Testing Information Diffusion in the Decentralized Unsecured Market for Euro Funds

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The views expressed in the paper are solely those of the author and do not necessarily represent the views of the Eurosystem.
Motivation

- **Money Market rates** (EURIBOR, EONIA, ..) and their dispersion are key indicators for a wide set of phenomena
  - Market expectations
  - Financial tensions
  - Cost of mortgages and loans to the real economy (pass-through)
  - ...

- First ($E[p_{ij,t}]$) and second ($E[(p_{ij,t} - E(p_{ij,t}))^2]$) moments of a sample of prices. Traditionally $p_{ij,t} = f(x_i,t, x_j,t, L(t))$.

- It is a decentralized market, composed by not anonymous bilateral trades, unknown by others.
Motivation

• Rates are relational by definition, thus they can be characterized by cross sectional dependence.

• The unsecured interbank market is a network, thus we can model this cross sectional dependence with spatial econometrics.

  • Bank $i$ is the borrower of $p_{ij,t}$ and the lender of $p_{ki,t}$, these prices are connected. $p_{ij,t} = f(x_{i,t}, x_{j,t}, L(t), A_{ij,t}P_t)$
The market for CB money is generated by the reserve requirement and liquidity needs (on the demand side) and has CB RTGS system as an institutionally designed support, as standard in modern economic systems.

From **TARGET2** data we can identify loans applying the Furfine (1999) algorithm, see Arciero et al. (2013) when $i$ is strictly positive and Rainone and Vacirca (2015) when they can be zero or negative. Banks covariates are from Bankscope.
Preliminary Evidence

Moran’s I Statistic for maturities from one to three days, computed for distances from 1 to 10.
The Econometric Model

\[ p_{bl,m,t} = \alpha_{m,t} + \phi_{m,t} \sum_{ij} a_{ij,bl,m,t} p_{ij,m,t} + x_{b,m,t} \beta_{B,m,t} + x_{l,m,t} \beta_{L,m,t} + \epsilon_{bl,m,t}, \]

In matrix form

\[ \tilde{P}_{m,t} = \alpha_{m,t} \iota + \phi_{m,t} A_{m,t} \tilde{P}_{m,t} + \beta_{B,m,t} X_{B,m,t} + \beta_{L,m,t} X_{L,m,t} + \epsilon_{m,t}. \]

where \( \tilde{P}_{m,t} = vec(P_{m,t}) \times I(vec(P_{m,t}) \neq 0) \) is the vector of connected prices, \( A_{m,t} \) is the row-normalized prices' adjacency matrix, \( \iota \) is a \( N_{m,t} \) vector of ones, all evaluated for maturity \( m \) at time \( t \). The term \( \alpha_{m,t} \) captures the general market conditions for maturity \( m \) at time \( t \). \( X_{B,m,t} \) and \( X_{L,m,t} \) are two \( N_{m,t} \times K \) matrices collecting respectively the lenders and borrowers' characteristics for each loan observed. \( \epsilon_{m,t} \) is an error term i.i.d normally distributed with zero mean and variance \( \sigma_{\epsilon_{m,t}} \).
Dealing with Endogeneity

- **Simultaneity**

\[
E[(A_m,t \bar{P}_m,t)' \epsilon_m,t] = E[(A_m,t(I - \phi_m,t A_m,t)^{-1}(\alpha_m,t \iota + \beta_B X_B,m,t + \beta_L X_L,m,t + \epsilon_m,t))' \epsilon_m,t] \neq 0.
\]

The last inequality holds if

\[
E[(A_m,t(I - \phi_m,t A_m,t)^{-1} \epsilon_m,t)' \epsilon_m,t] = \sigma_{\epsilon_m,t}^2 tr(A_m,t(I - \phi_m,t A_m,t)^{-1}) \neq 0.
\]

OLS may fail to consistently estimate the price transmission parameter $\rightarrow$ IV approach

\[
TIV_{m,t} = E(A_m,t \bar{P}_m,t) = E[A_m,t(I - \phi_m,t A_m,t)^{-1}(\alpha_m,t \iota + \beta_B X_B,m,t + \beta_L X_L,m,t)],
\]

since the parameters are unknown and the term $(I - \phi_m,t A_m,t)^{-1}$ brings to an infinite sum of elements, assuming $|\phi_m,t| < 1$, a linear approximation of involved vectors is used for the empirical IV, in practice we use a (one side) second order approximation

\[
AIV_{m,t} = E[A_m,t X_L,m,t, A_m^2,t X_L,m,t].
\]

**Figure:** Instrumental variables’ chain
Identification

Identification is guaranteed if \((A_{m,t} \bar{P}_{m,t}, \nu, X_{B,m,t}, X_{L,m,t})\) has full column rank, it can be shown that if \((\nu, X_{B,m,t}, X_{L,m,t})\) has full column rank and \(I_{m,t}, A_{m,t}\) and \(A^2_{m,t}\) are linear independent this condition is met.

**Figure:** Network structure and identification

Panel (a): the network is formed by an intransitive triad, so that \(I_{m,t}, A_{m,t}\) and \(A^2_{m,t}\) are linear independent.
Panel (b): the network is formed by a transitive triad, so that \(I_{m,t}, A_{m,t}\) and \(A^2_{m,t}\) are linear dependent since \(A^2_{m,t} = I_{m,t} + A_{m,t}\). For the sake of simplicity, loans and prices are supposed to be symmetric in this example.
Empirical Results

(c) $\hat{\phi}_{m,t} - \text{OLS}$

(d) $\hat{\phi}_{m,t} - \text{2SLS}$

(e) Endogenity

(f) Residuals Moran’s I
Dealing with Endogeneity

- **Endogenous interbank network**
  
  - The presence of **unobservables** driving both the **link formation**, 
    
    \[ g_{ij} = f(x_i, x_j) + v_{ij} = c_{ij} + v_{ij}, \]
    
    and the **outcome**, 
    
    \[ p_{ij} = \alpha + \phi \sum_{kl} a_{ij,kl} p_{kl} + \beta_i x_i + \beta_j x_j + \epsilon_{ij}, \]
    
    equation may lead to **biased estimates**. Given that \( a_{ij,kl} = g_{ij} g_{lk} \), if \( v_{ij} \) is not independent from \( \epsilon_{ij} \) the estimate of \( \phi \) may be biased.
  
  - Banks may be linked because they are in the same **community/location**, or, more in general, because of the presence of **social networks** among treasurers.
Dealing with Endogeneity

- **Endogenous interbank network**
  - In a broader view this may be interpreted as a *selection bias*, following the concept illustrated in many papers by Heckman, Lee and other labour econometricians. Notable papers dealing with this issue are are Goldsmith-Pinkham and Imbens (2013), Hsieh and Lee (2014), Patacchini and Rainone (2014), Qu and Lee (2015) and Arduini et al. (2015).
  
- Let us define

  \[ \psi(c_{ij}) = E(\epsilon_{ij}|g_{ij}, x_i, x_j) = E(\epsilon_{ij}|g_{ij}, c_{ij}), \]

  as the correction term which controls for this possible dependence.

  \[ p_{ij} = \alpha + \phi \sum_{kl} a_{ij,kl} p_{kl} + \beta_i x_i + \beta_j x_j + \sum_h \gamma_h \hat{r}_{ij}^h + u_{ij}. \]

  (1)

  Since \( \psi(c_{ij}) \) is an unknown function, we can use a vector of functions \( \tau_k \) with the properties that for large \( K \) a linear combination can approximate the unknown function.
Empirical Results

2SLS and SC2SLS estimation time series of $\phi_{m,t}$, for maturities from one to three days.

Black line represents 2SLS, Red line represents SC2SLS.
Robustness check: rewiring the network structure

I use a simulation approach to randomly change a certain percentage of links in the interbank network, $p$, one hundred times for each value of $p$ ranging from 0 to 1 with a pace of 0.001. I thus draw one hundred network structures (samples) of size equal to the real one for each value of $p$, one hundred thousand network structures in total.
Direction of Diffusion

Influence Flows

(g) first leg flow
(h) reverse flow
(i) common-borrower influence
(j) common-lender influence
(k) reverse flow
(l) common-borrower influence
(m) common-lender influence
Interpretation and Mechanism

- **Prices** contain information (Hayek; 1945);
- **Information transmission** in rational expectation equilibrium (Grossman, 1981; Grossman and Stiglitz, 1980);
- **Process of trade** can transmit some considerable information in a decentralized market (Wolinsky; 1990);
- Babus and Kondor (2013) proposed a model with information diffusion in **decentralized markets**. Dealers have heterogeneous valuations of the asset \( \theta_i = \bar{\theta} + \eta_i \) and each bilateral price partially aggregates the private information of other dealers, depending on the **market network structure**.

Residual inverse demand function:

\[
   p_{ij} = -\frac{b^i_j + \sum_{k \in g_j, k \neq i} c^i_{jk} p_{jk} + q_{ji}}{c^i_{ji} + \beta_{ji}}
\]

- Here it is measured by network-based spillover effects among connected prices.
Suppose an exogenous shock $\Delta p > 0$, and $p_{ji} = p_{kj} = p_{gk} = p^* = \text{EONIA}$ are the prices before the shock. Without diffusion the new EONIA will be

$$p^{**} = \frac{3p^* + \Delta p}{3},$$

with diffusion the new EONIA will be

$$p^{***} = \frac{3p^* + (1 + \phi + \phi^2)\Delta p}{3} > p^{**}, \text{if } \phi > 0.$$
# Centralized vs Decentralized Markets

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<td><strong>Systemic risk</strong></td>
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Conclusions

- Focus on the **network** nature of interest rates in the unsecured money market.
- Propose consistent estimator for testing the presence of **diffusion** in rates.
- Do an empirical **analysis** of European unsecured money market.
  - diffusion takes place only with high uncertainty;
  - it flows in multiple directions.
- Uncover a behavioral **mechanism** implemented by banks in the unsecured money market.
THANK YOU!