Production Networks and International Fiscal Spillovers

Michael B. Devereux\textsuperscript{1} Karine Gente\textsuperscript{2} Changhua Yu\textsuperscript{3}

\textsuperscript{1}University of British Columbia \textsuperscript{2}Aix Marseille School of Economics \textsuperscript{3}CCER, Peking University

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Motivation

- Increasing importance of fiscal policy in macroeconomics
  - Zero lower bound
  - Eurozone, single currency areas
- Cross country effects of fiscal policy becoming critical
  - Large country effects on exchange rates, interest rates
  - Stimulus effects across borders in the Eurozone
- Large body of evidence on impacts of monetary policy
- Understanding spillovers of fiscal policy more difficult
  - Identification
  - Channels of transmission
Starting point

- Large empirical and theoretical literature on fiscal spillovers
- Empirical evidence: Spillovers can be large, depending on identification strategy
- Theory - suggests small spillovers, given size of trade openness at aggregate level
- But recent evidence suggests that production linkages between countries can have important implications for aggregate comovements
  - Even controlling for overall trade openness
- This paper looks at importance of production networks in accounting for macro spillovers across countries
- Here we will focus on the implications for fiscal spillovers but can be thought of as representing general characteristics of spillovers of demand shocks
In the paper

- A model with K countries and $N_k$ sectors per country
- We measure allocation of spending across sectors for firms, governments and private consumption using data from WIOD
- We show analytically that with a) a symmetric network, b) balanced fiscal expansion across countries: the fiscal multiplier is independent of the network
- But the own and spillover multiplier effects of country-specific shocks depend sensitively on network interconnections
- Using WIOD, we find negative spillovers across France and Germany
Plan of Presentation

- Basic model of production networks in DSGE
- Simplified model with analytical results
- Fiscal spillovers and network interconnections through numerical examples
- Some evidence on importance of production networks for European countries
- Application using WIOD
The model

- Each country has $N_K$ sectors.
- Use $i$ or $n$ to denote a country and $j$ or $k$ for a sector.
- Sector $j$ in country $i$ has a measure of $h_{ij} > 0$ and $\sum_{j=1}^{K} h_{ij} = 1$.
- Production:
  \[
  Y_{ijt} = A_{ijt} L_{ijt}^{\alpha_j} M_{ijt}^{1-\alpha_j}
  \]
  \[
  M_{ijt} = \left[ \sum_{n=h}^{f} \sum_{k=1}^{K} \omega_{ijnk} Y_{ijnkt}^{1-\frac{1}{\gamma}} \right]^{\frac{1}{\gamma-1}}
  \]
- $\sum_{n=h}^{f} \sum_{k=1}^{K} \omega_{ijnk} = 1$. $\gamma$ is the elasticity of substitution between input varieties. $Y_{ijnkt}$ is the input of type $k$ in country $n$ used for production of sector $j$ in country $i$. 
Preferences

- Expected utility,

\[ E_0 \sum_{t=0}^{+\infty} \rho_i^t (1 - L_{it})^\lambda \left( \frac{C_{it}^{1-\sigma} - 1}{1 - \sigma} \right) \]  \quad (3)

with \( C_{it} \) has a CES form over goods produced by domestic and foreign firms,

\[ C_{it} = \left[ \sum_{n=h}^{f} \sum_{k=1}^{K} \omega_{cink} C_{ink}^{1-\frac{1}{\gamma}} \right]^{\gamma-1} \]  \quad (4)

where \( \sum_{n=h}^{f} \sum_{k=1}^{K} \omega_{cink} = 1. \)
Policy

- Lump-sum tax
- Government expenditure composite $G_{it}$ has a CES form over goods produced by domestic and foreign firms,

$$G_{it} = \left[ \sum_{n=h}^{f} \sum_{k=1}^{K} \omega_{gink} G_{ink}^{\frac{1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}$$  \hspace{1cm} (5)

where $\sum_{n=h}^{f} \sum_{k=1}^{K} \omega_{gink} = 1$. 

Some special cases

- Assume Cobb Douglas elasticities of substitution across intermediates
- Also Cobb Douglas preferences with $\beta_i$ denoting preference for good $i$
- Assume no trade in assets (financial autarky)
- How does the network structure affect the impacts of fiscal policy?
Conditions: $N$ sectors; $N_h$ home and $N - N_h$ foreign

Goods market

$$p_iy_i = \sum_{j=1}^{N} (1 - \alpha_j)\omega_{ji}p_jy_j + \beta_{ih}E_h + \beta_{if}E_f + p_ig_i$$

$i = 1..N$

$$E_f = \sum_{i=N_h+1}^{N} p_i(y_i(1 - \sum_{j=1}^{N}(1 - \alpha_i)\omega_{ij}) - g_i)$$
Conditions

Home labor markets (normalize home wage to 1)

\[
\frac{\lambda}{1 - \sum_{i=1}^{N_h} p_i y_i \alpha_i} = \frac{1}{E_h}
\]

Foreign labor market with foreign wage \(w_f\)

\[
\frac{\lambda}{1 - w_f \sum_{i=N_h+1}^{N} p_i y_i \alpha_i} = \frac{w_f}{E_f}
\]
Prices determined by marginal cost

Pricing equations home:

\[ p_i = \Lambda_i \Pi_{j=1}^{N} p_j^{(1-\alpha_i)\omega_{ij}}, \quad i = 1..N_h \]

Pricing equations foreign:

\[ p_i = \Lambda_i w_f^{\alpha_i} \Pi_{j=1}^{N} p_j^{(1-\alpha_i)\omega_{ij}}, \quad i = N_h + 1..N \]

2N+3 conditions in \( p_i, y_i, i = 1..N, E_h, E_f, \) and \( w_f. \)
The network structure and fiscal policy

- Does the effect of government spending shocks on Home and Foreign GDP depend on the network?
First Result

- With a) a symmetric network, b) balanced fiscal expansion across countries: the fiscal multiplier is independent of the network.

Simple Proof:
Now let $Y_i \equiv p_i y_i$, and $G_i \equiv p_i g_i$
So we get:

$$Y_i = \sum_{j=1}^{N} a_{ji} Y_j + \beta_i \frac{1 - \sum_{i=1}^{n_1} Y_i \alpha_i}{\lambda} + \beta_i^* \frac{w^* - \sum_{i=n+1}^{N} Y_i \alpha_i}{\lambda} + G_i, \ i = 1..N$$
First Result

Write in matrix form:

\[
Y = \text{diag}(1 - \alpha)A'Y + \frac{\beta_h}{\lambda} + \frac{\beta_f}{\lambda}w_f \\
- \frac{1}{\lambda} \beta_h (1 - \alpha_h)'Y - \frac{1}{\lambda} \beta_f (1 - \alpha_f)'Y + G
\]

- \( Y = [Y_1..Y_N]' = [Y_1..Y_{Nh}, Y_{Nh+1}..Y_N]' \)
- \( \beta_h = [\beta_{ih}..\beta_{Nh}]', \beta_f = [\beta_{if}..\beta_{Nf}]' \)
- \( 1 - \alpha_h = [1 - \alpha_1..\alpha_{Nh}, 0_{N_f}]', 1 - \alpha_f = [0_{Nh}, \alpha_{Nh+1}..1 - \alpha_N]' \)
- \( 1 - \alpha = [1 - \alpha_1..1 - \alpha_N]' \)
Irrelevance of the network

- With symmetry
- \( A = A' \), rows of \( A \) sum to 1, \( \beta_i = \frac{1}{N}, w_f = 1 \)
- so

\[
Y_i \alpha = \frac{2}{N} + \lambda G \frac{1}{1 + \lambda}
\]

- Multiplier is \( \frac{\lambda}{1+\lambda} \), independent of network effects.
General determination of nominal spending outcomes

\[ Y = M^{-1} \left( \frac{\beta_h}{\lambda} + \frac{\beta_f}{\lambda} w_f + G \right) \]

\[ M = [I - \text{diag}(1 - \alpha)A' + \frac{1}{\lambda} \beta (1 - \alpha_h)' + \frac{1}{\lambda} \beta_f (1 - \alpha_f)'] \]

- where \( M \) is the ‘influence matrix’
- In general, with
  - non-symmetric matrix \( A \),
  - differences in preferences \( \beta \),
  - country specific shocks
- Network will matter for multiplier effects and spillovers
Let’s go through some examples

- Example 1: One sector in each country
- Simple network linkages:

\[ A = \begin{pmatrix} \omega_{11} & \omega_{12} \\ \omega_{21} & \omega_{22} \end{pmatrix} \]
Equations for value added

\[ y_1(1 - \omega_{11} - \omega_{12}) = \frac{w_2 - (1 - \omega_{21} - \omega_{22})\omega_{12}}{1 - \omega_{11}(1 - \omega_{22} - \omega_{12}\omega_{21})} + \lambda g_1 (1 + \lambda) \]

\[ y_2(1 - \omega_{21} - \omega_{22}) = \frac{\omega_{21}(1 - \omega_{11} - \omega_{12})}{1 - \omega_{11}(1 - \omega_{22} - \omega_{12}\omega_{21})} + \lambda g_2 (1 + \lambda) \]

- \( w_2 \) = foreign wage. This represents terms of trade
- Note again if \( w_2 = 1 \), network is irrelevant
- Also, if \( \omega_{12} = 0 \) (\( \omega_{21} = 0 \)), then no spillovers from foreign (home) to home (foreign)
- Spillovers depend on impact of \( g \) on terms of trade
Response of the terms of trade

\[ \hat{w}_2 = \left[ \frac{\lambda}{(1 - \omega_{11} - \omega_{12})(1 + \lambda)} - \frac{1}{(1 - \omega_{11}) + \omega_{12}} \right] \frac{dg_1}{\bar{y}_1} \]

- If \( \omega_{12} = 0 \) (home doesn’t use foreign inputs), then terms of trade appreciates (\( \hat{w}_2 < 0 \)), and spillover is negative.
- But when \( \omega_{12} \) is positive and big enough, terms of trade will depreciate, spillover is positive.
Example 2: 5 sectors in each country

Look at increasing sequences of interconnectivity

\[
A(1) = \begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}
\]

\[
A(2) = \begin{pmatrix}
0.5 & 0.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.5 & 0.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots \\
0.5 & 0.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.5
\end{pmatrix}
\]

\[
A(10) = \begin{pmatrix}
0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 \\
0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 \\
\vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots \\
0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 \\
0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 \\
\vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots \\
0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1
\end{pmatrix}
\]
Balanced shocks on both countries

Same G-shock in the 10 sectors: the network is irrelevant
Balanced home shocks

Home country expansion (sectors 1 to 5): network matters
More complex network interaction 2

- Example 3: 6 sectors in each country
- Look at different sequences of interconnectivity

\[ A(1) = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 1 \end{pmatrix} \]

\[ A(2) = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 1 \\ 0 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 0 \end{pmatrix} \]
No matter the sector in which the government spend... when sectors are not connected
But in case sectors are connected...

Spending in sector 1 is better for multiplier
But in case sectors are connected...

Spending in sector 6 is better for spillover
More complex interactions 3: A central sector

- Example 3: Central Sectors
- Sectors 5 (home) and 6 (foreign) are central
- Sector 5 (6) linked to sector 6 (5)
More complex interactions 3: A central sector

Spending in sector 1 increases the multiplier effect.
More complex interactions 3: A central sector

Spending in sector 5 increases the spillover effect
Introducing financial constraints

- Assume DRS so that

\[ y_i = \left( \ell_i^{\alpha_i} \left( \prod_{j=1}^{N} \omega_{ij} \right)^{1-\alpha_i} \right)^{\eta_i} \]

- Input financing constraint

\[ w\ell_i + \sum_{j=1}^{N} p_j x_{ij} \leq \phi_i p_i y_i \]

- How do financial constraints impact on the multiplier
- How do they interact with the network linkages?
Balanced Expansion - networks enhance (home) constrained country
Home Fiscal Expansion - constraints reduce effect of networks
World Input - Output Database

- A time-series of world input output tables which covers 43 countries plus the rest of the world over the period 2000-2014.
- A set of national input output tables connected with each other by bilateral international trade flows.
- The WIOTs have an industry by industry format and provide details for 56 industries mostly at the two-digit ISIC rev. 3 level.
- We consider a two country example with France and Germany dealing with 54 sectors.
World Input - Output Database construction

<table>
<thead>
<tr>
<th>Supply from country-industries</th>
<th>Use by country-industries</th>
<th>Final use by countries</th>
<th>Total use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country 1</td>
<td>Industry 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>...</td>
<td>Industry N</td>
<td></td>
</tr>
<tr>
<td>Country M</td>
<td>Industry 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>...</td>
<td>Industry N</td>
<td></td>
</tr>
<tr>
<td>Value added by labour and capital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross output</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Timmer et al. (2015)
France-Germany 54-sector network - Measure of node importance

- Indegree: Number of incoming edges to each node
- Outdegree: Number of outgoing edges from each node
- Closeness: Average number of hops from a node to the rest of the network
- Betweenness measures how frequently a node appears on the shortest path between two nodes
- Pagerank measures a node’s influence on the network
France-Germany 54-sector network

- Two asymmetric structures
- In Germany 51 sectors have a Betweenness indicator higher than 5 against 0 in France!

<table>
<thead>
<tr>
<th>Measures for Year 2013</th>
<th>France</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Node</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indegree</td>
<td>101.38</td>
<td>105.72</td>
</tr>
<tr>
<td>Outdegree</td>
<td>100.20</td>
<td>106.9</td>
</tr>
<tr>
<td>Incloseness</td>
<td>0.0088</td>
<td>0.0092</td>
</tr>
<tr>
<td>Outcloseness</td>
<td>0.0088</td>
<td>0.0093</td>
</tr>
<tr>
<td>Betweenness</td>
<td>2.40</td>
<td>6.41</td>
</tr>
<tr>
<td>PageRank</td>
<td>0.009</td>
<td>0.0095</td>
</tr>
</tbody>
</table>
Now use WIOD numbers

- France-Germany 54 sectors in each country
- Again use the simple static Cobb-Douglas model

<table>
<thead>
<tr>
<th>Results Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiplier</td>
</tr>
<tr>
<td>Balanced</td>
</tr>
<tr>
<td>France</td>
</tr>
<tr>
<td>Germany</td>
</tr>
</tbody>
</table>
Conclusion

▶ We show analytically that with symmetric networks (and same preferences), the structure of the network has no effect on the multiplier in case of a balanced fiscal policy.
▶ In case of asymmetric networks, when connection increases between sectors, the multiplier effect decreases and the spillovers may become positive.
▶ We extend this setting in a multi-country DSGE model with DRS and financial frictions.