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)

- **Quantitatively,** the IRBC models have trouble matching the magnitude of the Frankel-Rose result (“trade-comovement puzzle”), and latest work emphasizes vertical linkages

- 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 $i, j = 1, \ldots, I$ sectors:

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

- Business cycle (aggregate) covariance is then:

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

$$= \sum_{i=1}^{I} \sum_{j=1}^{I} s_i^c s_j^d \text{Cov} \left( y_i^c, y_j^d \right)$$
• Or, rewritten in terms of correlations:

\[ \rho_{cd} = \frac{1}{\sigma_c \sigma_d} \sum_{i=1}^{I} \sum_{j=1}^{I} s_i^c s_j^d \sigma_i^c \sigma_j^d \rho_{ij}^{cd}, \]

where \( \sigma_c \) and \( \sigma_d \) are the standard deviations of aggregate growth in the two countries, while \( \sigma_i^c \) and \( \sigma_j^d \) are the standard deviations of the growth rates in individual sectors \( i \) and \( j \) in countries \( c \) and \( d \) respectively.
Estimating Equations

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

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   1. Baseline specification:

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

   2. Intra- vs. Inter-industry effect:

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

\[
\rho_{ij}^{cd} = \alpha + \beta_1 \text{Trade}_{ij}^{cd} + \gamma_1 \left( IO_{ij} \text{Exports}_{i}^{cd} + IO_{ji} \text{Exports}_{j}^{dc} \right) + u + \epsilon_{ij}^{cd}
\]

4 Vertical Linkages Within and Across Sectors

\[
\rho_{ij}^{cd} = \alpha + \beta_1 \text{Trade}_{ij}^{cd} + \gamma_1 \left( IO_{ij} \text{Exports}_{i}^{cd} + IO_{ji} \text{Exports}_{j}^{dc} \right) \\
+ \beta_2 \mathbf{1}_{[i=j]} \text{Trade}_{ij}^{cd} + \gamma_2 \left( \mathbf{1}_{[i=j]} IO_{ij} \text{Exports}_{i}^{cd} \\
+ \mathbf{1}_{[i=j]} IO_{ji} \text{Exports}_{j}^{dc} \right) + u + \epsilon_{ij}^{cd}
\]
Trade Measures

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

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

(Measure I)

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

(Measure II)

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

(Measure III)

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

(Measure IV)
Estimation and Data

- Rich set of fixed effects to account for omitted variables
  - importer and exporter effects + sector effects
  - importer \times 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

<table>
<thead>
<tr>
<th>Sample</th>
<th>Average correlation</th>
<th>Trade/GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>0.115</td>
<td>0.0011</td>
</tr>
<tr>
<td>OECD/OECD</td>
<td>0.397</td>
<td>0.0036</td>
</tr>
<tr>
<td>non-OECD/non-OECD</td>
<td>0.065</td>
<td>0.0011</td>
</tr>
<tr>
<td>OECD/non-OECD</td>
<td>0.091</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Trade/ GDP (1)</th>
<th>Trade/ Output (2)</th>
<th>Trade/ Total Trade (4)</th>
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</thead>
<tbody>
<tr>
<td>β</td>
<td>0.018**</td>
<td>0.016**</td>
<td>0.020**</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.003)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.383</td>
<td>0.383</td>
<td>0.385</td>
</tr>
</tbody>
</table>

#### Manufacturing Sector Correlation

<table>
<thead>
<tr>
<th></th>
<th>Trade/ GDP (1)</th>
<th>Trade/ Output (2)</th>
<th>Trade/ Total Trade (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>β</td>
<td>0.014**</td>
<td>0.014**</td>
<td>0.016**</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.003)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>Observations</td>
<td>1496</td>
<td>1496</td>
<td>1496</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.465</td>
<td>0.467</td>
<td>0.467</td>
</tr>
</tbody>
</table>

Notes: All specifications include importer and exporter effects

** significant at 1% level
**Impact of Trade on Comovement at the Sector-Level**

Dependent variable: $\rho_{ij}^{cd}$

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trade</strong></td>
<td>0.0015**</td>
<td>0.0013**</td>
<td>0.0012**</td>
<td>0.0011**</td>
</tr>
<tr>
<td></td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
</tr>
<tr>
<td><strong>Trade \times Same Sector</strong></td>
<td>–</td>
<td>0.0037**</td>
<td>–</td>
<td>0.0016**</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>(0.0003)</td>
<td>–</td>
<td>(0.0005)</td>
</tr>
<tr>
<td><strong>Trade \times IO</strong></td>
<td>–</td>
<td>–</td>
<td>0.0242**</td>
<td>0.0239**</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>(0.0015)</td>
<td>(0.0025)</td>
</tr>
<tr>
<td><strong>Trade \times Same Sector \times IO</strong></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–0.0073$^+$</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>(0.0040)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>653,588</td>
<td>653,588</td>
<td>653,588</td>
<td>653,588</td>
</tr>
<tr>
<td><strong>$R^2$</strong></td>
<td>0.173</td>
<td>0.173</td>
<td>0.173</td>
<td>0.173</td>
</tr>
</tbody>
</table>

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):

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

- 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:

\[
\Delta \rho^{cd} = \frac{1}{\sigma^c \sigma^d} \sum_{i=1}^{I} \sum_{j=1}^{J} s_i^c s_j^d \sigma_i^c \sigma_j^d \Delta \rho_{ij}^{cd}
\]
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:

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

and

$$\Delta \rho_{cd}^{ij} = \frac{1}{\sigma_c \sigma_d} \sum_{i=1}^{I} \sum_{j=1}^{I} \sigma_i^c \sigma_i^d \Delta \rho_{ij}$$

  2. Within- and Cross-Sector:

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

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

and

$$\Delta \rho_{cd}^{ij} = \frac{1}{\sigma_c \sigma_d} \sum_{i=1}^{I} \sigma_i^c \sigma_i^d \Delta \rho_{ii} + \frac{1}{\sigma_c \sigma_d} \sum_{i=1}^{I} \sum_{j \neq i} \sigma_i^c \sigma_i^d \Delta \rho_{ij}$$

Within-Sector Component

Cross-Sector Component
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

$$\Delta \rho_{cd} = \frac{1}{\sigma^c \sigma^d} \sum_{i=1}^{I} \sum_{j=1}^{I} s^c_i s^d_j \sigma^c_i \sigma^d_j \beta_1 \Delta \text{Trade}_{ij}^{cd}$$

Main Effect

$$+ \frac{1}{\sigma^c \sigma^d} \sum_{i=1}^{I} \sum_{j=1}^{I} s^c_i s^d_j \sigma^c_i \sigma^d_j (\text{IO}_{ij} + \text{IO}_{ji}) \gamma_1 \Delta \text{Trade}_{ij}^{cd}$$

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

<table>
<thead>
<tr>
<th>Specification</th>
<th>Total Effect</th>
<th>Cross-Sector Component</th>
<th>Within-Sector Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline: Pooled</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \rho_A$</td>
<td>0.032</td>
<td>0.0274</td>
<td>0.0061</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.0004)</td>
</tr>
<tr>
<td>Share of Total</td>
<td>0.82</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>Separate Within- and Cross-Sector Coefficients</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \rho_A$</td>
<td>0.034</td>
<td>0.025</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Share of Total</td>
<td>0.71</td>
<td>0.29</td>
<td></td>
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</table>
## Impact on Aggregate Comovement: Main Effect vs. Vertical Linkage Estimates for Subsamples

<table>
<thead>
<tr>
<th>Subsample</th>
<th>Total Effect</th>
<th>Main Effect</th>
<th>Vertical Linkage Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OECD/OECD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \rho_A$</td>
<td>0.103</td>
<td>0.086</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Share of Total</td>
<td><strong>0.83</strong></td>
<td></td>
<td><strong>0.17</strong></td>
</tr>
<tr>
<td><strong>non-OECD/non-OECD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \rho_A$</td>
<td>0.031</td>
<td>0.029</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Share of Total</td>
<td><strong>0.94</strong></td>
<td></td>
<td><strong>0.06</strong></td>
</tr>
<tr>
<td><strong>OECD/non-OECD</strong></td>
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<td></td>
</tr>
<tr>
<td>$\Delta \rho_A$</td>
<td>0.008</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Share of Total</td>
<td><strong>0.44</strong></td>
<td></td>
<td><strong>0.56</strong></td>
</tr>
</tbody>
</table>
• 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...