarithm of the average value added per exporter. We test:

$$\text{Corr GDP}_{ijt} = \beta_1 \left[\frac{\text{Entry - Exit}}{\text{Nb Exp}}\right]_{ijt} + \beta_2 \ln\left(\left[\frac{\text{value}}{\text{exporter}}\right]_{ijt}\right) + \text{CP}_{ij} + \text{TW}_t + \epsilon_{ijt} \tag{5}$$

Table **??**, column (Avg.), summarizes the results. Point estimates imply that an increase of 1% of the number of new net exporters is associated with an increase in real GDP correlation of about 3.5%. On the contrary, we find that the relationship between the IM and GDP correlation is not statistically significant. We then investigate in column (Std.) whether more variability along the extensive and intensive margins are associated with more real GDP correlation within the considered time-windows. We test:

$$\text{Corr GDP}_{ijt} = \beta_1 \ln(\text{std nb exp}_{ijt}) + \beta_2 \ln\left(\left[\text{std } \frac{\text{value}}{\text{exporter}}\right]_{ijt}\right) + \text{CP}_{ij} + \text{TW}_t + \epsilon_{ijt} \tag{6}$$

Results feature a positive and significant relationship between variations in the number of exporters and GDP correlation, while variations along the intensive margin is negatively correlated with GDP comovement.

Table. 15. Cross-country GDP correlations and the margins of trade.

	Corr GDP$^{\text{HP filter}}$	
	(Avg.) specification	(Std.) specification
EM measure	3.480***	0.109*
	(1.285)	(0.065)
IM measure	−0.038	−0.022
	(0.163)	(0.043)
CP + TW FE	Yes	Yes
N	135	135
R^2	0.586	0.558

Notes: *p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation. SE clustered on country-pairs. We use EDD data from 1997 to 2014.
Avg. refers to specifications where we assess the link between GDP comovement and the average of each margin. Std. refers to specifications where we assess the link between GDP comovement and the volatility (standard deviation) of each margin in each configuration.

A.6.2 Robustness: HK decomposition using HS6 classification

In table 16, we provide the results of the estimation performed in section 6 of the paper using the Hummels and Klenow (2005) (HK) decomposition with the HS6 classification. It turns out that our results are consistent with this alternative specification (i.e. the slope is positive with respect to EM and negative with respect to IM). Only results with volatility of the EM measures is statistically significant. This could be due to the fact that we are not able to identify enough variation in the data with only two time windows, since our sample with the HS6 classification started from 1995 to 2006.

Table. 16. Extensive and Intensive margins and GDP correlation with 5 years time windows using HS6

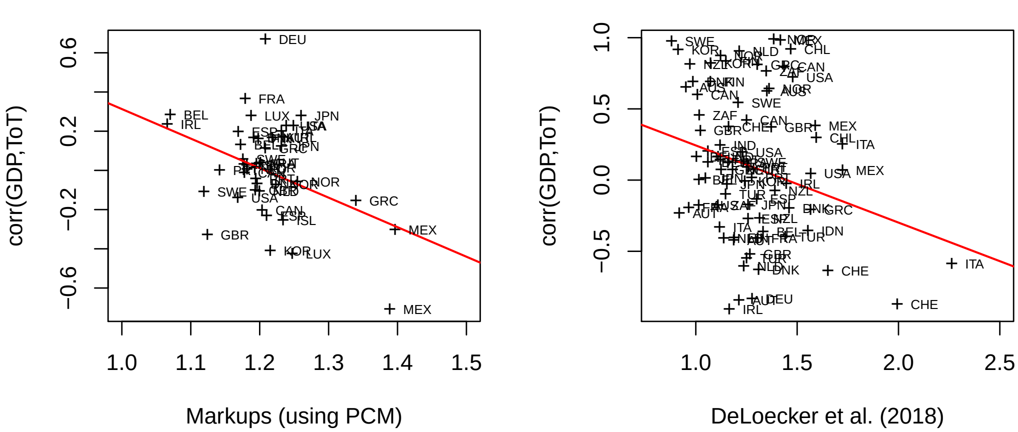
	Corr GDP$^{\text{HP filter}}$		Corr ΔGDP	
	(1)	(2)	(3)	(4)
ln(EM)	0.057		0.059	
	(0.087)		(0.098)	
ln(IM)	-0.103^{**}		-0.204^{***}	
	(0.051)		(0.059)	
ln(std(EM))		0.050^{**}		0.031
		(0.024)		(0.027)
ln(std(IM))		-0.034^{*}		-0.123^{***}
		(0.017)		(0.019)
Country-Pair FE	Yes	Yes	Yes	Yes
Time Window FE	No	Yes	No	Yes
N	1,122	1,122	1,122	1,122
R^2	0.238	0.239	0.209	0.066

Notes: *p<0.1; **p<0.05; ***p<0.01. In parenthesis: std. deviation.

A.7 Markup estimates and Corr GDP-ToT

Figure 2 displays the relationship between $corr(GDP, ToT)$ and markups, measured as PCM (left panel) and using estimates in De Loecker and Eeckhout (2018) (right panel).

Figure 2. Markups and correlation GDP and Terms-of-trade.



B An Economy Without Imported Inputs

In order to clarify the importance of international input-output linkages in generating a link between foreign shocks and domestic productivity, we review the intuitions presented in the paper in a situation with no imported input. In such a case, we show that markups(μ_{nt}) impact the measurement of GDP fluctuations only insofar that they vary over time. In other words, constant markups do not introduce any link between foreign shocks and domestic productivity.

Basic Setup In absence of imported inputs, the production function in country n at time t is directly expressed in value added terms as:

$$Y_{nt} = Z_{nt} K_{nt}^{\alpha} L_{nt}^{1-\alpha}$$

where Y_{nt} is the quantity of goods produced, K_{nt} and L_{nt} are the capital and labor inputs and Z_t is a measure of a country's efficiency at transforming inputs into output. Real GDP change between $t-1$ and t is constructed using previous period prices as base period prices, such that:

$$\widehat{GDP}_{nt} = \frac{P_{nt-1} \Delta Y_{nt}}{P_{nt-1} Y_{nt-1}} = \widehat{Y}_{nt} \approx \widehat{Z}_{nt} + \alpha \widehat{K}_{nt} + (1-\alpha) \widehat{L}_{nt} \tag{7}$$

Equation (7) illustrates that without international input-output linkages, the presence of markups in the base period prices used in RGDP construction does not introduce a term that creates a link between foreign goods and real GDP fluctuation. Keeping the TFP as an exogenous variable, this means that any endogenous change in real GDP in response to a foreign shocks comes from a change in factor supply ($\widehat{K}_{nt}$ or $\widehat{L}_{nt}$). If foreign goods and domestic inputs are complement, domestic real GDP can increase as a response to a positive foreign shock. However, this response is disciplined by the elasticity of factor supply.

Productivity Based on equation (7), we can construct proportional changes in the Solow Residual $\widehat{SR}_{nt}$ as:

$$\widehat{SR}_{nt} = \widehat{GDP}_{nt} - \alpha \widehat{K}_{nt} - (1-\alpha) \widehat{L}_{nt} = \widehat{Z}_{nt}$$

Without international input-output linkages, the negative result from Kehoe and Ruhl (2008) holds both with and without markups: domestic productivity is only driven by domestic technology and does not react to foreign shocks. Note however that despite the fact that μ_{nt} does not appear directly in equation (7), the presence of *variable* markups would have an impact on real GDP through its impact on labor and capital supply.

C Quantitative Appendix

C.1 Benchmark: parameter values

Table. 17. Intermediate shares in 2000 and implied γ_i. *Source:* WIOD

Country	AUS	AUT	CAN	DNK	FRA	DEU	IRL	ITA	JPN	MEX	NLD	ESP	GBR	USA
$1-\gamma_i$	0.32	0.39	0.37	0.38	0.36	0.37	0.31	0.31	0.41	0.44	0.33	0.35	0.36	0.43

Table. 18. Self-employed persons relative to total employment (%)*

Country	AUS	AUT	CAN	DNK	FRA	DEU	IRL	ITA	JPN	MEX	NLD	ESP	GBR	USA
Model $\frac{M}{L}$	34.0	3.1	12.3	10.4	14.9	4.8	15.2	14.6	6.7	11.3	21.4	5.4	11.1	11.9
Data	20.0	13.9	14.7	10.8	15.3	9.7	23.5	28.3	21.5	8.6	11.4	25.4	13.6	12.1

*Data for the US are from the Bureau of Labor Statistics (BLS) in 1994. Data for all the other economies are from the World Bank in 1991. Data for Mexico reports total number of business registered relative to total employment (%).

Table. 19. Working age population: target and associated χ.

Country	AUS	AUT	CAN	DNK	FRA	DEU	IRL	ITA	JPN	MEX	NLD	ESP	GBR	USA
Work. pop.	23	9	36	6	64	81	5	60	127	120	17	46	64	319
χ	8e−3	0.06	4e−3	0.14	1e−3	7e−4	0.16	1e−3	3e−4	5e−4	0.01	2e−3	1e−3	5e−5

C.2 SR measurement and attenuation bias

A possible concern when evaluating the trade-productivity slope is whether the Solow Residual (SR) is properly measured. As is standard, we defined SR such that it captures the change in real GDP ($RGDP$) that are not explained by movements of Labor and Capital. However, Huo et al. (2020) highlighted that such an approach is not perfect, as standard measures of factor inputs might be biased due to the presence of unobserved elements. As discussed in their paper, effective labor used in production might include a level of "unobserved effort" which implies that measures such as hours worked, which is available in standard database, do not accurately describe the effective level of labor input.

To better understand how measurement error can affect our results, we use our model as a data generating process. In particular, we assume that labor input effectively used in production is the combination of an observed factor $\widetilde{L}_{it}$ (for instance, total employment), and an unobserved factor u_{it} (for instance, labor utilization), so that $L_{it} = \widetilde{L}_{it} * u_{it}$. To investigate how the presence of unobserved factors impact our results, we define the "true" and the "mis-measured" Solow Residuals as follows:

$$\text{"True" SR}: \quad SR_{it} \quad = \log(RGDP_{it}) - \alpha \log(L_{it}) - (1-\alpha) * \log(K_{it}) \tag{8}$$

$$\text{"Mis-measured" SR}: \quad SR_{it}^{measured} \quad = \log(RGDP_{it}) - \alpha \log(\widetilde{L}_{it}) - (1-\alpha) * \log(K_{it}) \tag{9}$$

We model the unobserved part of labor input u_{it} as a stochastic variable and assume that it is positively synchronized with technology $Z_{i,t}$, i.e. $cov(Z_{it}, u_{it}) > 0$. This assumption captures the intuition that unobserved labor utilization (or effort level) is likely to co-move with the state of the aggregate economy. An econometrician only observes $\widetilde{L}_{it}$ and hence takes $SR_{it}^{measured}$ as a definition of the Solow Residual, even though it is not an exact measure of SR_{it}. The higher the variance of the unobserved factor u_{it}, the higher the generated measurement error in the evaluation of SR_{it}.

We investigate the consequences of measurement errors due to the presence of an unobserved factor on our results by setting $u_{it} = v_{it} + \mu\epsilon_{it}$, with ϵ_{it} the innovation used in the AR(1) generation of Z_{it} and $v_{it} \sim \mathcal{N}(\bar{v}, \sigma_v^2)$. The parameter μ captures the correlation between the unobserved factor with the aggregate TFP shock and v_{it} introduces additional movements in the unobserved factor that are not linked to the TFP shock. We set $\sigma_v = 0.032$, $\mu = 0.833$ and $\overline{v} = 0.17$. Table 20 provides the results and compares the result of using "true" and "mis-measured" SR in our regressions.

As expected, because L is not used directly in the definition of $RGDP$, the trade-comovement slope with respect to $RGDP$ is not affected by the presence of measurement error, as shown in the first row. More importantly, the presence of a measurement error in labor supply has consequences on both the SR-trade slope (second row) and the $RGDP$-trade slope once controlling for $corr(SR)$ (third row). First, the SR-slope is positive and significant for trade intensity in intermediate inputs, but the point estimate associated with a "mis-measured" SR is lower than its counterpart using the "true" value for SR. This is intuitive: "mis-measured" SR is more noisy than its "true" counterpart, and the cross-country correlation of the SR is lower. As a result, the explanatory power associated with trade in intermediate inputs is reduced. Second, in the third row, we look at the inclusion of $corr(SR)$ as a control in the regression of $corr(RGDP)$ on trade intensity. When $corr(SR)$ is properly measured, its inclusion as a control brings the input-trade slope close to zero. However, when $corr(SR)$ is mis-measured, the input-trade slope is reduced but still remains at 0.01, ten times higher than the point estimate of 0.001 obtained when using "true" $corr(SR)$ as a control. The presence of measurement error generates an attenuation bias which reduces the estimated association between $corr(RGDP)$ and $corr(SR)$. This, in turn, increases the point estimate for input trade. Overall, this analysis highlights that the presence of measurement error can explain why, in our empirical investigation, the inclusion of $corr(SR)$ as a control does not bring the trade slope to zero.

Table. 20. SR-trade comovement with measurement error, using model simulations

	"True" value for SR		With measurement error	
	Input	*Final*	*Input*	*Final*
$corr(RGDP)$ - trade slope	0.056***	0.006***	0.056***	0.006***
$corr(SR)$ - trade slope	0.051***	0.003***	0.045***	0.005***
$corr(RGDP)$ - trade slope, controlling for $corr(SR)$	0.001***	0.003***	0.010***	0.001***

*p<0.1; **p<0.05; ***p<0.01. SE clustered by country-pairs.

C.3 Business cycle properties

In an effort to locate our framework in the broader literature on international business cycles, we report business cycle properties in table 21. By comparing the data in column (1) to different versions of our model in columns (2) to (4), we find that adding extensive margin and price distortions leads to an increase in investment and consumption volatility relative to GDP, while keeping other properties unchanged.

Interestingly, our baseline calibration features a higher cross-country correlation of GDP than consumption, implying that the model is not subject to the Backus et al. (1992)'s consumption correlation puzzle.[9] Another dimension worth looking at is the volatility of extensive margin adjustments as measured by the standard deviation of the (log) number of exporters. Compared to the data, our model tends to be conservative as it slightly underpredicts the volatility of this margin.[10] Columns (5) of table 21 shows the Business Cycle

[9]The so called "BKK consumption correlations puzzle" refers to the fact in standard models, consumption is more correlated across countries than output, which is at odds with the data.

[10]Note that introducing life cycle properties in firms' behavior, such as "long term fixed costs" instead of per-period fixed costs, would only widen the gap with the data as such elements tend to give more persistence to exporting decisions.

properties when the covariance matrix of technology shocks are calibrated using the Solow Residual from Penn World Tables. Such a calibration leads to strong overshooting in terms of GDP, consumption and investment volatility as well as all cross-country correlations. Finally, column (6) displays the properties of a version with complete financial markets. As expected, consumption becomes less correlated with GDP but more synchronized. Interestingly, there is an increase in extensive margin fluctuations, as measured by the standard deviation of the number of exporters.

Table. 21. Business Cycle Statistics: Data and Models.[a]

	Avg std.	Avg Std. relative to Y			Cross-country corr.				Corr. with *RGDP*			
	RGDP	*C*	*I*	*L* [b]	*Y*	*C*	*I*	*L*	Y_{-1}	*C*	*I*	*L*
Data	1.4	1.03	3.21	0.93	0.27	0.16	0.25	0.29	0.84	0.69	0.77	0.60
Baseline	1.4	1.77	3.84	0.23	0.27	0.28	0.29	0.34	0.84	0.97	0.89	0.62

[a] All model-based statistics are computed using log transformation and HP-filter after being deflated by their corresponding price index. Recall that the baseline model targets an international contemporaneous cross correlations of about 0.27 and a GDP auto-correlation of 0.80. All statistics in the data refer to the mean values in the data from 1980Q1 - 1999Q4.
[b] Data from Ohanian and Raffo (2012). We select countries appearing in our model sample.

References

Backus, David K, Patrick J Kehoe, and Finn E Kydland (1992): "International Real Business Cycles," *Journal of Political Economy*, Vol. 100, pp. 745–75.

De Loecker, Jan and Jan Eeckhout (2018): "Global Market Power," Working Paper 24768, National Bureau of Economic Research.

Hummels, David and Peter J. Klenow (2005): "The Variety and Quality of a Nation's Exports," *American Economic Review*, Vol. 95, pp. 704–723.

Huo, Zhen, Andrei A Levchenko, and Nitya Pandalai-Nayar (2020): "Utilization-Adjusted TFP Across Countries: Measurement and Implications for International Comovement," Working Paper 26803, National Bureau of Economic Research.

Johnson, Robert C. (2014): "Trade in Intermediate Inputs and Business Cycle Comovement," *American Economic Journal: Macroeconomics*, Vol. 6, pp. 39–83.

Johnson, Robert C. and Guillermo Noguera (2017): "A Portrait of Trade in Value Added over Four Decades," *The Review of Economics and Statistics*, Vol. 99(5), pp. 896–911.

Kehoe, Timothy J. and Kim J. Ruhl (2008): "Are shocks to the terms of trade shocks to productivity?" *Review of Economic Dynamics*, Vol. 11, pp. 804 – 819.

Ohanian, Lee E and Andrea Raffo (2012): "Aggregate hours worked in OECD countries: New measurement and implications for business cycles," *Journal of Monetary Economics*, Vol. 59, pp. 40–56.

World Bank, WDR team (2019): "World Development Report 2020 — Global Value Chains: Trading for Development," *World Bank*.