Production Networks and International Fiscal Spillovers

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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 identifcation 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:

$$Y_{ijt} = A_{ijt} L_{ijt}^{\alpha_j} M_{ijt}^{1-\alpha_j} \tag{1}$$

$$M_{ijt} = \left[\sum_{n=h}^{f} \sum_{k=1}^{K} \omega_{ijnk}^{\frac{1}{\gamma}} Y_{ijnkt}^{1-\frac{1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}} \tag{2}$$

- $\sum_{n=h}^{f} \sum_{k=1}^{K} \omega_{ijnk} = 1$. γ 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,

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

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

$$C_{it} = \left[\sum_{n=h}^{f} \sum_{k=1}^{K} \omega_{cink}^{\frac{1}{\gamma}} C_{inkt}^{1-\frac{1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}} \tag{4}$$

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,

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

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 β_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

$$p_i y_i = \sum_{j=1}^{N} (1-\alpha_j)\omega_{ji} p_j y_j + \beta_{ih} E_h + \beta_{if} E_f + p_i g_i$$

$$i = 1..N$$

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

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:

$$\mathbf{Y} = \text{diag}(1-\alpha)A'\mathbf{Y} + \frac{\beta_{\mathbf{h}}}{\lambda} + \frac{\beta_{\mathbf{f}}}{\lambda}\mathbf{w_f}$$

$$-\frac{1}{\lambda}\beta_{\mathbf{h}}(\mathbf{1}-\alpha_{\mathbf{h}})'\mathbf{Y} - \frac{\mathbf{1}}{\lambda}\beta_{\mathbf{f}}(\mathbf{1}-\alpha_{\mathbf{f}})'\mathbf{Y} + \mathbf{G}$$

- $\mathbf{Y} = [Y_1..Y_N]' = [Y_1..Y_{N_h}, Y_{N_{h+1}}..Y_N]'$
- $\beta_h = [\beta_{ih}..\beta_{Nh}]'$, $\beta_f = [\beta_{if}..\beta_{Nf}]'$,
- $1-\alpha_h = [1-\alpha_1..\alpha_{N_h}, 0_{N_f}]'$, $1-\alpha_f = [0_{N_h}, \alpha_{N_{h+1}}..1-\alpha_N]'$
- $1-\alpha = [1-\alpha_1..1-\alpha_N]'$

Irrelevance of the network

- With symmetry
- $A = A'$, rows of A sum to 1, $\beta_i = \frac{1}{N}$, $w_f = 1$,
- so
$$Y_i \alpha = \frac{\frac{2}{N} + \lambda G}{1 + \lambda}$$
.
- Multiplier is $\frac{\lambda}{1+\lambda}$, independent of network effects.

General determination of nominal spending outcomes

$$\mathbf{Y} = M^{-1}\left(\frac{\beta_{\mathbf{h}}}{\lambda} + \frac{\beta_{\mathbf{f}}}{\lambda}w_f + \mathbf{G}\right)$$

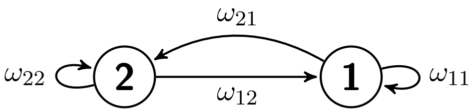
$$M = [I - \text{diag}(1-\alpha)A' + \tfrac{1}{\lambda}\beta(\mathbf{1}-\alpha_{\mathbf{h}})' + \tfrac{1}{\lambda}\beta_{\mathbf{f}}(\mathbf{1}-\alpha_{\mathbf{f}})']$$

- where M is the 'influence matrix'
- In general, with
  - non-symmetric matrix A,
  - differences in preferences β,
  - 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

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

$$y_2(1-\omega_{21}-\omega_{22}) = \frac{w_2^{\frac{\omega_{21}(1-\omega_{11}-\omega_{12})}{(1-\omega_{11})(1-\omega_{22})-\omega_{12}\omega_{21}}} + \lambda g_2}{(1+\lambda)}$$

- 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 ω_{12} is positive and big enough, terms of trade will depreciate, spillover is positive.

More complex network interaction 1

- Example 2: 5 sectors in each country
- Look at increasing sequences of interconnectivity

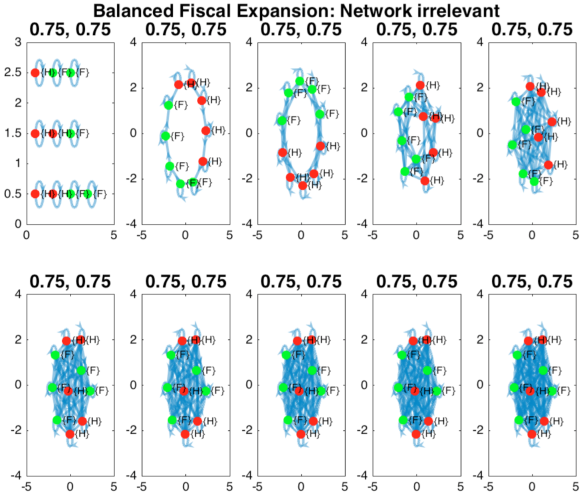
$$A(1) = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0\ldots & & & & & & \\ . & & & & & & & & & \\ 0 & & & & & & & .. & 0 & 1 \end{pmatrix}$$

$$A(2) = \begin{pmatrix} 0.5 & 0.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.5 & 0.5 & 0\ldots & & & & & & \\ . & & & & & & & & & \\ 0.5 & & & & & & & .. & 0 & 0.5 \end{pmatrix}$$

$$\vdots$$

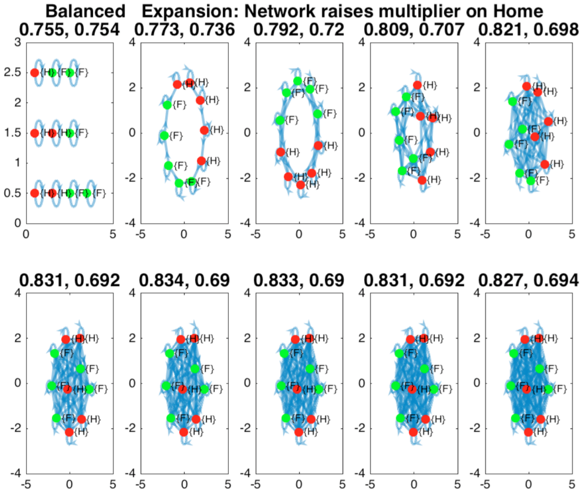
$$A(10) = \begin{pmatrix} 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 & 0.1 \\ 0.1 & 0.1 & 0.1 & 0.1\ldots & & & & & & \\ . & & & & & & & & & \\ 0.1 & & & & & & & .. & 0.1 & 0.1 \end{pmatrix}$$

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

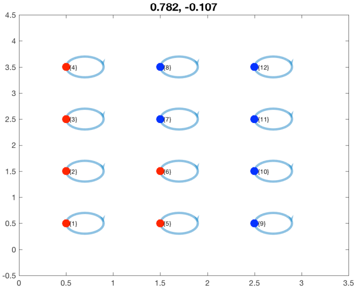
More complex network interaction 2

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

$$A(1) = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0\ldots & & & & & & & & \\ . & & & & & & & & & & & \\ 0 & & & & & & & \ldots & 0 & 0 & 0 & 1 \end{pmatrix}$$

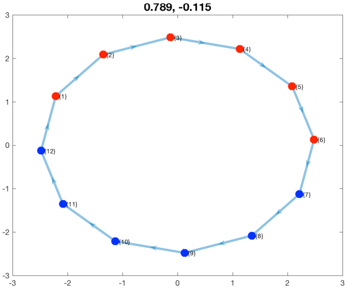
$$A(2) = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0\ldots & & & & & & & & \\ . & & & & & & & & & & & \\ 0 & & & & & & & .. & 0 & 0 & 1 & 0 \end{pmatrix}$$

No matter the sector in which the government spend...



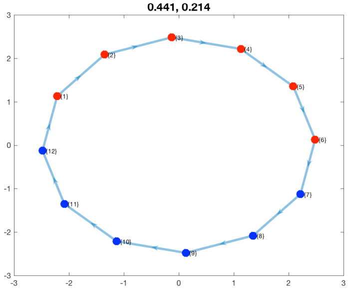
when sectors are not connected

But in case sectors are connected...



Spending in sector 1 is better for multiplier

But in case sectors are connected...

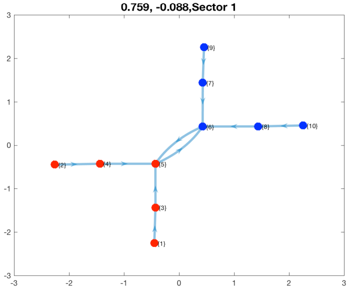


Spending in sector 6 is better for spillover

More complex interactions 3: A central sector

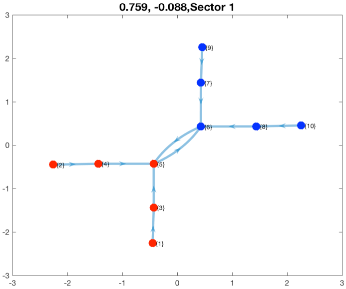
- Example 3: Central Sectors
- Sectors 5 (home) and 6 (foreign) are central
- Sector 5 (6) linked to sector 6 (5)

More complex interactions 3: A central sector



Spending in sector 1 increases the mutlplier effect

More complex interactions 3: A central sector



Spending in sector 5 increases the spillover effect

Introducing financial constraints

- Assume DRS so that

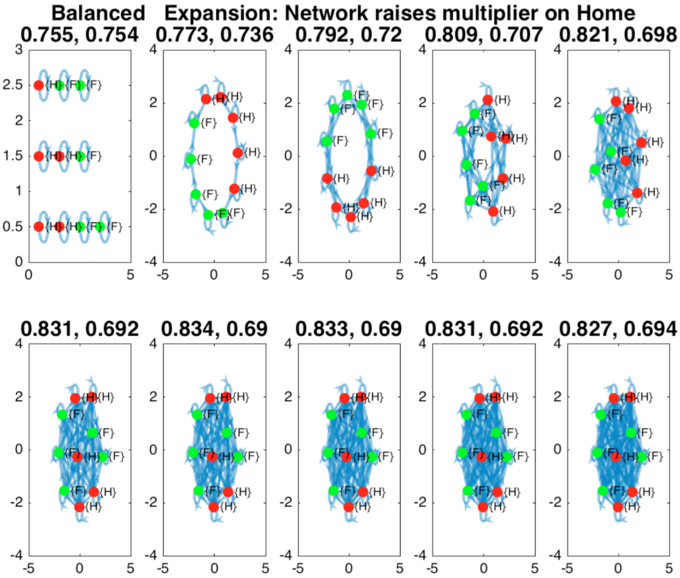
$$y_i = \left(\ell_i^{\alpha_i} (\Pi_{j=1}^N x_{ij}^{\omega_{ij}})^{1-\alpha_i} \right)^{\eta_i}$$

- Input financing constraint

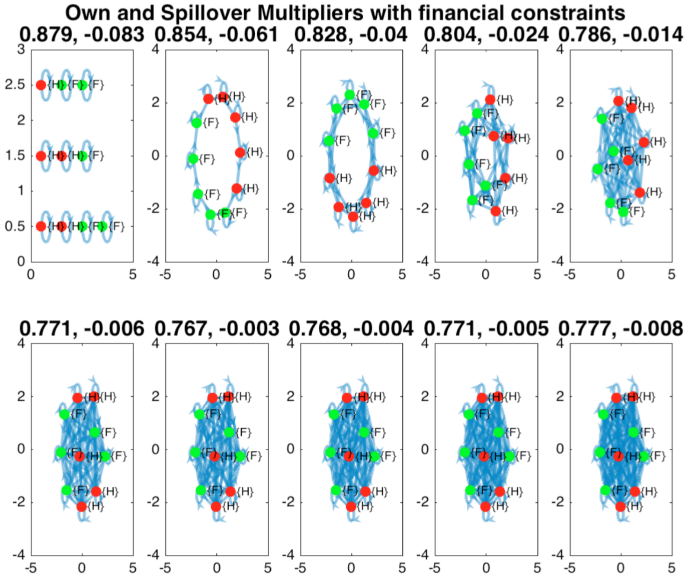
$$w\ell_i + \sum_{j=1}^{N} p_j x_{ij} \leq \phi_i p_i y_i$$

- 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

			Use by country-industries							Final use by countries			Total use
			Country 1			...	Country M			Country 1	...	Country M	
			Industry 1	...	Industry N	...	Industry 1	...	Industry N		...		
Supply from country-industries	Country 1	Industry 1											
		...											
		Industry N											
	......												
	Country M	Industry 1											
		...											
		Industry N											
Value added by labour and capital													
Gross output													

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
- Betweennes 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!

Measures for Year 2013		
Average Node	France	Germany
Indegree	101.38	105.72
Outdegree	100.20	106.9
Incloseness	0.0088	0.0092
Outcloseness	0.0088	0.0093
Betweenness	2.40	6.41
PageRank	0.009	0.0095

Now use WIOD numbers

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

Results Table		
Multiplier	France	Germany
Balanced	0.76	0.74
France	0.9	-0.14
Germany	-0.12	0.87

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.