Inter-Country Spillovers: Measurement with Hybrid Networks

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Motivation

- Contagion spillover effects between financial markets of different countries have shown their disruptive impact during the recent crises.
- Market spillovers may be explained by actual imbalances between countries, besides market expectations evolution.
- We aim to understand to what extent the evolution of capital flows imbalances can explain price spillovers, and to what extent spillovers are endogeneous to the markets.
- Understanding the reasons of market spillovers can help tailoring financial stability measured aimed at market integrity or rather at capital imbalances.

Literature

- Market based contagion has been addressed analysing market prices by means of correlation network models, see e.g. Billio et al., 2012, Diebold and Yilmaz,2014, Hautsch et al., 2015, Ahelegbey et al., 2016, Basu et al., 2016, Barigozzi et al., 2017, Acharya et al., 2017, Adrian et al., 2016
- Capital flows based contagion has been addressed analysing bilateral exposure data by means of physical network models, see e.g. Cont, 2013, Minoiu and Reyes, 2013, Halaj, 2015, Avdjiev et al., 2019.
- We aim to combine the two perspectives, and propose a novel "Hybrid" econometric model to do so. We estimate the market-based linkages via a VAR model, and the capital flows linkages via a social relations model (SRM), which is embedded into the VAR.

Social network model for financial market returns

Let Y_t denote n-dimensional vector of measurements that captures the performance of financial markets of n countries at time t, $(t = 1, \ldots, T)$.

$$Y_t = BY_{t-1} + U_t, \quad U_t \sim \mathcal{N}(\mathbf{0}, \Sigma_u) \tag{1}$$

where B is $n \times n$ coefficient matrix, U_t is n-dimensional error term, and U_t is independent of Y_{t-1}.
To build a return based network, we assign a latent binary indicator matrix $G_B \in \{0,1\}^{n \times n}$ associated with the coefficient matrix B such that

$$G_B(i,j) = 0 \iff B_{ij} = 0, \qquad \text{and} \qquad G_B(i,j) = 1 \iff B_{ij} \neq 0 \tag{2}$$

Social network model for capital flows

Let X be an $n \times n$ matrix whose entry X_{ij} measures the bilateral financial flow between countries i and j. Let X^k be a measure of X at time k so that X_{ij}^k is the measurement of the relation from i to j at time k. Following the social relations model (SRM) of Kenny et al. (1984) and Warner et al., 1979, we decompose the logarithmic transformation of X_{ij}^k into a linear random-effects model:

$$\bar{X}_{ij}^k = \mu^k + \alpha_i^k + \beta_j^k + \gamma_{ij}^k + \epsilon_{ij}^k \tag{3}$$

where $\bar{X} = \log X$, μ^k is the average of the overall transfers among countries at time k, α_i^k (β_j^k) measure sender i's (receiver j's) effect averaged across many receivers (senders), γ_{ij}^k capture the bilateral relationship between sender i and receiver j, and ϵ_{ij}^k is the error associated with the pairwise interactions.

Social network model for capital flows - continued

To build a capital flows network, we employ the interaction parameter $\Gamma = \{\gamma_{ij}\}$, whose significance we test for $k \geq 1$. We define $G_\gamma \in \{0,1\}^{n \times n}$ as the adjacency matrix of the bilateral relationships such that

$$G_\gamma(i,j) = \begin{cases} 1 & \iff \Gamma_{ij} \neq 0 \quad \text{if} \quad j \text{ receive transfers from } i \\ 0 & \iff \Gamma_{ij} = 0 \quad \text{if} \quad \text{otherwise} \end{cases} \tag{4}$$

Hybrid model

We assume that shocks to financial markets propagate not only through the autoregressive structure, but also through the bilateral interactions from the SRM Model:

$$Y_t = BY_{t-1} + (I - \Gamma_\theta)^{-1}\xi_t \tag{5}$$

where $\theta = \{R, S\}$ such that $\Gamma_R = \Gamma$, $(\Gamma_S = \Gamma')$, is a receiver (sender) induced bilateral relationships, respectively, from the SRM model, and ξ_t is n-dimensional random noise with mean zero and a diagonal covariance matrix.

Hybrid model

We denote with $G_A^\theta \in \{0,1\}^{n\times n}$, the adjacency matrix associated with the interaction matrix, A_θ, such that

$$G_A^\theta(i,j) = \begin{cases} 1 & \text{if} \quad \left[G_B\left(I + G_\gamma^\theta\right)\right]_{i,j} \neq 0 \\ 0 & \text{if} \quad \text{otherwise} \end{cases} \tag{6}$$

where $(\circ)$ is the element-by-element product.

Application

Data

- Quarterly intercountry banks' foreign claims of national banking systems obtained from the Consolidated Banking Statistics (CBS)
- Daily equity market index obtained from the Bloomberg database.
- We consider the 10 reporting countries: France-FR, Germany-GE, Greece-GR, Ireland-IR, Italy-IT, Japan-JP, Portugal-PT, Spain-SP, United Kingdom-UK, and the United States-US.
- We partition the sample series into 4 sub-periods:
  1. **Pre-crisis** period (2006-2007)
  2. **Financial crisis** period (2008-2009)
  3. **Sovereign crisis** period (2010-2012)
  4. **Post-crisis** period (2013-2015)

Application

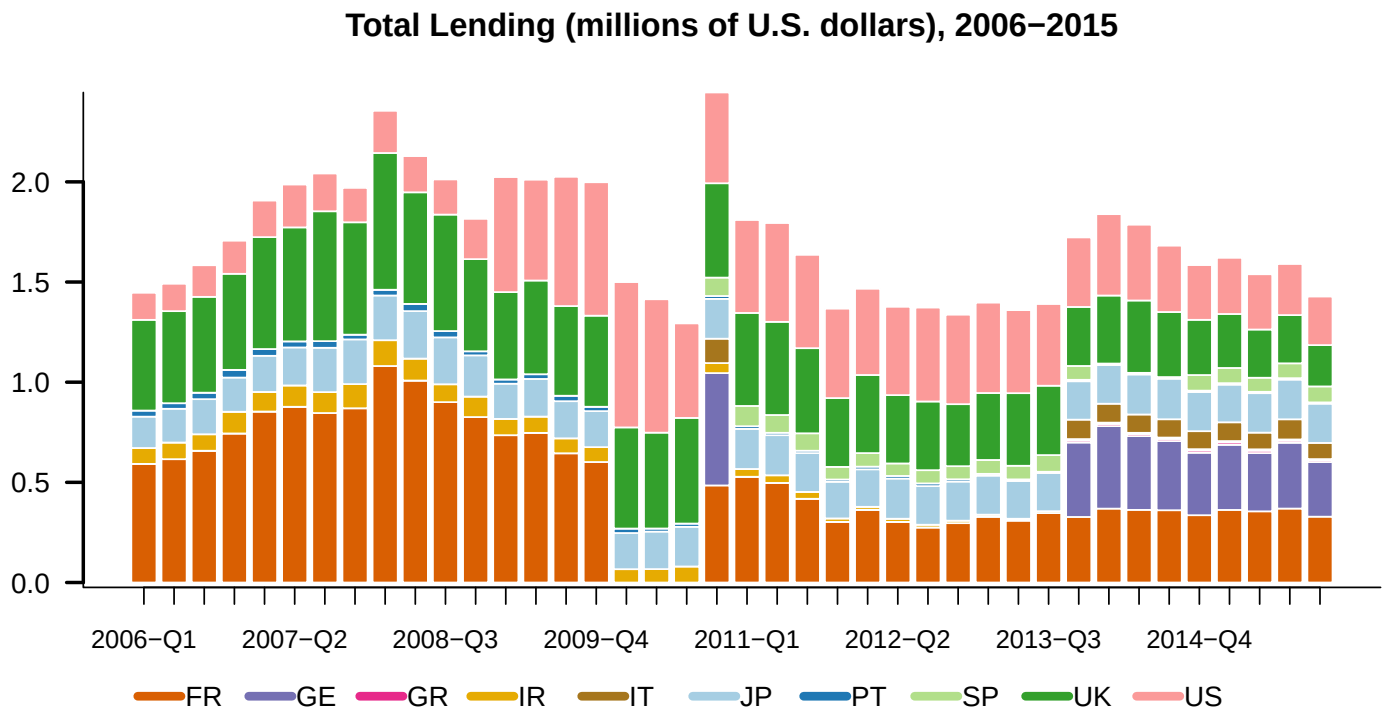


Figure: Financial flows between country banking systems in terms of Lending

Application

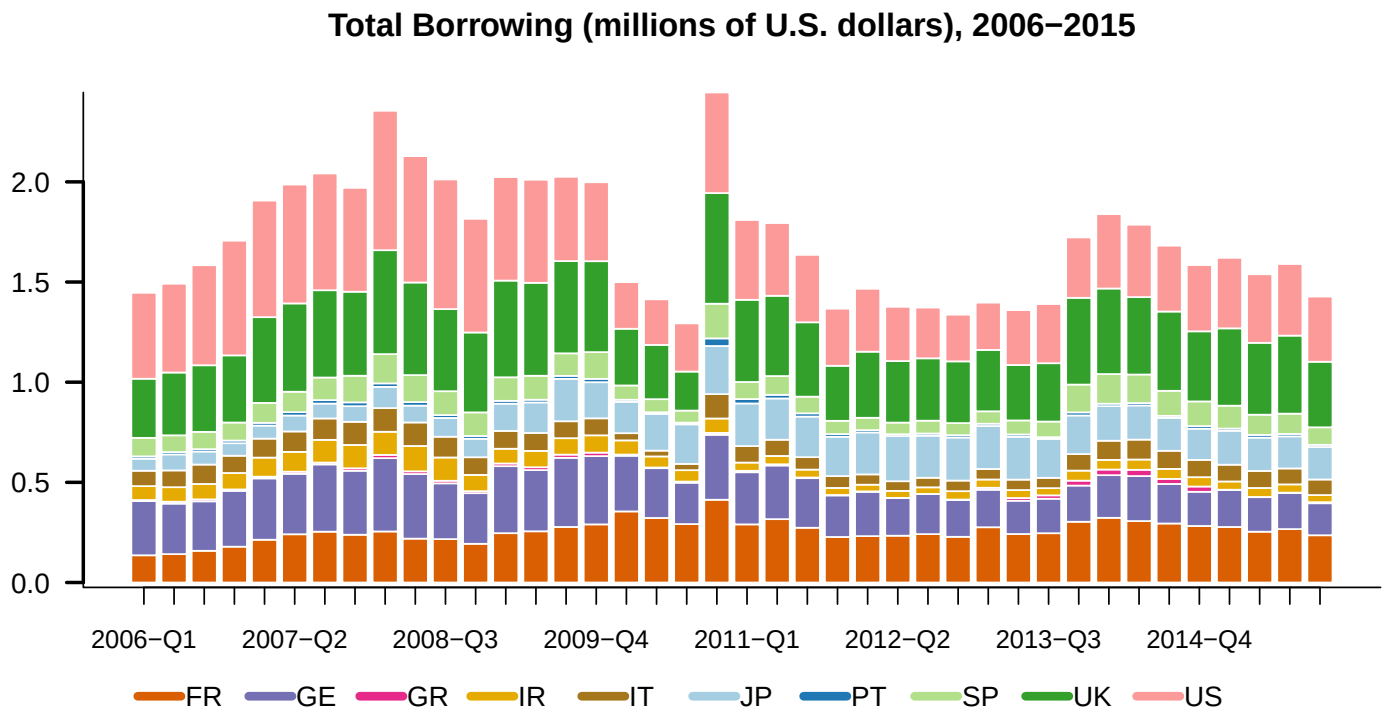


Figure: Financial flows between country banking systems in terms of Borrowing.

Application

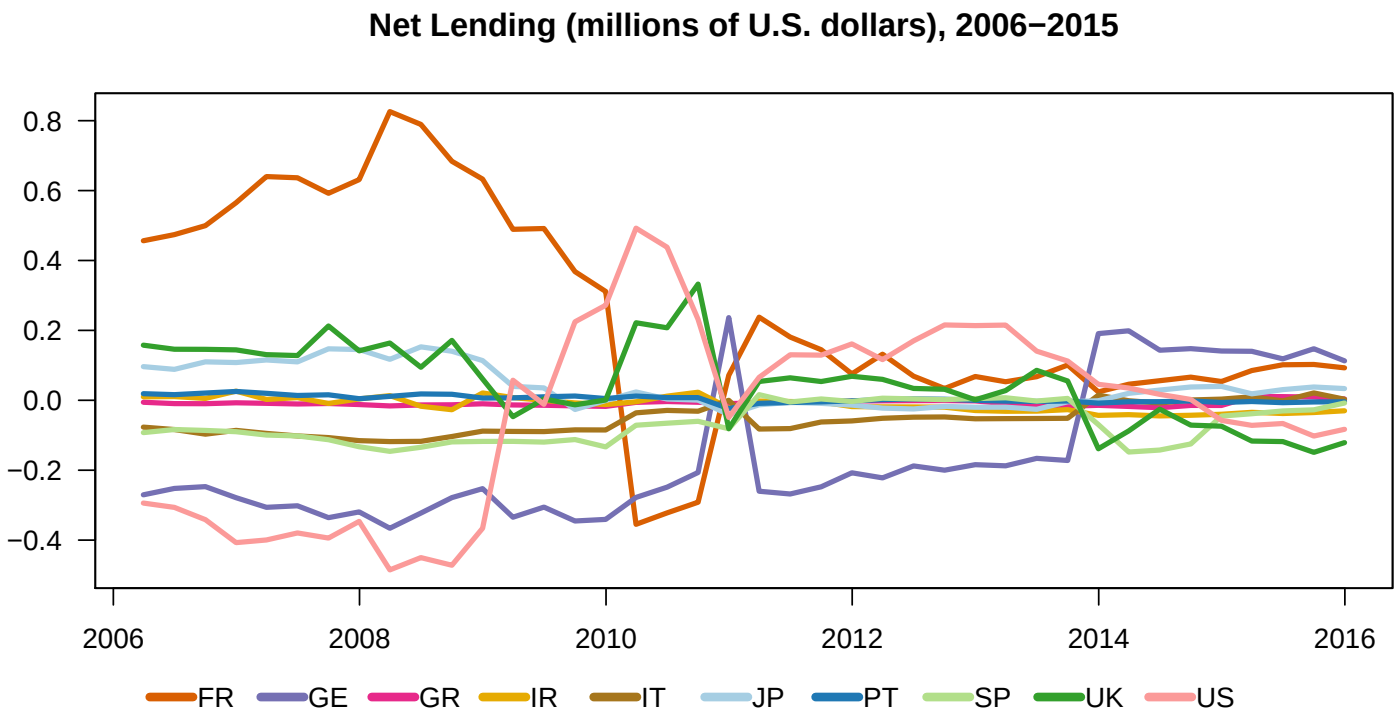


Figure: Financial flows between country banking systems in terms of Net-Lending.

Application

Results

- Financial flows among country banking systems have increased, after the financial crisis.
- In 2006–2007 lending was concentrated in the banking systems of France and the UK, and borrowing in the US and UK.
- In 2014–2015, France and Germany dominated in terms of lending while the UK and US dominated in terms of borrowing. Besides France and UK also Germany, Japan and the US appear with large proportions of lending. And, on the borrowing side, France, Germany and Japan increase their shares, getting closer to the US and the UK.
- Research question: which are the most central countries, overall, and in different periods of time, on the basis of the actual capital flows ?

Application

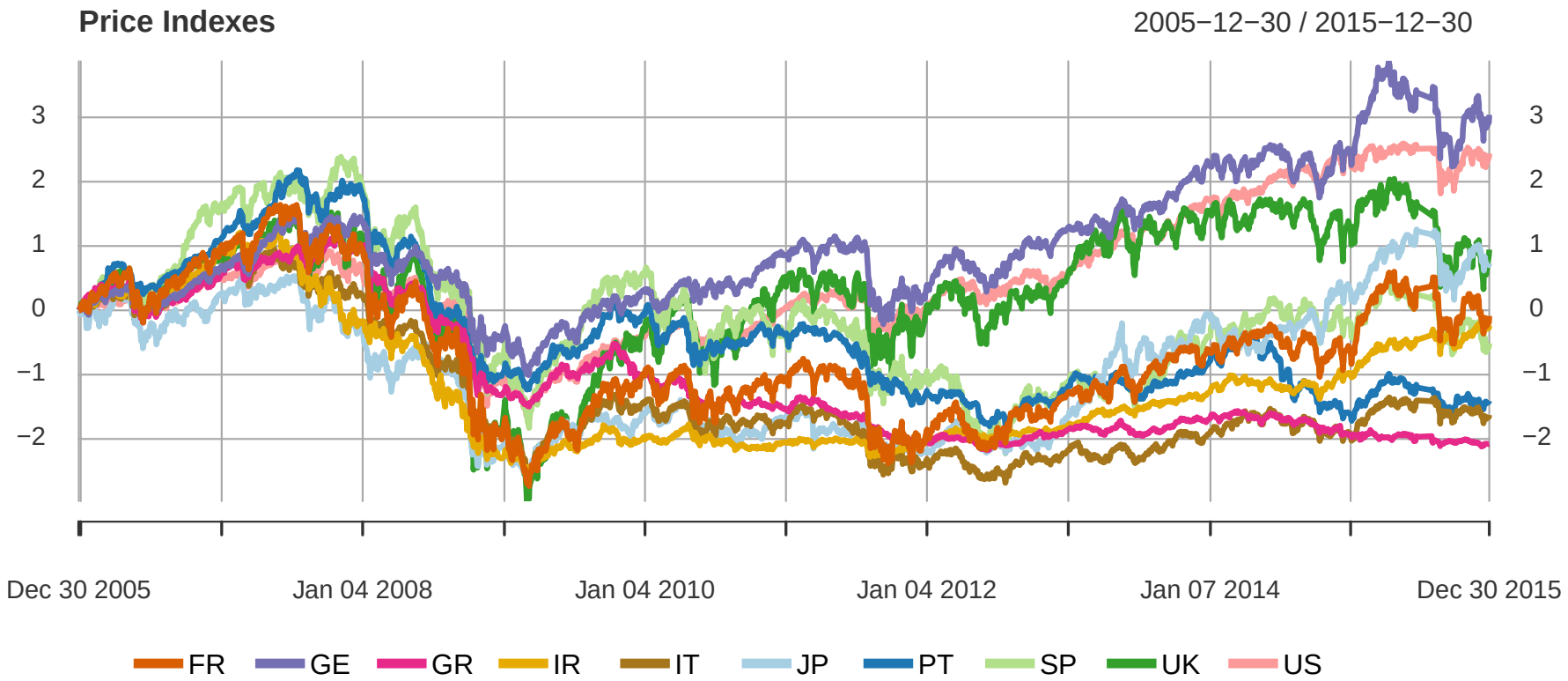
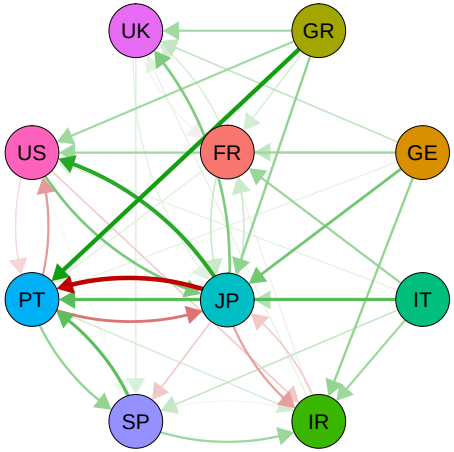


Figure: Time series of Log daily prices for France-FR, Germany-GE, Greece-GR, Ireland-IR, Italy-IT, Japan-JP, Portugal-PT, Spain-SP, United Kingdom-UK, and the United States-US.

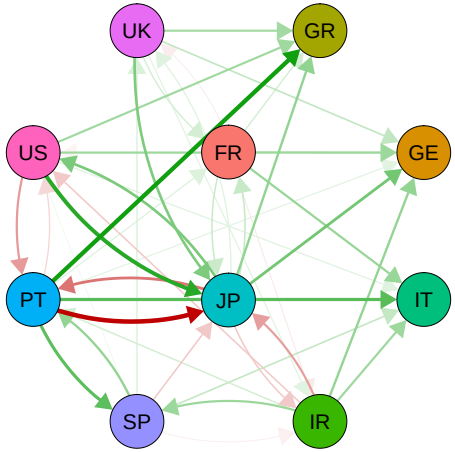
Results

- The log prices plots show a decline in the prices for all countries during the 2008 crisis period. In addition, they display the slow recovery of some countries, specifically Greece, Ireland, Italy, Portugal and Spain, with Greece having the slowest price recovery.
- The daily returns plots confirm that all countries peaked during the 2008 crisis. They also record the highest values during the European crisis, notably for France, Ireland, Greece, Italy, Spain and Portugal, with Greece reporting unusual values for an extended period between 2012–2016.
- Research question: which are the most central countries, overall, and in different periods of time, on the basis of market price spillovers?
- Research question: can we explain market price spillovers with capital flows centralities?

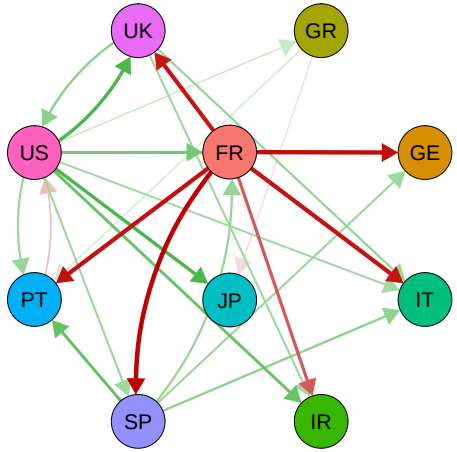
Results (2008–2009)



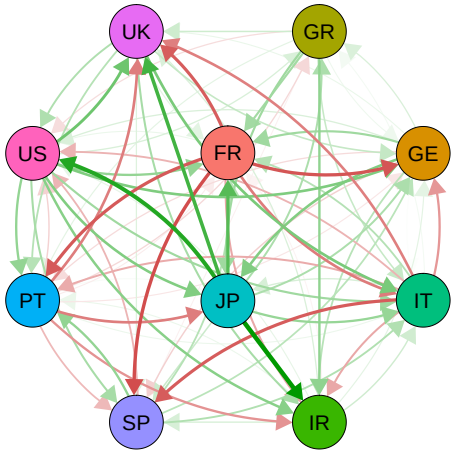
(a) Borrowing Net



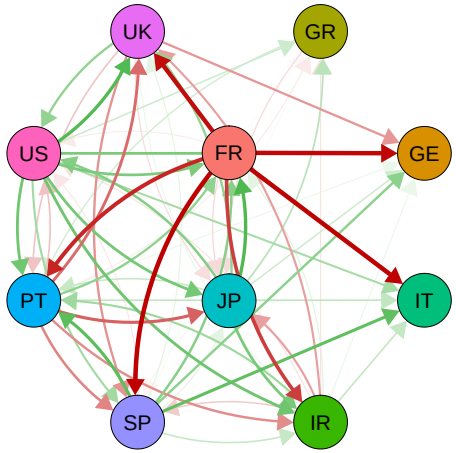
(b) Lending Net



(c) Market Net

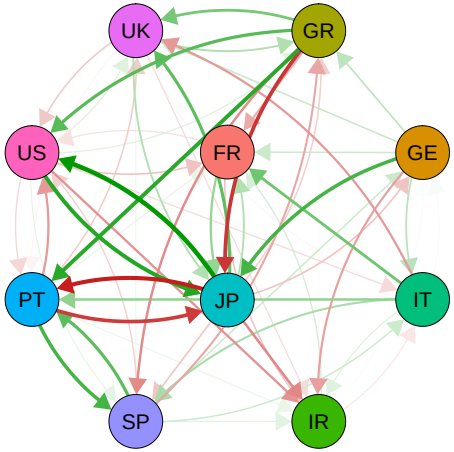


(d) Hybrid (B) Net

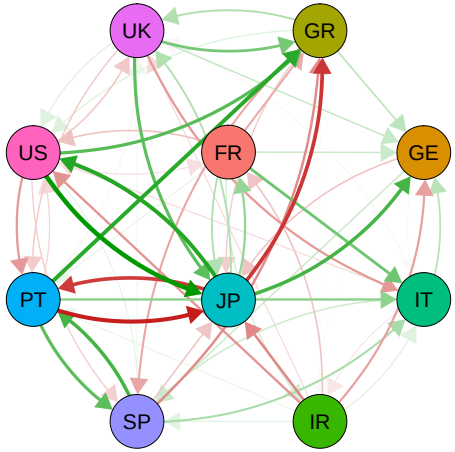


(e) Hybrid (L) Net

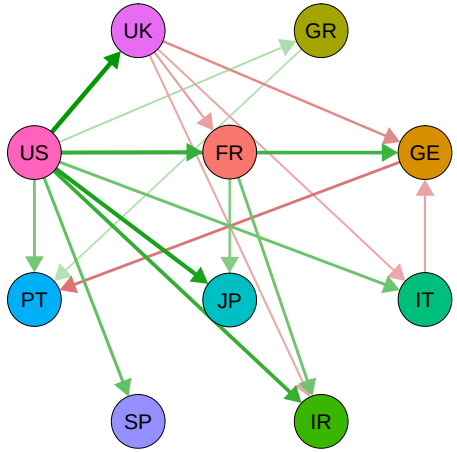
Results (2010–2012)



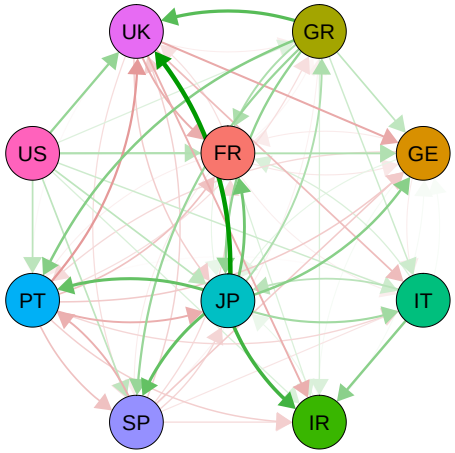
(a) Borrowing Net



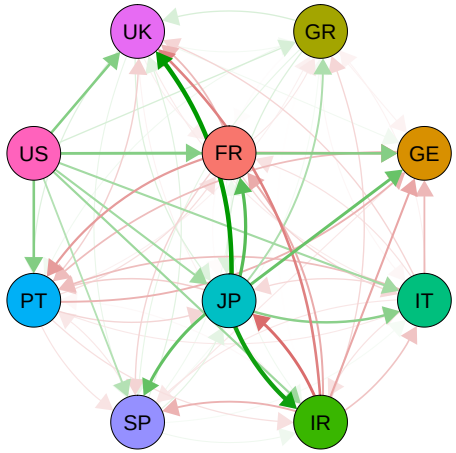
(b) Lending Net



(c) Market Net



(d) Hybrid (B) Net



(e) Hybrid (L) Net

Results: In-Exposure Centrality

	Periods	FR	GE	GR	IR	IT	JP	PT	SP	UK	US	Mean
Borrowing	Overall	2.97	0.01	0.11	1.68	0.12	3.27	3.33	0.72	3.37	3.28	1.89
	PreC	3.76	0.00	0.00	3.90	0.00	3.70	3.98	0.00	3.66	3.95	2.29
	GFC	4.15	0.00	0.00	3.97	0.00	4.00	3.89	0.00	3.99	3.94	**2.40**
	ESDC	2.14	0.00	0.00	2.02	0.00	3.58	3.43	1.51	3.63	3.45	**1.98**
	PostC	1.83	0.05	0.45	-3.19	0.47	1.81	2.03	1.37	2.20	1.78	0.88
Lending	Overall	0.65	5.07	4.86	-0.37	5.03	-0.17	-0.90	4.06	0.46	0.18	1.89
	PreC	0.55	6.00	6.14	-0.67	5.95	-0.35	-0.65	5.95	0.28	-0.27	2.29
	GFC	0.55	6.03	6.28	-0.46	6.11	-0.09	-0.93	6.10	0.42	-0.07	**2.40**
	ESDC	1.35	5.08	5.92	-0.63	5.42	-0.08	-0.89	2.66	0.53	0.42	**1.98**
	PostC	0.15	3.15	1.10	0.27	2.65	-0.17	-1.11	1.53	0.61	0.62	0.88
Market	Overall	0.30	0.16	0.30	0.34	0.15	0.56	0.19	-0.02	0.23	0.05	0.23
	PreC	0.40	0.36	0.38	0.67	0.37	0.74	0.07	0.01	0.40	0.20	0.36
	GFC	0.14	0.30	0.58	0.10	-0.04	0.60	0.44	-0.04	0.19	-0.10	**0.22**
	ESDC	0.47	-0.01	0.11	0.15	0.14	0.28	0.13	-0.31	-0.10	0.10	**0.10**
	PostC	0.19	-0.03	0.14	0.45	0.11	0.62	0.13	0.27	0.44	0.00	0.23
Hybrid (B)	Overall	1.51	0.74	0.94	1.50	0.71	1.58	0.94	0.04	1.24	-0.12	0.91
	PreC	2.07	1.29	1.60	2.20	1.62	3.33	0.40	0.11	1.78	-0.50	1.39
	GFC	1.70	1.17	1.62	1.70	0.01	1.68	2.35	-0.10	1.65	-0.39	**1.14**
	ESDC	1.71	0.23	0.37	1.01	1.13	0.72	0.16	-0.72	0.06	0.43	**0.51**
	PostC	0.56	0.26	0.17	1.10	0.09	0.60	0.83	0.87	1.46	0.00	0.60
Hybrid (L)	Overall	0.10	0.04	0.73	0.65	0.11	0.13	0.19	-0.26	-0.13	0.54	0.21
	PreC	0.05	0.26	0.28	2.28	0.27	0.34	0.10	-0.18	0.29	1.87	0.56
	GFC	-1.32	0.28	2.31	-0.83	-0.38	0.74	0.72	-0.29	-1.03	0.08	**0.03**
	ESDC	1.16	-0.03	0.15	0.10	0.28	-0.40	0.46	-0.93	-0.37	0.20	**0.06**
	PostC	0.51	-0.36	0.19	1.06	0.25	-0.15	-0.51	0.37	0.59	0.00	0.19

Results: Out-Exposure Centrality

	Period	FR	GE	GR	IR	IT	JP	PT	SP	UK	US	Mean
Borrowing	Overall	0.65	5.07	4.86	-0.37	5.03	-0.17	-0.90	4.06	0.46	0.18	1.89
	PreC	0.55	6.00	6.14	-0.67	5.95	-0.35	-0.65	5.95	0.28	-0.27	2.29
	GFC	0.55	6.03	6.28	-0.46	6.11	-0.09	-0.93	6.10	0.42	-0.07	**2.40**
	ESDC	1.35	5.08	5.92	-0.63	5.42	-0.08	-0.89	2.66	0.53	0.42	**1.98**
	PostC	0.15	3.15	1.10	0.27	2.65	-0.17	-1.11	1.53	0.61	0.62	0.88
Lending	Overall	2.97	0.01	0.11	1.68	0.12	3.27	3.33	0.72	3.37	3.28	1.89
	PreC	3.76	0.00	0.00	3.90	0.00	3.70	3.98	0.00	3.66	3.95	2.29
	GFC	4.15	0.00	0.00	3.97	0.00	4.00	3.89	0.00	3.99	3.94	**2.40**
	ESDC	2.14	0.00	0.00	2.02	0.00	3.58	3.43	1.51	3.63	3.45	**1.98**
	PostC	1.83	0.05	0.45	-3.19	0.47	1.81	2.03	1.37	2.20	1.78	0.88
Market	Overall	-0.65	0.22	0.07	0.00	-0.04	-0.03	-0.07	0.00	-0.17	2.92	0.23
	PreC	0.44	0.63	0.00	0.00	0.00	0.00	-0.14	0.00	-0.61	3.26	0.36
	GFC	-0.81	0.48	0.12	0.00	0.00	-0.10	0.00	-0.94	0.00	3.42	**0.22**
	ESDC	-2.69	0.00	0.02	0.00	0.00	0.00	-0.13	0.92	0.61	2.22	**0.10**
	PostC	0.47	-0.24	0.13	0.00	-0.16	0.00	0.00	0.00	-0.67	2.79	0.23
Hybrid (B)	Overall	-0.95	1.96	1.53	-0.40	0.59	3.80	-1.20	0.49	0.34	2.92	0.91
	PreC	-0.20	4.04	1.89	-0.81	1.35	2.02	-0.39	1.75	0.74	3.52	1.39
	GFC	-0.87	3.13	0.02	-1.41	1.50	4.91	-0.86	0.92	1.00	3.05	**1.14**
	ESDC	-2.46	0.86	1.12	0.51	-1.45	3.27	-1.53	0.71	1.38	2.68	**0.51**
	PostC	-0.25	-0.18	3.09	0.12	0.96	5.01	-2.03	-1.41	-1.78	2.42	0.60
Hybrid (L)	Overall	-0.39	0.22	0.12	-2.08	-0.28	3.33	-1.97	0.16	-0.01	3.00	0.21
	PreC	2.60	0.63	0.00	-3.11	0.00	4.94	-2.95	0.00	0.15	3.30	0.56
	GFC	0.24	0.48	0.12	-2.74	0.00	2.84	-2.96	-0.94	-0.04	3.25	**0.03**
	ESDC	-3.03	0.00	0.02	-0.19	0.00	1.50	-0.89	1.33	-0.36	2.24	**0.06**
	PostC	-1.36	-0.24	0.32	-2.27	-1.13	4.04	-1.07	0.23	0.23	3.21	0.19

Conclusions

- On the borrowing side, FR, JP and UK are selected based on capital flows during both crisis periods (GFC and ESDC), which reflects their higher vulnerability (In-Exposure) to the changes in lending strategies used by the other countries. While a higher contagion (Out-Exposure) is pointed out for GR, IT, SP and GE, indicating their ability to disturb the system (network) in case of lower debt repayment ability.
- The evidence from market spillovers shows that JP, and PT are more vulnerable during both crisis periods, but US and GR are more contagious for the same periods.
- The joint analysis (banking flows/Market) shows that the market has a larger effect on the structure of the hybrid borrowing network while the lending flows seem to have a stronger effect within the hybrid lending structure.

Acknowledgments

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