Value Added and Productivity Linkages Across Countries

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Motivation

What is the relationship between trade and business cycle synchronization?

Trade Comovement Puzzle (TCP)

- Strong empirical link between *trade* and *GDP comovement*
- The international RBC explains only 10% of the trade-comovement slope

This paper

This paper proposes the first quantitative solution for the TCP

Three main contributions:

1. Uncovers the strong role of trade in intermediates for BC synchronization
2. Quantitative model of International Business Cycle
    - Key ingredients: global value chains, markups and firms entry/exit
    - Calibrate to 15 countries
    - In simulated dataset, matches the empirical Trade-Comovement slope
3. Tests other predictions and finds support for the role of key ingredients
    - Solow Residual comovement increases with trade in intermediate inputs

Literature

Empirics

- Strong empirical link between *trade* and *GDP comovement*

  Frankel and Rose (1998), Baxter and Kouparitsas (2005), di Giovanni and Levchenko (2010), Kalemli-Ozcan et al (2013), Duval et al (2016), di Giovanni, Levchenko and Mejean (2016)

Theory

- International Real Business Cycle

  Backus, Kehoe and Kydland (1994), Ghironi and Melitz (2005), Alessandria and Choi (2007)

- Variants of IRBC investigating the trade-comovement slope

  Kose and Yi (2001, 2006), Kehoe and Ruhl (2008), Burstein, Kurz and Tesar (2008), Arkolakis and Ramanarayanan (2009), Johnson (2014), Liao and Santacreu (2015), Drozd, Kolbin and Nosal (2018)

- Propagation in Network models

  Long and Plosser (1983), Acemoglu et al (2012), Baqaae (2016)

Empirical Motivation

Using 40 countries, data between 1970 and 2009 from Johnson & Noguera (2017):

- Create 4 non-overlapping periods of 10 years (create a *panel*).
- Compute correlation of filtered GDP for each country-pair.
- Construct the (symmetric) index of trade:

$$Trade_{ij}^{\text{input}} = \frac{Trade\_Intermediates_{ij}}{GDP_i + GDP_j} \quad \text{and} \quad Trade_{ij}^{\text{final}} = \frac{Trade\_Final_{ij}}{GDP_i + GDP_j}$$

- Estimate the following equation:

$$\text{corr}(GDP_{it}^{HP}, GDP_{jt}^{HP}) = \alpha_2 + \beta_I \log(\text{Trade}_{ijt}^{\text{input}}) + \beta_F \log(\text{Trade}_{ijt}^{\text{final}}) + controls + \epsilon_{2,ijt}$$

Controls

- **Financial control 1**: FDI data from UNCTAD – *reduces the sample.*

$$FDI\_Control_{ij} = \frac{\text{Total Bilateral FDI}}{GDP_i + GDP_j}$$

- **Financial control 2**: Locational Banking Statistics from BIS – *even smaller sample.*

$$BIS\_Control_{ij} = \frac{\text{Cross Country Claims}}{GDP_i + GDP_j}$$

- **Third Country Exposure** – Similarity index between 0 and 1

$$Third_{country}(i,j) = 1 - \frac{1}{2}\sum_{k \neq i,j} \left| \frac{T_{i\to k} + T_{k\to i}}{\overline{T}_i} - \frac{T_{j\to k} + T_{k\to j}}{\overline{T}_j} \right|$$

$$\overline{T}_i = \sum_k T_{i\to k} + T_{k\to i}$$

- **Country Pair FE** controls for distance, language, etc...
- **Time Window FE** controls for aggregate events moving all bilateral GDP correlations.

Trade Slope – Strong Role for Trade in Intermediates

	corr GDP^{HP}				corr ΔGDP			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln(\text{Trade}^{\text{input}})$	0.050^{***}	0.042^{**}	0.234^{***}	0.261	0.051^{***}	0.050^{***}	0.204^{***}	0.368^{**}
	(0.019)	(0.020)	(0.072)	(0.164)	(0.017)	(0.018)	(0.069)	(0.144)
$\ln(\text{Trade}^{\text{final}})$	-0.022	-0.032^{**}	-0.095^{*}	-0.024	-0.029^{**}	-0.038^{***}	-0.173^{***}	-0.153
	(0.014)	(0.015)	(0.051)	(0.119)	(0.015)	(0.015)	(0.048)	(0.106)
CP FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TW FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Third Index	No	Yes	No	No	No	Yes	No	No
FDI controls	No	No	Yes	No	No	No	Yes	No
BIS controls	No	No	No	Yes	No	No	No	Yes
N	2,296	2,296	733	328	2,296	2,296	733	328
R^2	0.320	0.323	0.503	0.652	0.343	0.347	0.541	0.704

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

Input-Output linkages alone is not sufficient

Consider a small open economy:

- Final good produced using imports x and domestic factors: $y = F(\ell, x)$

GDP is measured using base period prices

$$GDP = p_y^b \cdot y - p_x^b \cdot x$$

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- *Keeping prices at their base value*, GDP change when foreign price rises:

$$\frac{dGDP}{dp_x} = \underbrace{p_y^b F_\ell(\ell, x) \frac{\partial \ell}{\partial p_x}}_{\text{Factor Supply Effect}} + \underbrace{\frac{\partial x}{\partial p_x}(p_y^b F_x(\ell, x) - p_x^b)}_{\text{Input-Output Effect}}$$

- With perfect competition, FOC yields: $p_y^b F_x(\ell, x) = p_x^b$
  $\Rightarrow$ Action comes only from the change in factor supply
  $\Rightarrow$ **Productivity is unchanged** – Kehoe-Ruhl (2008)

Adding New Ingredients

1. **Markups**
   - Mass $\mathcal{M}$ of importers with identical techno. : $m = x$
   - Price wedge: $p_m = \mu \times p_x$

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   - Final good uses a CES bundle of intermediates and domestic factors:
   - $y = F(\ell, \mathcal{I})$ with $\mathcal{I} = \left(\int_0^{\mathcal{M}} m_i^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}$

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GDP change after a foreign shock:

$$\frac{dGDP}{dp_x} = \underbrace{p_y^b F_\ell(\ell, m) \frac{\partial \ell}{\partial p_x}}_{\text{Factor Supply Effect}} + \underbrace{\left(\mathcal{M} \frac{\partial m}{\partial p_x} + \frac{\partial \mathcal{M}}{\partial p_x} m \right) (\mu - 1) p_x^b}_{\text{Markup Effect}} + \underbrace{\frac{1}{\sigma - 1} p_m^b m \frac{\partial \mathcal{M}}{\partial p_x}}_{\text{Entry/Exit Effect}}$$

New ingredients at play

$$\frac{dGDP}{dp_x} = \underbrace{p_y^b F_\ell(\ell, m)\frac{\partial \ell}{\partial p_x}}_{\text{Factor Supply Effect}} + \underbrace{\left(\mathcal{M}\frac{\partial m}{\partial p_x} + \frac{\partial \mathcal{M}}{\partial p_x} m\right)(\mu - 1)\, p_x^b}_{\text{Markup Effect}} + \underbrace{\frac{1}{\sigma - 1} p_m^b m \frac{\partial \mathcal{M}}{\partial p_x}}_{\text{Entry/Exit Effect}}$$

Markup

- GDP is **not** equal to factor payment
- Wedge between marginal cost and marginal benefit of imported inputs

Entry/Exit and Love for Variety

- If $\sigma \neq \infty$, variations of $\mathcal{M}$ change the production possibility frontier.

GDP changes over and beyond factor supply

$\Rightarrow$ foreign shocks impact the Solow residual

Taking Stock

Data

- Trade-Comovement slope is high and significant.
- Trade in intermediate inputs seems to play an important role.

Theory

- Markups and firms' entry/exit make domestic GDP more reactive to foreign shocks

Next: We build a dynamic GE model with:

1. Trade in intermediate inputs
2. Monopolistic competition
3. Adjustments along the extensive margin

$\Rightarrow$ The model replicates more than 85% of the Trade-Comovement slope

Full model - Production side

- Firm with productivity φ in country k uses inputs from all other countries:

$$Q_{i,t}(\varphi) = Z_{i,t}.\varphi \ . \ I_{i,t}(\varphi)^{1-\eta_i-\chi_i} \ . \ \ell_{i,t}(\varphi)^{\chi_i} \ . \ k_{i,t}(\varphi)^{\eta_i}$$

with $$I_{i,t}(\varphi) = \left(\sum_i \omega_i(j)^{\frac{1}{\rho^I}} M_{j,i,t}^{\frac{\rho^I-1}{\rho^I}} \right)^{\frac{\rho^I}{\rho^I-1}}$$

and $$M_{j,i,t} = \left(\int_{s \in \Omega_{j,i,t}} m_{j,i,t}(s)^{\frac{\sigma_i-1}{\sigma_i}} ds \right)^{\frac{\sigma_i}{\sigma_i-1}}$$

- Define matrix $W = (\omega_i(j))_{i,j}$ - **network structure** of input/output linkages

TFP process:

- $\log Z_{k,t} - 1 = \rho_z(\log Z_{k,t-1} - 1) + \epsilon_{k,t}$
- φ distributed according to Pareto-(γ)

Trade Structure

Trade structure

- Trade in Intermediate goods only
- Fixed cost $f_{k,k'}$ and iceberg variable cost $\tau_{kk'}$
- Threshold $\varphi_{k,k'}$ above which firms from k serve market k'

Free Entry – Mass of firms

- Overhead sunk entry cost $f_{E,k}$, before productivity is realized.

Consumers

A representative consumer in each country solves:

$$U_0 = \mathbb{E}_0 \left[\sum_{t=0}^{+\infty} \beta^t \left(\log \left(C_{i,t}^F \right) - \psi_i \frac{L_{i,t}^{1+\nu}}{1+\nu} \right) \right]$$

with $C_{i,t}^F = \left(\sum_j \omega_i^F(j)^{\frac{1}{\rho^F}} \cdot C_{j,i,t}^{\frac{\rho^F - 1}{\rho^F}} \right)^{\frac{\rho^F}{\rho^F - 1}}$ and $C_{j,i,t} = \left(\int_{s \in \Omega_{j,i,t}^F} c_{j,i,t}(s)^{\frac{\sigma_i - 1}{\sigma_i}} ds \right)^{\frac{\sigma_i}{\sigma_i - 1}}$

s.t. $P_{k,t} \left(C_{k,t} + K_{k,t+1} - (1-\delta) K_{k,t} \right) = w_{k,t} L_{k,t} + r_{k,t} K_{k,t}$

Closing the model

- **Firms' prices** depend on the price of all firms
- **Revenues** depend on every customers' revenues
- **Entry thresholds** for every market-pair defined as productivity that equates variable profit and entry cost
- Usual Labor Maket equilibrium and Euler Equation

More

GDP definition

Using double deflation, GDP is defined from the production side as:

$$GDP_{k,t} = \underbrace{\widehat{\mathcal{P}^{ss}_{k}} \frac{X_{k,t}}{\widehat{\mathcal{P}_{k,t}}}}_{\text{Final Good consumed at Home}} + \underbrace{\sum_{k'} \widehat{\mathcal{P}^{ss}_{k,k'}} \frac{T_{k\to k',t}}{\widehat{\mathcal{P}_{k,k',t}}}}_{\text{Exports}} - \underbrace{\sum_{k'} \widehat{\mathcal{P}^{ss}_{k',k}} \frac{T_{k'\to k,t}}{\widehat{\mathcal{P}_{k',k,t}}}}_{\text{Imports}}$$

- Statistical agencies do not account for variety effect when constructing price indexes (Feenstra (1994)).
- Define BEA-consistent price indexes as:

$$\widehat{\mathcal{P}_{k,k'}} = \left(M_k . \varphi_{k,k'}^{-\gamma}\right)^{1/(\sigma-1)} \mathcal{P}_{k,k'}$$

Network Propagation

Lemma: In the special case with $\rho = 1$ and fixed factors supply (no dynamics), the elasticities of **Gross National Income** $(=C + I)$ in all countries w.r.t. a techno shock in country 1 are the solutions of:

$$\begin{pmatrix} \eta_{GNI_1,Z_1} \\ \vdots \\ \eta_{GNI_N,Z_1} \end{pmatrix} = (\mathcal{I}_N - (1-\eta-\chi)W - T)^{-1} \begin{pmatrix} 1 \\ 0 \\ \vdots \end{pmatrix}$$

- T the "Transmission" matrix function of γ and σ:
  $T = \Lambda \mathcal{I}_N$, with $\Lambda = \frac{1}{\sigma + \frac{(\sigma-1)^2}{\gamma-(\sigma-1)}}$

Calibration

Mix of micro and macro calibration:

Table: Fixed parameters taken from the literature.

Parameter	Symbol	Value	Moment / Source
A. Common Parameters			
Discount factor	β	0.99	Annual discount rate of 4%
Labor curvature	ν	1.0	Frisch elasticity of 1.0
Labor share	$\frac{\chi_i}{(\chi_i+\eta_i)}$	2/3	67% of domestic value added
Macro elast. of subst.	ρ^I, ρ^F	1.0	Saito (2004), Feenstra et al (2014)
Micro elast. of subst.	$\sigma_i, \forall i$	5.0	Markup: 25%, profit: 17.4%
B. Country Specific Parameters			
Sunk entry cost	f_i^E / f_{US}^E	[0.4 - 3.9]	*Doing Business* - World Bank
Fixed trade cost	f_{ij}^c / f_{US}^E	[1.7 - 5.3]	*Doing Business* - World Bank
Iceberg trade cost	τ_{ij}	[1 - 2.8]	ESCAP - World Bank
Pareto shape	γ_i	$\sigma_i - 0.4$	Fattal-Jaef and Lopez (2014)

Calibration

Table: **Calibrated parameters.**

Parameter	Symbol	Value	Main target
A. Steady states			
Inputs spending weights	$\omega_i^I(j)$	in appendix	Import shares in inputs
Final goods spending weights	$\omega_i^F(j)$	in appendix	Import shares in final goods
Trade imbalance	$\{\mathcal{T}_i, ..., \mathcal{T}_N\}$	in appendix	Trade imbalance over GDP
B. Simulation: TFP process			
Persistency of TFP shocks	ρ_Z	0.785	Avg. GDP auto-correlation
Std. of TFP shocks	$\sigma_Z(i)$	$[0.0024, 0.0057]$	GDP volatility (de-trended)
Covariance of TFP shocks	$\sigma_Z(i,j), \forall i \neq j$	0.19	Avg. GDP correlation 0.27

Quantitative Exercise

Goal: As in the empirical exercise, use *within country pair variations* to estimate the trade comovement slope.

1. Calibrate to 14 countries and the Rest of the World
2. Simulate a sequence of country-specific shocks Z_k
3. Vary "home bias" +/- 10% *separately* for intermediate and final goods.
4. Apply the *same* shocks in the new economy
   This creates a **Panel Dataset**
5. Perform Fixed-Effect regression on simulated dataset

Baseline Results

Trade Comovement Slope in Intermediates vs. Final goods.

		Corr $GDP_{ij}^{\text{HP filter}}$				
		Data		Model		
		(1)	(2)	(3)	(4)	(5)
Trade index measure				Bench.	$\rho^F = 1$	$\rho^F = 1.05$	$\rho^F = .95$
$\left(\frac{Trade_{ij}+Trade_{ij}}{GDP_i+GDP_j}\right)$	$\ln(Trade_{Input})$	0.054**	0.053**	0.051***	0.067***	0.064***
	$\ln(Trade_{Final})$	0.003	-0.030	0.017***	0.006***	0.023***
$\max\left(\frac{Trade_{ij}}{GDP_i}, \frac{Trade_{ij}}{GDP_j}\right)$	$\ln(Trade_{Input})$	0.066***	0.048**	0.052***	0.068***	0.065***
	$\ln(Trade_{Final})$	-0.015	-0.032	0.016***	0.003*	0.021***
Country FE		Yes	Yes	Yes	Yes	Yes
Time windows FE		No	Yes	-	-	-

*p<0.1; **p<0.05; ***p<0.01.

Decomposition - Role of the ingredients

Table: Decomposition of the roles of markups and the extensive margin.

Model	Benchmark $\rho^F = 1$		High elasticity $\rho^F = 1.05$	
	TCP - Slope [a]		TCP - Slope [a]	
	Input	*Final*	*Input*	*Final*
Data (with CP + TW)	0.053**	-0.030	0.053**	-0.030
I/O linkages + Markups + EM	0.051***	0.017***	0.067***	0.006***
I/O linkages + Markups	0.024***	0.005***	0.026***	0.002***
I/O linkages	0.007***	0.006***	0.007***	0.004***

*p<0.1; **p<0.05; ***p<0.01.

[a]The trade indexes used in those experiments are $(Trade_{ij} + Trade_{ij})/(GDP_i + GDP_j)$.

$\Rightarrow$ **Markups and Entry/Exit play a key role in getting the results.**

Quantitative Results: Sensitivity Analysis

				TC - slope	
Experiment	Elasticity	Markup	GDP corr	*Inter. inputs*	*Final goods*
Data (CP and TW)	-	-	0.270	0.053**	-0.030
Baseline	$\sigma = 5.0$	25%	0.270	0.050***	0.017***
High markups	$\sigma = 4.0$	33%	0.284	0.080***	0.024***
Low markups	$\sigma = 6.0$	20%	0.255	0.039***	0.014***
Het. markups, PCM	$\sigma_i \in [3.20, 5.65]$	26%	0.270	0.051***	0.017***
Het. markups, DeL. & E. (2018)	$\sigma_i \in [3.68, 6.07]$	26%	0.277	0.055***	0.018***

Other Robustness Checks

Experiment	Parameter change	TC - slope *Inter. inputs*	TC - slope *Final goods*
Baseline	-	0.051***	0.017***
A. Model parameters			
High pareto shape	$\gamma_i = \sigma_i - 0.3$	0.051***	0.017***
Low pareto shape	$\gamma_i = \sigma_i - 0.5$	0.051***	0.017***
Low Frisch elasticity	$\nu = 0.75$	0.066***	0.024***
High Frisch elasticity	$\nu = 1.25$	0.041***	0.013***
B. Productivity process			
PWT TFP shocks	$\widetilde{\sum}$	0.048***	0.015***
Uncorrelated TFP shocks	$cov(Z_i, Z_j) = 0$	0.023***	0.008***
C. Trade imbalance			
No trade imbalance	$\mathcal{T}_i = 0,\ \forall i$	0.050***	0.017***
D. Reference period *for* $\{\omega^I, \omega^F\}$			
Cobb-Douglas $\rho^F = 1.0$	1990-2000	0.088***	0.034***
CES specification $\rho^F = 1.05$	1990-2000	0.119***	0.012**

Trade and the Synchronization of the Solow Residual

Construct Solow Residual from simulated dataset as:

$$SR_{it} = log(GDP_{it}) - \left(\frac{\eta_i}{\eta_i + \chi_i}\right) log(K_{it}) - \left(\frac{\chi_i}{\eta_i + \chi_i}\right) log(L_{it}) \qquad (SR.1)$$

$$\Delta SR_{it} = \Delta log(GDP_{it}) - \left(\frac{\eta_i}{\eta_i + \chi_i}\right) \Delta log(K_{it}) - \left(\frac{\chi_i}{\eta_i + \chi_i}\right) \Delta log(L_{it}) \qquad (SR.2)$$

		Exact TFP (Z)		*Solow Residual (SR)*			*Trade-TFP slope*	
		corr	ACF	corr	ACF	$\frac{\sigma_{SR}}{\sigma_Z}$	*inputs*	*final*
Data (PWT)				0.240	0.637		0.044*	-0.025
Baseline ($\sigma = 5.0$)	(*SR*.1)	0.198	0.785	0.248	0.751	1.317	0.037***	0.005***
	(*SR*.2)	0.197	-0.114	0.245	-0.119		0.037***	0.005***
High markup ($\sigma = 4.0$)	(*SR*.1)	0.198	0.785	0.287	0.739	1.231	0.065***	0.010***
	(*SR*.2)	0.197	-0.114	0.281	-0.121		0.064***	0.011***
Low markup ($\sigma = 6.0$)	(*SR*.1)	0.198	0.785	0.233	0.759	1.545	0.026***	0.003***
	(*SR*.2)	0.197	-0.114	0.230	-0.118		0.026***	0.004***

The role of Markups

Lower markups associated with lower GDP sensitivity to foreign shocks

	$Corr(ln(GDP_i^{HP}), ln(ToT_i^{HP}))$				
	Data				Model
Markup measure	PCM [a]		DeL & E. (2018)		
Markup index	-1.507**	-2.650**	-0.542**	-0.778*	-0.665***
	(0.557)	(0.911)	(0.234)	(0.417)	(0.104)
Country FE	Yes	Yes	Yes	Yes	Yes
Time windows FE	No	Yes	No	Yes	-
N	43	43	80	80	98
R^2	0.151	0.322	0.064	0.164	0.330

- Price Cost Margin from STAN, 22 countries and 2 time windows.
- DL&E estimates, 29 countries and 3 time windows.
- ToT defined as import deflator divided by export deflator.

Strong Impact of the Extensive Margin

	Corr $GDP_{ijt}^{HP\ filter}$						
	HK decomposition		EDD measures				Model
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\ln(EM_{ijt}^{HK})$	0.098***	0.055***					
	(0.019)	(0.021)					
$\ln(IM_{ijt}^{HK})$	−0.015	−0.008					
	(0.017)	(0.017)					
$\left[\frac{\text{Entry - Exit}}{\text{Nb Exp}}\right]_{ijt}$			1.756*	3.051***			
			(0.934)	(1.043)			
$\ln\left(\left[\frac{value}{exporter}\right]_{ijt}\right)$			0.520***	−0.334**			
			(0.109)	(0.135)			
$\ln(\text{std nb exp}_{ijt})$					0.044	0.094**	
					(0.042)	(0.038)	
$\ln\left(\left[\text{std } \frac{value}{exporter}\right]_{ijt}\right)$					0.035	−0.116***	
					(0.048)	(0.037)	
$\ln(EM_{ijt})$							0.051***
							(0.008)
$\ln(IM_{ijt})$							-0.015***
							(0.006)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Window FE	No	Yes	No	Yes	No	Yes	-
N	2580	2580	157	157	157	157	455
R^2	0.021	0.099	0.226	0.459	0.020	0.447	0.247

Conclusions

Trade-Comovement relationship updated and refined.

- Strong role for trade in intermediates

First Quantitative solution for the Trade Comovement Puzzle with:

1. Global supply chains (network of I/O linkages)
2. Monopolistic pricing (markups)
3. Extensive margin adjustment (+ love for variety)

$\Rightarrow$ The model matches the observed TC slope thanks to those ingredients.

Validation

- Markups and Extensive margin play a role in the data
- Trade synchronizes *Solow Residual* fluctuations