ASSESSING THE ROLE OF INTERBANK NETWORK STRUCTURE IN FINANCIAL AND BUSINESS CYCLE ANALYSIS

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INTRODUCTION

Propose a canonical modelling framework for introducing financial *interconnectedness* into a DSGE Model

- Credit market imperfections and an active banking sector
- *Interbank network structure* as driver of banking sector dynamics + interactions with the wider economy
- Variable impact of liquidity injections on interbank market stabilisation and business cycles depending on the network structure

Why networks?

Importance for systemic risk measurement - *well-established*

- Financial contagion through network of interlocking exposures (Acemoglu et al., 2015)
- "*Robust-yet-fragile*" property (Haldane, 2009)

Intro into (macroprudential) policy discussions - *in progress*

- BCBS: Interconnectedness to identify G-SIBS (FSB, 2011)

MODEL ASPECTS: TWO DIMENSIONS

1. Bank microfoundations

- *Baseline*: RBC-DSGE model developed by De Walque et al. (2010) (WPR). Main features:
  - Heterogenous banking sector + interbank market
  - Credit market imperfections: Endogenous defaults on interbank loans *and* firm credit
  - Supervisory and monetary authority set capital ratio and liquidity injections, respectively
- *Extension*: Combine deposit and merchant bank microfoundations
  - Direct intermediation between households and firms
  - Endogenous interbank lending *and* borrowing
  - Endogenous default on borrowing *and* subject to default on interbank loans
- *Substitution*: Above combination precludes an interbank market transferring liquidity from deposit to merchant banks as in WPR...

Model aspects: two dimensions

2. Simulated interbank network

- Based on stylised *four-node* representation developed by Allen and Gale (2000) and Lee (2013)
  - Four regions (den. A, B, C, D) each comprising one firm, household and bank
  - Bank intermediates between regional households and firms
  - Inter-regional interbank market provides an additional source of bank funding

  Banks' borrowing and lending counterparties given by *network structure*:
  - Incorporated directly into banks' microfoundations
  - **`Cyclical`**: Analysis of shock transmission
  - **`Complete`**: Maximum connectivity $\rightarrow$ stability?
  - **`Core-periphery`**: Asymmetry and shock location

CONTRIBUTION

Main features of the model:

- Show how the network not only drives interbank market dynamics (rates, volumes and defaults), but also;
- transmission to real economy due to impact on credit and output and;
- impact/efficacy of *liquidity injections* dependent on network structure

Simulations: *Crisis experiment*, several scenarios comprising

1. Negative aggregate productivity shock
   - Baseline approach
   - Shock transmission through the network is *indirect*
2. Negative regional banking shock
   - *Direct* transmission through bank portfolio optimisation
3. Positive aggregate central bank liquidity shock
   - Focus on real economy stabilisation

MODEL ECONOMY

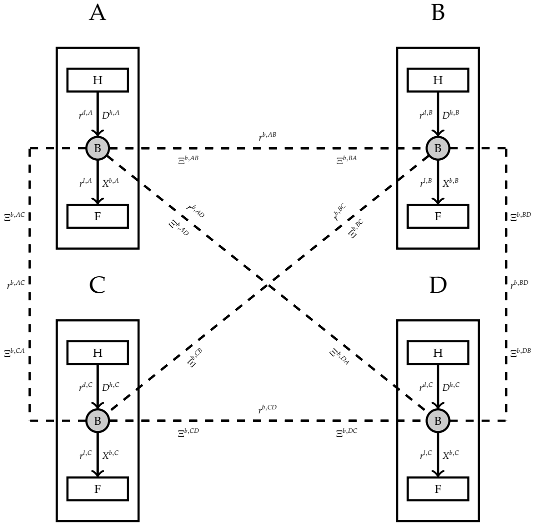

Figure : Flows between agents, generic network structure

MODEL

Firm and household optimisation follow WPR

- Each region: One HH+one firm maximisation programme

Bank optimisation (under generic network structure):

$$\max_{\substack{\left\{\left\{\delta_t^{b,ij}, B_t^{b,ij}\right\}_{j\in\mathcal{S}_i}, \left\{L_t^{b,ij}\right\}_{j\in\mathcal{D}_i}, \\ D_t^{b,i}, X_t^{b,i}, F_t^{b,i}, S_t^{b,i}, \pi_t^{b,i}\right\}}} \sum_{s=0}^{\infty} E_t \left\{ \beta^s \left[\ln\left(\pi_{t+s}^{b,i}\right) - d_b \sum_{j\in\mathcal{S}_i} \left(1 - \delta_{t+s}^{b,ij}\right) + d_{Fb} \left(F_{t+s}^{b,i} - k \left(w_{t+s}^{f,i} X_{t+s}^{b,i} + \sum_{j\in\mathcal{D}_i} w_{t+s}^{b,ij} L_{t+s}^{b,ij} + w_t^S S_{t+s}^{b,i} \right) \right) \right] \right\},$$

under the following constraints:

1) Bank profit function:

$$\begin{aligned}
\pi_t^{b,i} \quad = \quad & \frac{D_t^{b,i}}{1+r_t^{d,i}} - \frac{X_t^{b,i}}{1+r_t^{l,i}} + (1+\Gamma_t) S_{t-1}^{b,i} - S_t^{b,i} \\
+ \quad & \sum_{j\in\mathcal{S}_i} \frac{B_t^{b,ij}}{1+r_t^{b,ij}} + \sum_{j\in\mathcal{D}_i} \delta_t^{bji} L_{t-1}^{b,ij} + \zeta_b \sum_{j\in\mathcal{D}_i} \left(1-\delta_{t-1}^{bji}\right) L_{t-2}^{b,ij} + \alpha_t^{f,i} X_{t-1}^{b,i} + \zeta_f \left(1-\alpha_{t-1}^{f,i}\right) X_{t-2}^{b,i} \\
- \quad & \left[D_{t-1}^{b,i} + \sum_{j\in\mathcal{D}_i} \frac{L_t^{b,ij}}{1+r_t^{b,ij}} + \sum_{j\in\mathcal{S}_i} \delta_t^{b,ij} B_{t-1}^{b,ij} + \frac{\omega_b}{2} \left(\sum_{j\in\mathcal{S}_i} \left(1-\delta_{t-1}^{b,ij}\right) B_{t-2}^{b,ij} \right)^2 \right]
\end{aligned}$$

Model

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- Each region: One HH+one firm maximisation programme

Bank optimisation (under generic network structure):

$$\max_{\substack{\left\{\left\{\delta_t^{b,ij},B_t^{b,ij}\right\}_{j\in\mathcal{S}_i},\left\{L_t^{b,ij}\right\}_{j\in\mathcal{D}_i},\\ D_t^{b,i},X_t^{b,i},F_t^{b,i},S_t^{b,i},\pi_t^{b,i}\right\}}} \sum_{s=0}^{\infty} E_t\Bigg\{\beta^s\Bigg[\ln\left(\pi_{t+s}^{b,i}\right)-d_b\sum_{j\in\mathcal{S}_i}\left(1-\delta_{t+s}^{b,ij}\right) + d_{Fb}\left(F_{t+s}^{b,i}-k\left(w_{t+s}^{f,i}X_{t+s}^{b,i}+\sum_{j\in\mathcal{D}_i}w_{t+s}^{b,ij}L_{t+s}^{b,ij}+w_t^S S_{t+s}^{b,i}\right)\right)\Bigg]\Bigg\},$$

under the following constraints:

2) Insurance fund contributions:

$$F_t^{b,i}=(1-\xi_b)\,F_{t-1}^{b,i}+\nu_b\pi_t^{b,i}$$

3) Risk-sensitive credit weights:

$$w_t^{f,i} = \tilde{w}^f\left[\left(\frac{\alpha}{\alpha_{t+1}^{f,i}}\right)^{\eta_f}\right]$$

$$w_t^{b,ij} = \tilde{w}^b\left[\left(\frac{\delta}{\delta_{t+1}^{b,ij}}\right)^{\eta_b}\right] \text{ for each } j\in\mathcal{D}_i$$

MODEL

Government: Lump-sum tax levied on households

- Partially finance banks' insurance schemes
- Rest is financed by insurance fund contributions
- Does *not* fund central bank liquidity injections
- Assumption: *Regional* government responsible for minimising *outgoing* spillovers due to local strains:

$$T_t^i + \xi_b F_{t-1}^{b,i} = \zeta_b \sum_{j \in \mathcal{D}_i} \left(1 - \delta_{t-1}^{b,ij}\right) B_{t-2}^{b,ij} + \left(1 - \alpha_{t-1}^{f,i}\right) X_{t-2}^{b,i}$$

Central bank: Interbank liquidity injections. Shock features a

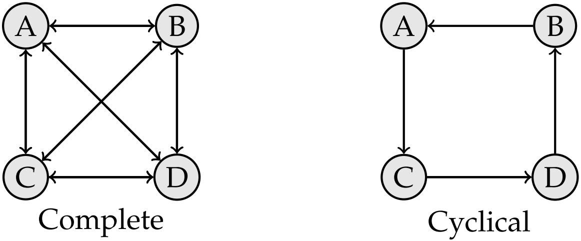
- *Stochastic component* - M_t^S: AR(1) specification
- *Deterministic component* - M_t^D: Increasing with deviation of mean interbank rate from long-run value

$$M_t = M_t^S + M_t^D \text{ where } M_t^D = \nu \left(\bar{r}^b - r^b\right)$$

$$M_t^{ij} = \frac{M_t}{|\mathcal{E}|} \text{ and } M_t^{ij} = B_t^{ij} - L_t^{ji}, \quad \forall i, j \in \mathcal{E}$$

Interbank network structures

Complete and cyclical topologies

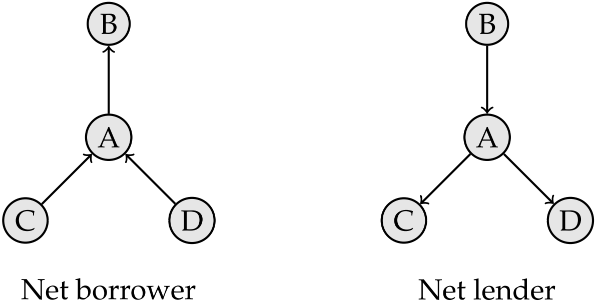


Both topologies are *symmetric* → nodes are ex-ante homogenous

- Location of banking shock is arbitrary (choose A)
- Each bank has the same number of counterparties
- `Completeness`: All banks are interconnected
  - Shock transmission is *direct* but dissipative effects can occur
- `Cyclicality`: One lender, one borrower for each bank
  - *Indirect* shock transmission via intermediary

INTERBANK NETWORK STRUCTURES

Core-periphery topologies

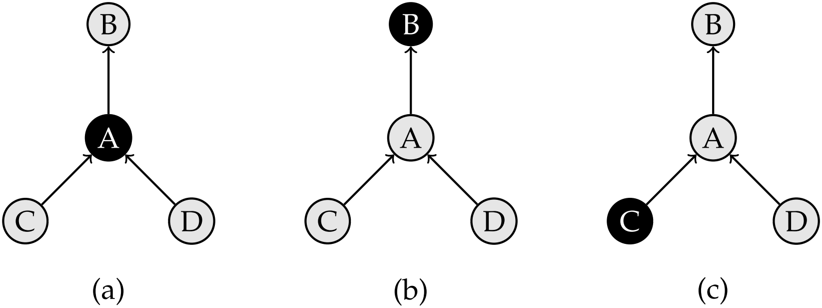


Asymmetric topologies → banks' role depends on location

- *B* is the sole recipient or provider of wholesale funding
- *A*'s central position: Financial stability implications
- Shock location is no longer arbitrary!

Interbank network structures

Core-periphery topologies



Asymmetric topologies → banks' role depends on location

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CALIBRATED PARAMETER VALUES

Table : Parameter calibration: Banks

Parameter	Definitions	Value
	Capital requirement	
k	Minimum own funds ratio	0.08
$\tilde{w}^{f,i}$	Risk weight: loans to firms	0.8
$\tilde{w}^{b,ij}$	Risk weight: interbank loans	0.05
$\tilde{w}^{S}$	Risk weight: market book	1.20
	Insurance fund	
ζ_b	Insurance coverage: interbank default	0.80
ζ_f	Insurance coverage: firm default	0.80
ϑ_b	Insurance fund contributions from profits	0.5

Inferred parameters: Banks (Symmetric networks)

Table : Inferred parameters: Banks (Symmetric networks)

Parameter	Definition	Network structure	
		Complete	**Cyclical**
r^d	Deposit rate	0.5%	0.5%
r^l	Prime lending rate	0.1%	0.5%
r^b	Interbank rate	1.2%	1%
d_b	Interbank default disutility	3773	3642
d_{Fb}	Own funds utility	7849	9148
ξ_b	Insurance fund contribution	0.0548	0.0640
ω_b	Interbank default cost	326	532

Inferred parameters: Banks (Asymmetric networks)

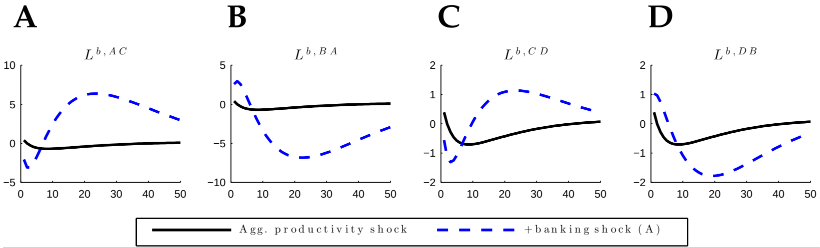
Table : Inferred parameters: Banks (Asymmetric networks)

Parameter	Network structure					
	CP-nb			**CP-nl**		
	A	B	C/D	A	B	C/D
r^d	″	0.05%	″	″	0.05%	″
r^l	″	0.04%	″		0.04%	″
r^b	″	0.09%	″	″	0.09%	″
d_b^i	3760	5233	-	2325	-	5233
$d_{F^b}^i$	10462	12458	9290	8131	150150	12458
ξ_b^i	0.0480	0.0403	0.0540	0.0617	0.0540	0.0403
ω_b		637			637	

Responses to a banking shock

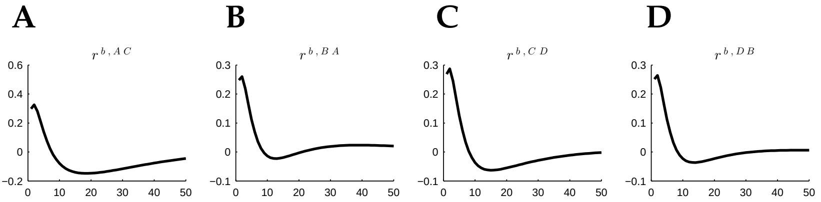
Cyclical network

Interbank volumes



- Minimal (but not negligible) impact of productivity shock on interbank volumes
- L^{AC}, L^{BA}: shocked bank's (A) lending and borrowing
  - ***A***: Perfectly offset Δ lending with borrowing
- L^{CD}, L^{DB}: D not (directly) connected to A
  - Evidence of shock transmission through the network
  - ***D***: Shock impact ↓ with distance from source

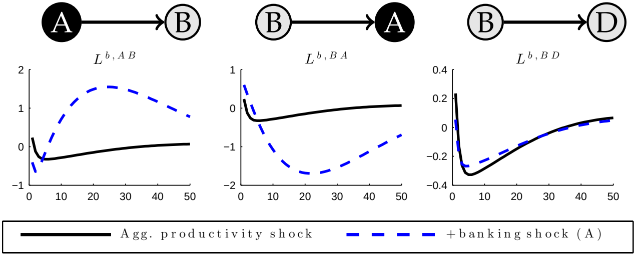
Interbank rates



- Isolate banking shock to observe impact on interbank rate
- Strong transmission of initial shock through the network
  - More pronounced than lending volumes
  - Highest spike in $r^{b,AC}$ (as expected)
  - Cyclical structure drives (small) decrease in magnitude
    - $AC > CD > DB > BA$
- Further evidence of shock propagation through the network

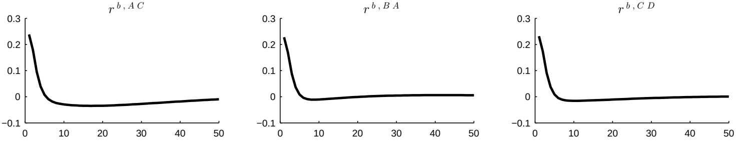
`Complete network`

Interbank volumes



- Representative IB counterparty analysis reveals that:
  - Shock impact on volumes is strongest when the shocked bank is one of the counterparties
  - Smaller magnitude of $B \to D$ lending: *dissipative* effects on the complete network
- Magnitudes: **smaller** than under cyclical structure

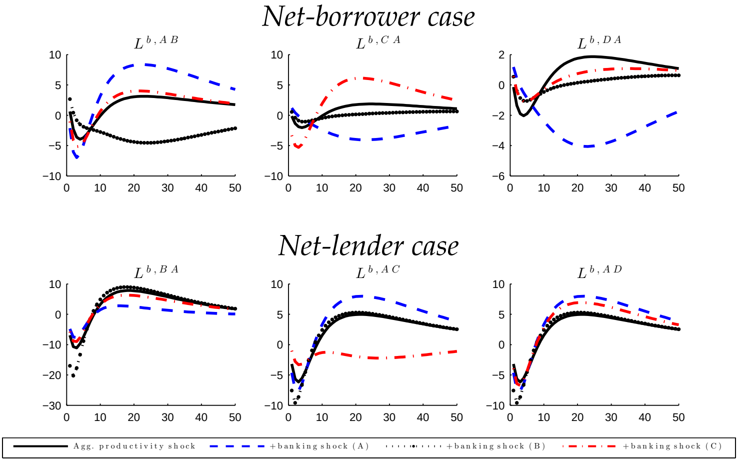
Interbank rates



- Increase in interbank rates across *all* bilateral markets but;
- exhibits less variation than IB rates under cyclicality
  - Structure does not permit the same transmission analysis
- Slightly lower increase on impact
  - Initial impact of the shock to A is spread out across counterparties
  - Dissipative effects of complete networks (again) at work
- **Conclusion**: Complete structure has *stability-enhancing* properties

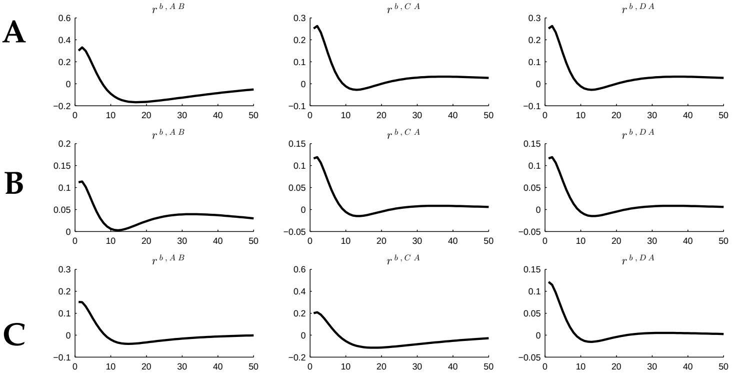
Core–periphery networks

Interbank volumes



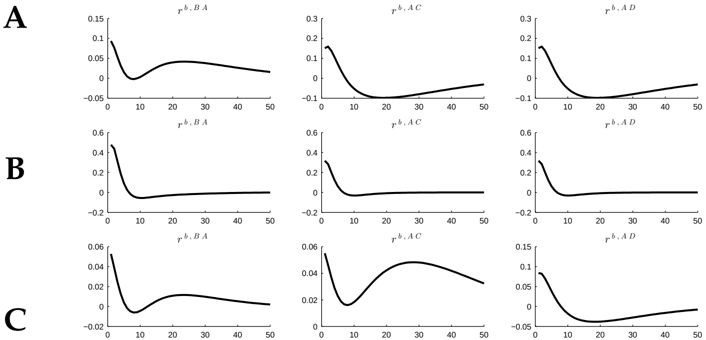
Interbank rates

Net-borrower case



Interbank rates

Net-lender case

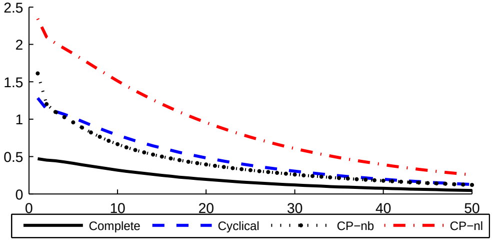


Interbank dynamics on CP network

Asymmetry in core-periphery network influences bank behaviour:

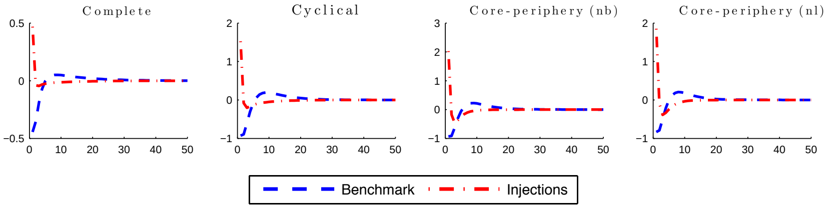
- Impact of baseline productivity shock on interbank volumes
  - Strongest impact on L^{AB} and L^{BA}: B as sole recipient/provider of interbank funding
  - Latter case: B has no access to interbank credit to mitigate shock from borrowing firm $\rightarrow$ culminates in a pro rata decrease in core lending to the periphery.
- Intuitive: Core banking shock has a larger impact in net borrower case $\rightarrow$ More important intermediating role
- Large variation in interbank rate dynamics depending on shock location and counterparties
  - Net-borrower case: Largest effect on impact when A is shocked
  - Net-lender case: B plays a much more important role in driving interbank fluctuations

REAL ECONOMIC IMPACT AND LIQUIDITY INJECTIONS



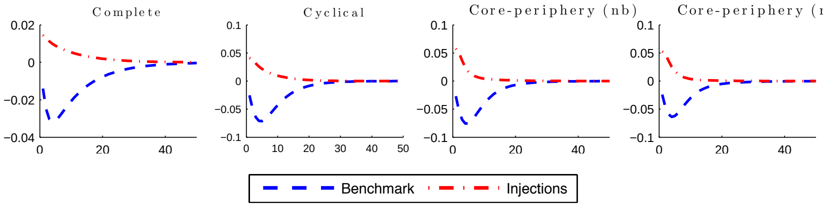
- *Normalisation*: Divide by number of interbank links
- Complete network: Lowest central bank intervention
- Net-lending core: Highest liquidity injections by CB
  - Further evidence of instability driven by this network structure
- Similar CB dynamics for cyclical and core-periphery network when core is a net borrower of funds.

Total credit



- **`Complete network`** exhibits lowest decrease in credit following a regional banking shock
  - Initial impact is symmetric relative to the decline: central bank is well placed to alleviate credit market strains
- **`Cyclical`** and **`core-periphery`** networks: Positive impact of liquidity injection is asymmetric relative to the benchmark
  - The same links that propagate the shock across the banking sector also act as a conduit for central bank liquidity

Total output



- Dynamics are similar to credit markets
  - Lowest decrease in output when banks are maximally connected
  - But asymmetry between injections and benchmark is less pronounced
- More persistent dynamics under complete followed by cyclical network
  - Dissipative effects due to interconnectedness also reduce the impact of liquidity injections
  - Faster convergence in core-periphery networks

CONCLUSIONS

Developed a novel approach for studying how the *interconnectedness* of the banking sector can have important implications for financial stability

- Go one step deeper: Vary the manner in which banks are interconnected using a stylised network representation
- First paper to look at DSGE from this perspective
- Framework allows for numerous extensions: alternative microfoundations, more complex networks, more in-depth analysis of macroprudential policy etc.

Several interesting results:

- Stability-enhancing role of complete networks due to dissipative effects
- Strong interbank dynamics of non-shocked banks due to *direct* and *indirect* spillovers
- Network structure also affects the effectiveness of monetary policy

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