Putting the Parts Together: Trade, Vertical Linkages, and Business Cycle Comovement

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Motivation

- Stronger bilateral trade linkages are associated with higher aggregate comovement
  - Frankel and Rose (1998), many others since: country pairs that trade more with each other have more correlated business cycles
- Trade has increased exponentially the last few decades. Increase is due not only to a reduction in barriers, but also a change in the production structure (Yi 2003)
- The mechanisms behind the trade-comovement regularity are not well understood

Motivation

- **Empirically,** debate about the role of intra-industry trade and sectoral similarity in accounting for the impact of trade on comovement
  - intra-industry trade: Koo and Gruben (2006), Calderon et al. (2007)
  - sectoral similarity: Imbs (2004), but not Baxter and Kouparitsas (2005)
- **Quantitatively,** the IRBC models have trouble matching the magnitude of the Frankel-Rose result ("trade-comovement puzzle"), and latest work emphasizes vertical linkages
  - Kose and Yi (2001, 2006), Huang and Liu (2007), Burstein, Kurz, and Tesar (2007)
- Currently, no disaggregated empirical evidence regarding the role of production structure, intra-industry trade, and input-output linkages

This Paper

- Examines the link between bilateral trade, sectoral comovement, and aggregate comovement using sector-level data on production and trade
- Uses Input-Output matrices to gauge the magnitude of vertical production linkages for the role of trade in increasing comovement
- Quantifies the relative importance of the various channels in generating aggregate comovement
  - Intra- vs. Inter-industry comovement
  - Input-Output linkages

Preview of Results

1. Trade at sector level has a robust positive effect on comovement at sector level
2. Intra-industry comovement-trade elasticity larger than inter-industry one, but intra-industry can only explain a small portion of aggregate effect: Within-Sector: 18%; Cross-Sector: 82%
3. Strong evidence that vertical production linkages are quantitatively important. Vertical linkages explain almost 30% of the overall impact of bilateral trade on comovement
4. Comovement-trade elasticity larger for North-North country pairs, but the relative role of vertical linkages in explaining this elasticity is larger for North-South pairs (17% vs. 56%)

Business Cycle Comovement

- Aggregate growth in two countries c and d, each comprised of $i, j = 1, \ldots, \mathcal{I}$ sectors:

$$y^c = \sum_{i=1}^{\mathcal{I}} s_i^c y_i^c \qquad y^d = \sum_{j=1}^{\mathcal{I}} s_j^d y_j^d$$

- Business cycle (aggregate) covariance is then:

$$\begin{aligned} \text{Cov}(y^c, y^d) &= \text{Cov}\left(\sum_{i=1}^{\mathcal{I}} s_i^c y_i^c, \sum_{j=1}^{\mathcal{I}} s_j^d y_j^d \right) \\ &= \sum_{i=1}^{\mathcal{I}} \sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \text{Cov}\left(y_i^c, y_j^d \right) \end{aligned}$$

Business Cycle Comovement

- Or, rewritten in terms of correlations:

$$\rho^{cd} = \frac{1}{\sigma^c \sigma^d} \sum_{i=1}^{\mathcal{I}} \sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d \rho_{ij}^{cd},$$

where σ^c and σ^d are the standard deviations of aggregate growth in the two countries, while σ_i^c and σ_j^d are the standard deviations of the growth rates in individual sectors i and j in countries c and d respectively

Estimating Equations

- Instead of examining the LHS of this identity, we use sector-level data to study the components of the RHS:

1. Baseline specification:

$$\rho_{ij}^{cd} = \alpha + \beta_1 \text{Trade}_{ij}^{cd} + \mathbf{u} + \varepsilon_{ij}^{cd}$$

2. Intra- vs. Inter-industry effect:

$$\rho_{ij}^{cd} = \alpha + \beta_1 \text{Trade}_{ij}^{cd} + \beta_2 \mathbf{1}_{[i=j]} \text{Trade}_{ij}^{cd} + \mathbf{u} + \varepsilon_{ij}^{cd}$$

Vertical Linkages

- We would like to exploit variation in the extent to which a sector uses other sectors as intermediates in production
- Hypothesis: trade increases comovement more in sectors that use each other as intermediates.

3. Vertical Linkages and Comovement

$$\rho_{ij}^{cd} = \alpha + \beta_1 \text{Trade}_{ij}^{cd} + \gamma_1 \left(\text{IO}_{ij} \text{Exports}_i^{cd} + \text{IO}_{ji} \text{Exports}_j^{dc} \right) + \mathbf{u} + \varepsilon_{ij}^{cd}$$

4. Vertical Linkages Within and Across Sectors

$$\begin{aligned} \rho_{ij}^{cd} = \alpha &+ \beta_1 \text{Trade}_{ij}^{cd} + \gamma_1 \left(\text{IO}_{ij} \text{Exports}_i^{cd} + \text{IO}_{ji} \text{Exports}_j^{dc} \right) \\ &+ \beta_2 \mathbf{1}_{[i=j]} \text{Trade}_{ij}^{cd} + \gamma_2 \left(\mathbf{1}_{[i=j]} \text{IO}_{ij} \text{Exports}_i^{cd} \right. \\ &\left. + \mathbf{1}_{[i=j]} \text{IO}_{ji} \text{Exports}_j^{dc} \right) + \mathbf{u} + \varepsilon_{ij}^{cd} \end{aligned}$$

Trade Measures

- Exports between the country-sector pairs normalized by output or total trade:

$$\text{Trade}_{ij}^{cd} = \log\left(\frac{1}{T}\sum_t \frac{X_{i,t}^{cd} + X_{j,t}^{dc}}{Y_t^c + Y_t^d}\right) \quad \text{(Measure I)}$$

$$\text{Trade}_{ij}^{cd} = \log\left(\frac{1}{T}\sum_t \frac{X_{i,t}^{cd} + X_{j,t}^{dc}}{Y_{i,t}^c + Y_{j,t}^d}\right) \quad \text{(Measure II)}$$

$$\text{Trade}_{ij}^{cd} = \log\left(\frac{1}{T}\sum_t \frac{X_{i,t}^{cd} + X_{j,t}^{dc}}{(X_t^c + M_t^c) + (X_t^d + M_t^d)}\right) \quad \text{(Measure III)}$$

$$\text{Trade}_{ij}^{cd} = \log\left(\frac{1}{T}\sum_t \frac{X_{i,t}^{cd} + X_{j,t}^{dc}}{(X_{i,t}^c + M_{i,t}^c) + (X_{j,t}^d + M_{j,t}^d)}\right) \quad \text{(Measure IV)}$$

Estimation and Data

- Rich set of fixed effects to account for omitted variables
  - importer and exporter effects + sector effects
  - importer×exporter: control for aggregate comovement, financial links, gravity determinants of trade, etc.
  - sector-pair effects: control for sector characteristics, as well as arbitrary relationships between each pair of sectors.
- Sector-level production data: UNIDO
  - Construct correlations of country-sector pair growth rates over 1970–99
  - Industrial production index
  - Also HP-filtered value added: results are robust
- Bilateral trade: World Trade Data Feenstra et.al. (2005)
- 55 countries; 1970-1999; 28 manufacturing sectors, plus total manufacturing (ISIC Rev. 2)

Input-Output Matrix

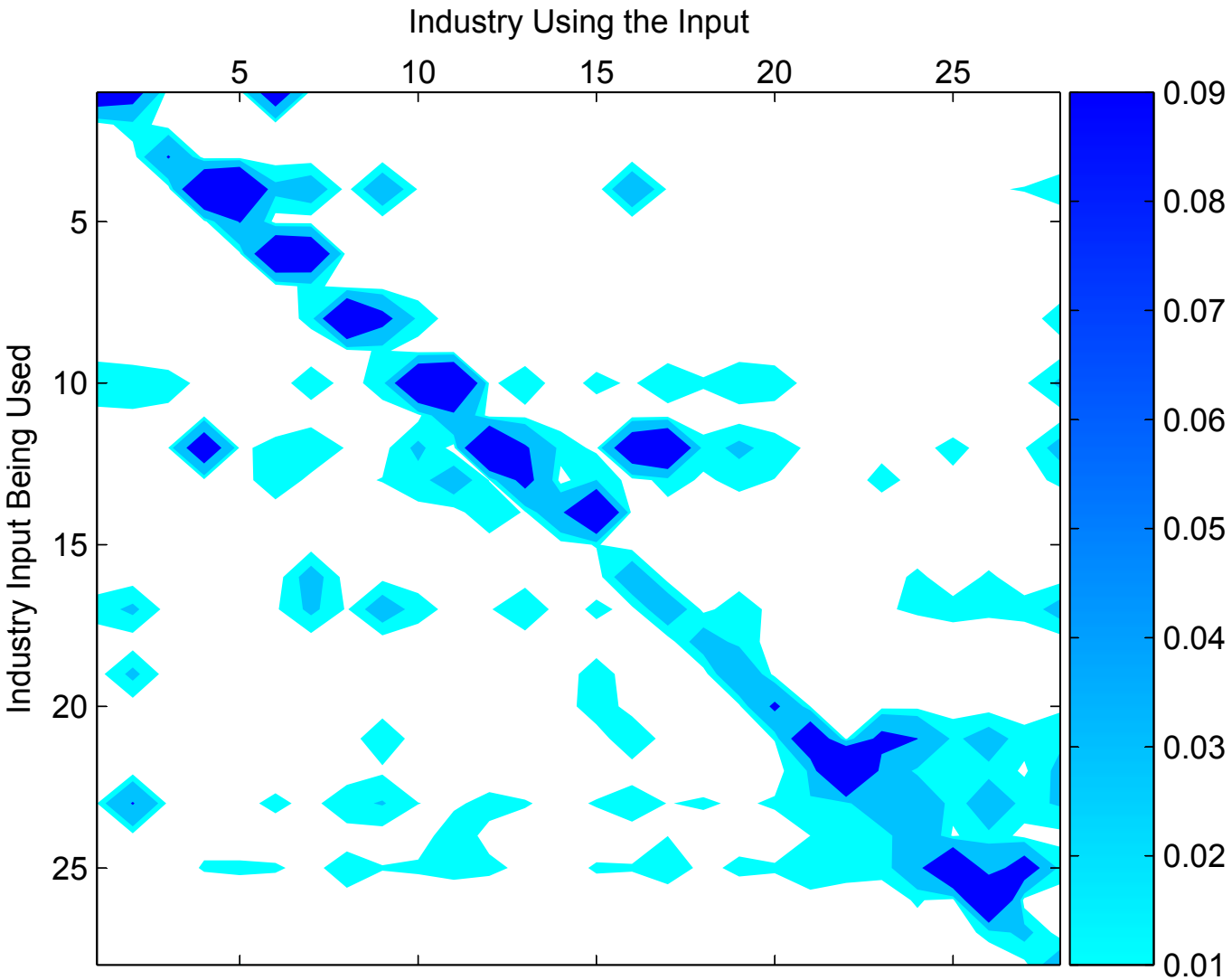
- Input-output data: U.S. Bureau of Economic Analysis 1997 Benchmark version. Aggregate up to 3-digit ISIC Rev. 2
- We build a *Direct Requirements Table* at the 3-digit ISIC Revision 2 level from the detailed *Make* and *Use* tables and a concordance between the NAICS and the ISIC classifications
- The (i, j)th cell in the *Direct Requirements Table* gives the amount of a commodity in row i required to produce one dollar of final output in column j
- Note: we also experimented with country-specific I-O tables sourced from GTAP. Less disaggregated (17 sectors), but results were robust

Sample Summary Statistics for the Manufacturing Sector: 1970–99

Sample	Average correlation	Trade/GDP
Full	0.115	0.0011
OECD/OECD	0.397	0.0036
non-OECD/non-OECD	0.065	0.0011
OECD/non-OECD	0.091	0.0005

Notes: Average correlation is the sample average of bilateral correlation of manufacturing output growth. Trade/GDP is sample average of the share of total bilateral sectoral trade of two countries to their GDP.

Contour Representation of the BEA Input-Output Matrix for 28 Manufacturing Sectors



GDP vs. Total Manufacturing Correlations

	GDP Correlation		
	Trade/ GDP	*Trade/ Output*	*Trade/ Total Trade*
	(1)	(2)	(4)
β	0.018**	0.016**	0.020**
	(0.004)	(0.003)	(0.004)
Observations	1967	1967	1967
R^2	0.383	0.383	0.385
	Manufacturing Sector Correlation		
	Trade/ GDP	*Trade/ Output*	*Trade/ Total Trade*
	(1)	(2)	(4)
β	0.014**	0.014**	0.016**
	(0.004)	(0.003)	(0.004)
Observations	1496	1496	1496
R^2	0.465	0.467	0.467

Notes: All specifications include importer and exporter effects
** significant at 1% level

Impact of Trade on Comovement at the Sector-Level

Dependent variable: ρ_{ij}^{cd}

	(1)	(2)	(3)	(4)
Trade	0.0015**	0.0013**	0.0012**	0.0011**
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Trade×Same Sector	–	0.0037**	–	0.0016**
	–	(0.0003)	–	(0.0005)
Trade×IO	–	–	0.0242**	0.0239**
	–	–	(0.0015)	(0.0025)
Trade×Same Sector×IO	–	–	–	–0.0073^{+}
	–	–	–	(0.0040)
Observations	653,588	653,588	653,588	653,588
R^2	0.173	0.173	0.173	0.173

Note: All specifications use Trade/GDP and country- and sector-pair effects. ** significant at 1% level, $^{+}$ significant at 10% level

Impact on the Aggregate Comovement

- What effect does each of these estimated channels have on the aggregate comovement?
- Aggregate comovement (from above):

$$\rho^{cd} = \frac{1}{\sigma^c \sigma^d} \sum_{i=1}^{\mathcal{I}} \sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d \rho_{ij}^{cd}$$

- The regressions map the change in bilateral sector-level trade to the change in bilateral sector-level correlation, so consider impact of sector-level change on the aggregate:

$$\Delta\rho^{cd} = \frac{1}{\sigma^c \sigma^d} \sum_{i=1}^{\mathcal{I}} \sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d \Delta\rho_{ij}^{cd}$$

Impact on the Aggregate Comovement

- We can use the three main sets of estimates to examine how $\Delta \text{Trade}_{ij}^{cd}$ impacts $\Delta \rho_{ij}^{cd}$:
  1. Baseline:

$$\Delta \rho_{ij} = \beta_1 \times \Delta \text{Trade}_{ij}^{cd},$$

and

$$\Delta \rho^{cd} = \frac{1}{\sigma^c \sigma^d} \sum_{i=1}^{\mathcal{I}} \sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d \Delta \rho_{ij}$$

  2. Within- and Cross-Sector:

$$\Delta \rho_{ij} = \beta_1 \times \Delta \text{Trade}_{ij}^{cd}$$

$$\Delta \rho_{ii} = (\beta_1 + \beta_2) \times \Delta \text{Trade}_{ij}^{cd}$$

and

$$\Delta \rho^{cd} = \underbrace{\frac{1}{\sigma^c \sigma^d} \sum_{i=1}^{\mathcal{I}} s_i^c s_i^d \sigma_i^c \sigma_i^d \Delta \rho_{ii}}_{\text{Within-Sector Component}} + \underbrace{\frac{1}{\sigma^c \sigma^d} \sum_{i=1}^{\mathcal{I}} \sum_{j \neq i}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d \Delta \rho_{ij}}_{\text{Cross-Sector Component}}$$

Impact on the Aggregate Comovement (2)

3. Vertical Linkages:

$$\Delta\rho_{ij} = \beta_1 \times \Delta \text{Trade}_{ij}^{cd} + \gamma_1 \times (\text{IO}_{ij} + \text{IO}_{ji}) \times \Delta \text{ Trade}_{ij}^{cd}$$

and

$$\Delta\rho^{cd} = \underbrace{\frac{1}{\sigma^c\sigma^d}\sum_{i=1}^{\mathcal{I}}\sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d \beta_1 \Delta \text{Trade}_{ij}^{cd}}_{\text{Main Effect}} + \underbrace{\frac{1}{\sigma^c\sigma^d}\sum_{i=1}^{\mathcal{I}}\sum_{j=1}^{\mathcal{I}} s_i^c s_j^d \sigma_i^c \sigma_j^d (\text{IO}_{ij} + \text{IO}_{ji}) \gamma_1 \Delta \text{Trade}_{ij}^{cd}}_{\text{Vertical Linkage Effect}}$$

Impact of Trade on Aggregate Comovement: Baseline, Within vs. Cross-Sector, and Vertical Linkage Estimates

Specification	Total Effect		
Baseline: Pooled			
$\Delta\rho_A$	0.032		
	(0.002)		
Separate Within- and Cross-Sector Coefficients		Cross-Sector Component	Within-Sector Component
$\Delta\rho_A$	0.034	0.0274	0.0061
	(0.002)	(0.0020)	(0.0004)
Share of Total		**0.82**	**0.18**
Vertical-Linkage Interaction		Main Effect	Vertical Linkage Effect
$\Delta\rho_A$	0.035	0.025	0.010
	(0.002)	(0.002)	(0.001)
Share of Total		**0.71**	**0.29**

Impact on Aggregate Comovement: Main Effect vs. Vertical Linkage Estimates for Subsamples

	OECD/OECD		
	Total Effect	Main Effect	Vertical Linkage Effect
$\Delta\rho_A$	0.103	0.086	0.018
	(0.005)	(0.005)	(0.001)
Share of Total		**0.83**	**0.17**
	non-OECD/non-OECD		
	Total Effect	Main Effect	Vertical Linkage Effect
$\Delta\rho_A$	0.031	0.029	0.002
	(0.005)	(0.005)	(0.001)
Share of Total		**0.94**	**0.06**
	OECD/non-OECD		
	Total Effect	Main Effect	Vertical Linkage Effect
$\Delta\rho_A$	0.008	0.004	0.004
	(0.003)	(0.003)	(0.001)
Share of Total		**0.44**	**0.56**

Conclusion

- Stronger bilateral trade linkages are associated with higher aggregate comovement, but the mechanisms behind this fact are not well understood.
  - Previous literature emphasized the role of intra-industry trade and vertical linkages
- This paper: takes aggregate comovement apart into its sector-level building blocks, then puts them back together
  - Intra-industry trade is important, but within-sector comovement only explains about 18% of the total impact;
  - Vertical linkages explain about 29% of the impact of trade on comovement
- Evidence on vertical linkages accords well with the recent quantitative studies that model transmission of shocks through production chains
- BUT, some 70% of the overall estimated impact is still "unexplained" by vertical linkages...