Stock Market Spillovers via the Global Production Network: Transmission of U.S. Monetary Policy[1]

Julian di Giovanni[1] Galina Hale[2]

[1]FRBNY, ICREA-UPF, BGSE, CREI and CEPR
[2]U.C. Santa Cruz, NBER, and CEPR

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[1]The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of New York.

Recent era of globalization

- Rise of international integration of firms' production chains (Johnson and Noguera, 2017) ▸ Figure

- Increased correlation of world stock markets (Dutt and Mihov, 2013) ▸ Figure

- Literature has focused on **financial** integration in propagation of shocks, particularly of U.S. monetary policy, across borders (e.g., global financial cycle; Rey, 2013)

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What is role of **real** linkages in transmission of shocks across international financial markets?

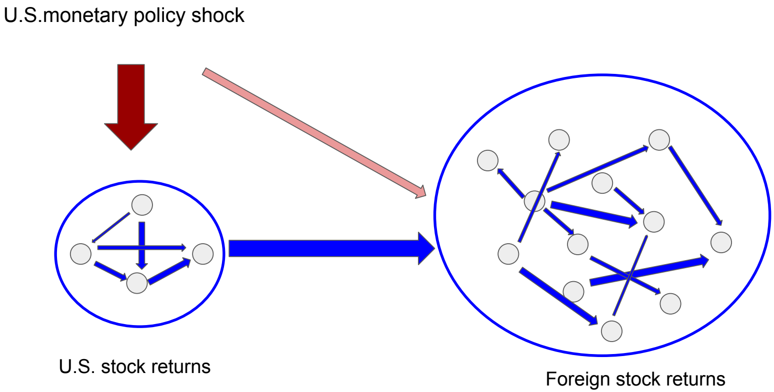
This paper

- Outlines a **conceptual framework** that delivers international monetary shock propagation through the *global* production network
- Constructs a new country-sector **database** that merges
  - World Input-Output Database (WIOD)
  - Firm-level stock market data (TREI) for 54 sectors and 26 countries for 2000–16
- Documents relationship between country-sector distance in production network and stock return correlations
- Estimates **panel spatial autoregression** of U.S. monetary policy (MP) shocks effect on stock prices via the global production network

Main results

1. Returns of country-sector cells that are “closer” in the global input-output network are more correlated
2. Global production network accounts for nearly **70%** of the total impact of U.S. MP shocks on stock returns
   - Baseline analysis 2000–07, but robust to other time periods
3. Results are robust to controlling for global financial cycle variables and value of the USD, which tend to impact returns directly
4. Results are robust to variety of specification changes

Story in a nutshell



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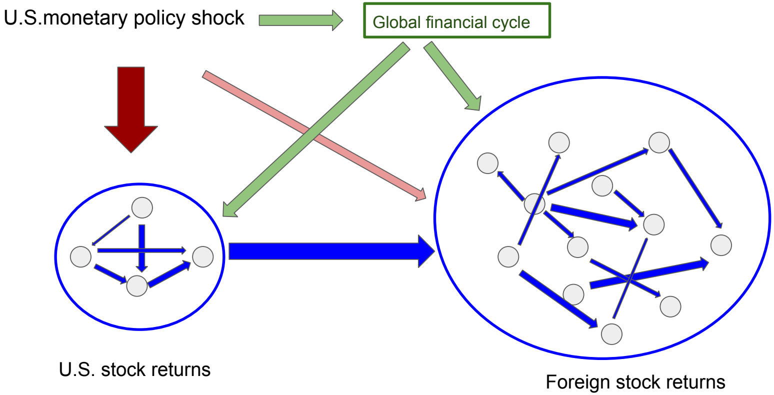

Related literature

- Country and sector factors in international asset pricing
  - Griffin and Stulz (2001), Bekaert et al. (2009), Lewis (2011)
- Transmission of shocks through production linkages
  - **International:** Burstein et al. (2008), Bems et al. (2010), Johnson (2014), Eaton et al. (2016), Auer et al. (2019), di Giovanni et al. (2018), Baqaee and Farhi (2019b), Huo et al. (2020), Wei and Xie (2020), Boehm et al. (2019), Carvalho et al. (2016)
  - **Domestic:** Foerster et al. (2011), Acemoglu et al. (2012), Atalay (2017), Grassi (2017), Ozdagli and Weber (2017) , Baqaee and Farhi (2019a), Pasten et al. (2019), La'O and Tahbaz-Salehi (2020), Rubbo (2020), Heskovic (2018), Richmond (2019)
- International transmission of U.S. monetary policy shocks
  - **Effect on asset prices:** Wongswan (2006), Ehrmann and Fratzscher (2009), Ammer et al. (2010), Miranda-Argippino and Rey (2020), etc.
  - **Via banking:** Cetorelli and Goldberg (2012), Bruno and Shin (2015), Buch et al. (2019), Claessens (2017, survey)
  - **Via capital flows:** Forbes and Warnock (2012), Bruno and Shin (2015), Avdjiev and Hale (2019)
  - **Via trade:** Bräuning and Sheremirov (2019), Chang et al. (2020)

Conceptual Framework: Main Ingredients

- Three elements are needed to produce monetary shock transmission through production linkages:
  - Technology + Market structure — positive profits in equilibrium
  - International production linkages — for international spillovers
  - Monetary shocks have real effects
- Notation:
  - countries m, n; industries i, j
  - $x_{mi,nj}$ is flow of goods from country m sector i to country n sector j

Conceptual Framework: Technology and Market Structure

- Output is produced with labor and intermediate goods

$$y_{nj} = z_{nj} F_{nj} \left(l_{nj,}, \{ x_{mi,nj} \} \right),$$

- z_{nj} is a Hicks-neutral technology parameter
- $F_{nj}(\cdot)$ can be CRS or DRS

Conceptual Framework: Market Clearing

- Expenditure of country-sector mi

$$\underbrace{R_{mi}}_{\text{Revenue } p_{mi}y_{mi}} = \underbrace{\mathcal{C}_{mi}}_{\substack{\text{Final goods} \\ \text{expenditure on } mi \\ \text{across } N \text{ countries}}} + \underbrace{\sum_{j=1}^{J}\sum_{n=1}^{N}\omega_{mi,nj}R_{nj}}_{\substack{\text{Intermediate input} \\ \text{expenditure}}}.$$

Input-output matrix coefficient: $\omega_{mi,nj} = \frac{p_{mi,n}x_{mi,nj}}{p_{nj}y_{nj}}$

LOOP for goods i such that $p_{mi,n} = p_{mi}$

- In matrix form

$$\mathrm{R} = \boldsymbol{\mathcal{C}} + \Omega\mathrm{R}$$

Conceptual Framework: Stock Returns

- Solving for R : $\mathrm{R} = (I - \Omega)^{-1}\mathcal{C}$

  $(I - \Omega)^{-1}$ is Leontief inverse of the IO matrix

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- These changes in profits are then reflected in stock returns:

$$\widehat{\boldsymbol{q}} = (I - \Omega)^{-1}\phi_\pi \circ \widehat{\boldsymbol{\mathcal{C}}}$$

Conceptual Framework: Monetary Policy Shocks

- Variety of models will predict

$$\widehat{C}_n = \phi_n \widehat{\mathcal{M}}_n$$

  where $\mathcal{M}_n$ is domestic money supply in country n, and ϕ_n follows from underlying model assumptions (e.g., $= 1$ in a cash-advance model)

- Combining with expression for profits (revenues) yields:

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or, specifically for the U.S. monetary policy shock:

$$\widehat{\boldsymbol{q}} = (I - \Omega)^{-1} \boldsymbol{\beta_{US}} \widehat{\mathcal{M}}_{US} \tag{1}$$

Conceptual Framework: Risk and Asset Pricing

- The conceptual framework is essentially static, and thus does not account for uncertainty, risk-aversion, or intertemporal optimization by households
  - These would lead to another transmission channel – via the stochastic discount factor (SDF)
- While we do not introduce factors that affect SDF into the model, we control for them empirically (e.g., VIX)

Heterogeneous panel SAR model

- Expressing (1) in spatial autoregressive (SAR) form:

$$\widehat{\boldsymbol{q}}_t = \boldsymbol{\alpha} + (I - \text{diag}(\boldsymbol{\rho})\,\mathrm{W})^{-1}\,\boldsymbol{\beta}\,\widehat{\mathcal{M}}_{US,t} + \boldsymbol{\varepsilon}_t$$

  where $\forall\, t$ the $NJ \times 1$ vector of errors $\boldsymbol{\varepsilon}_t = (I - \text{diag}(\boldsymbol{\rho})\,\mathrm{W})^{-1}\,\mathrm{u}_t$, elements of u_t are i.i.d.

- We allow for heterogeneity across country-sectors in parameter estimates
  - $\boldsymbol{\alpha}$: fixed effects
  - $\boldsymbol{\rho}$: spatial correlation "resistance" coefficient
  - $\boldsymbol{\beta}$: "partial" impact of monetary policy shock on stock returns

- Estimated using MLE following Aquaro, Bailey, Pesaran (2019), and use wild bootstrap for standard errors (Mammen, 1993)

Measuring Network Effects

- The total impact of U.S. MP shock is

$$\text{Total} = (\mathbf{I} - \text{diag}(\boldsymbol{\rho})\mathbf{W})^{-1}\boldsymbol{\beta}$$

- Following Acemoglu et al. (2016) this marginal effect for each *mi* can be decomposed into a direct effect of the shock and the network effect as

$$\begin{aligned} \text{Direct}_{AAK} &= \boldsymbol{\beta} \\ \text{Network}_{AAK} &= \text{Total} - \text{Direct}_{AAK} \end{aligned}$$

- Or following LeSage and Pace (2009)

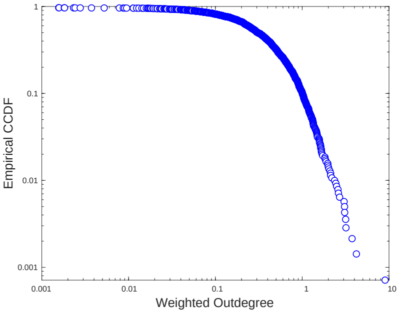
$$\begin{aligned} \text{Direct}_{LP} &= \text{diag}(\mathbf{I} - \text{diag}(\boldsymbol{\rho})\mathbf{W})^{-1}\boldsymbol{\beta} \\ \text{Network}_{LP} &= \text{Total} - \text{Direct}_{LP} \end{aligned}$$

Data

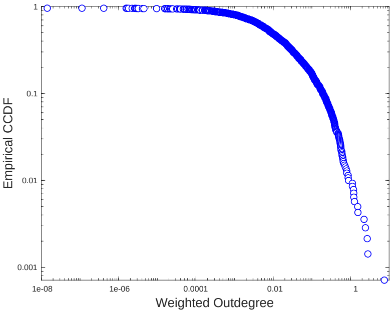
- Input-output: WIOD
  - Input-output linkages for 43 countries 56 sectors for 1996-2014 $\Rightarrow$ We use 26 countries and 54 industries
  - Matrix W: $w_{mi,nj} = \frac{Sales_{mi \rightarrow nj}}{Sales_{nj}}$
- Stock returns: Thompson-Reuters Eikon (TREI)
  - Firm-level stock prices and market capitalization, 2000–16
  - Use NAICS information in Eikon to crosswalk to WIOD industries

  $\Rightarrow$ **Monthly** market-cap weighted stock indexes and returns, expressed in USD
- Shocks:
  - U.S. monetary: Jarociński-Karadi (2020) (robust to other definitions)
  - Foreign monetary: Cieslak-Schrimpf (2019)
  - Global financial cycle: VIX, 2yr Treas. rate, USD Broad Index (Bloomberg)

Weighted outdegree of input-output network



(a) World linkages



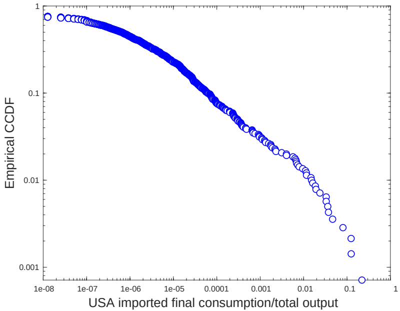
(b) International linkages

Source: WIOD, authors calculations; $out_{mi} = \sum_{n=1}^{N} \sum_{j=1}^{J} w_{mi,nj}$

Measures importance of a country-sector as a supplier in the global production network

▸ Persistence

Final good exports to the U.S. as a share of total country-sector exports



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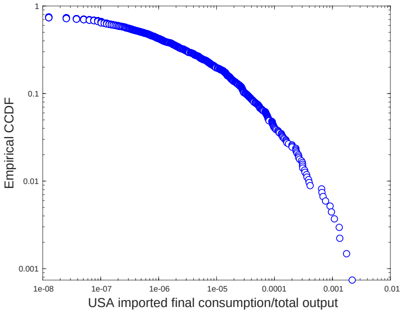
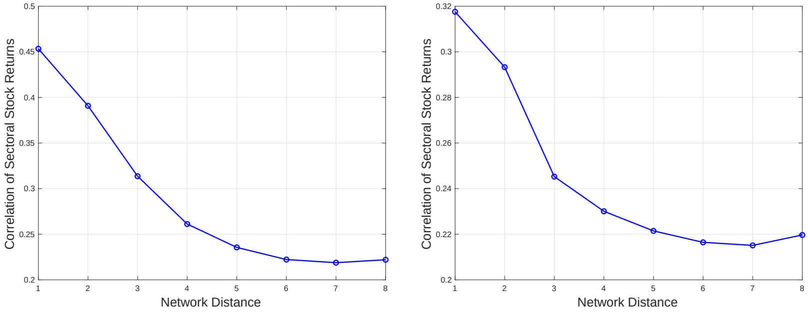


(b) International linkages

Source: WIOD (2000), authors calculations.

Network distance and bilateral returns correlations



(a) World linkages (b) International linkages

Source: WIOD, TREI, authors calculations

A binary network ($w_{mi,nj} < 0.05$ set to 0, else 1), where distance between two cells is defined as the length of the shortest path

Benchmark panel SAR

- 2000-2007; JK monetary policy shock

$$\widehat{\boldsymbol{q}}_t = \boldsymbol{\alpha} + (I - \mathrm{diag}(\boldsymbol{\rho})\,\mathrm{W})^{-1}\,\boldsymbol{\beta}\,\widehat{\mathcal{M}}_{US,t} + \boldsymbol{\varepsilon}_t$$

Panel A. Coefficient Estimates

	Average β	Average ρ	Observations
Full sample	-0.907	0.632	44,286
	(0.094)	(0.028)	
International	-0.828	0.635	40,986
	(0.101)	(0.029)	
USA	-1.871	0.585	3,300
	(0.271)	(0.044)	

Benchmark panel SAR: Decomposition

- 2000-2007; JK monetary policy shock

	Panel B. Total Effect Decomposition		
	Avg. **Direct**	Avg. **Network**	**Network/Total**
Decomposition 1 AAK			
Full Sample	-0.907	-1.808	0.666
	(0.274)	(0.317)	(0.064)
International	-0.828	-1.757	0.680
	(0.101)	(0.322)	(0.068)
USA	-1.871	-2.430	0.565
	(0.271)	(0.442)	(0.080)
Decomposition 2 LP			
Full Sample	-1.214	-1.501	0.553
International	-1.151	-1.435	0.555
USA	-1.988	-2.313	0.538

OLS results · Distributions of direct and network effects · Time periods · Definitions · Foreign MP shocks

Comparison by direct trade linkages with the U.S.

	Panel A. Full Sample				**Panel A.** International Sample			
	Direct/Total		**Network/Total**		**Direct/Total**		**Network/Total**	
	Low	High	Low	High	Low	High	Low	High
Cutoff definition:								
Mean	0.328	0.412	0.672	0.588	0.299	0.465	0.701	0.535
	(0.019)	(0.024)	(0.025)	(0.021)	(0.018)	(0.017)	(0.025)	(0.050)
Median	0.240	0.401	0.760	0.599	0.212	0.396	0.788	0.604
	(0.019)	(0.020)	(0.025)	(0.025)	(0.019)	(0.019)	(0.025)	(0.026)
P90	0.308	0.512	0.692	0.488	0.309	0.468	0.692	0.532
	(0.019)	(0.026)	(0.025)	(0.013)	(0.018)	(0.015)	(0.025)	(0.030)

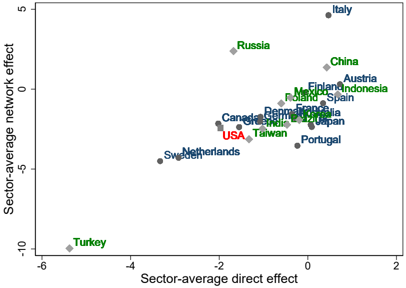
Average share of direct/network effects across bins of country-sectors based on the ranking of a country-sector's sales of final consumption goods to the U.S. relative to the country-sector's total output. Threshold for the cutoff of each bin is either the (i) mean, (ii) median, or (iii) ninetieth percentile (P90) of the consumption-to-output share observed in 2000.

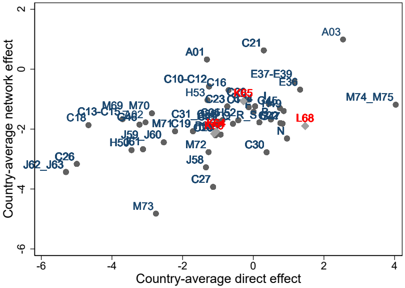
Counterfactual autarkic scenarios

	Total	**Total**$_{AUT1}$	**Total**$_{AUT2}$
Full Sample	-2.716	-1.221	-1.211
	(0.435)	(0.202)	(0.193)
International	-2.580	-1.091	-1.109
	(0.443)	(0.211)	(0.197)

(i) Autarky$_1$ assumes no intermediate input goods trade across any countries, and (ii) Autarky$_2$ only allows for the U.S. to source intermeidate inputs from abroad.

Heterogeneity across countries and sectors





Exploring heterogeneity

- Country size (c)
- External debt (c)
- Financial frictions (c) * financial dependence (s)
- Financial openness (c) * financial dependence (s)
- Price stickiness (s)
- Trade invoicing currency

Conditioning on Global Financial Cycle

- Two-step procedure
  - Regress stock returns on VIX, USD Broad Index, 2yT-rate using Mean Group estimator
  - Use residuals as LHS variable for SAR

$$\widehat{\boldsymbol{q}}_{\perp \mathrm{X},t} = \boldsymbol{\alpha} + (I - \mathrm{diag}(\boldsymbol{\rho})\,\mathrm{W})^{-1}\,\boldsymbol{\beta}\,\widehat{\mathcal{M}}_{US,t} + \boldsymbol{\varepsilon}_t$$

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	Avg. β	Avg. ρ	Avg. **Direct**	Avg. **Network**	**Network/Total**
Full sample	-1.001	0.589	-1.001	-1.880	0.653
	(0.106)	(0.035)	(0.269)	(0.310)	(0.063)
International	-0.936	0.589	-0.936	-1.848	0.664
	(0.108)	(0.035)	(0.108)	(0.315)	(0.066)
United States	-1.796	0.581	-1.796	-2.274	0.559
	(0.304)	(0.055)	(0.304)	(0.428)	(0.092)

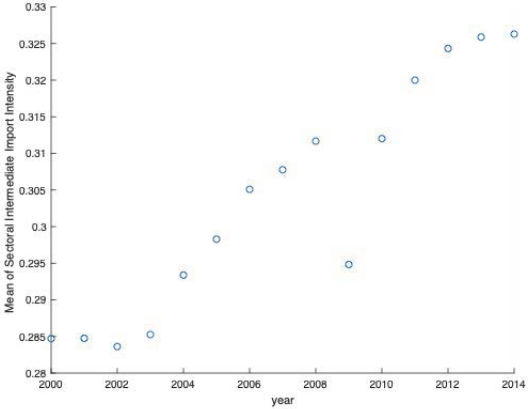
Least-squares estimates | First stage

$\Rightarrow$ Both the **Total** and the share of **Network** effects only decrease slightly compared to the baseline results

Conclusion

- We quantify the propagation of the U.S. monetary policy shocks to stock returns worldwide through trade
- We find an important role for the propagation of shocks upstream along the global production network
- Results are robust to numerous specification changes, including controlling for global financial cycle variables

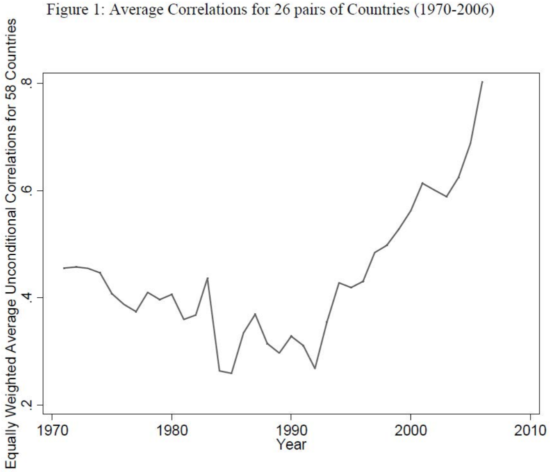
Global production chains lengthened



Source: WIOD, Authors' calculations.

Back

Cross-country stock market correlations increased



Source: Dutt and Mihov (2013), Figure 1.

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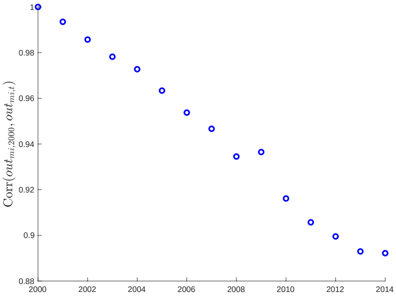
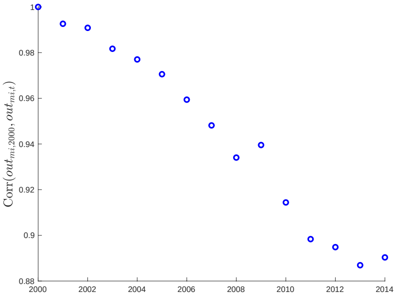
Persistence of trade linkages



(a) World linkages



(b) International linkages

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Benchmark linear regressions

$\widehat{q}_{mi,t} = \alpha + \beta^{LS}\widehat{\mathcal{M}}_{US,t} + \varepsilon_{mi,t}$

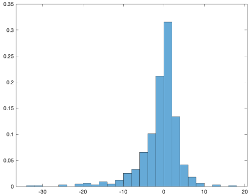
	(1)	(2)	(3)	(4)	(5)	(6)
MP shock	-2.669	-2.669	-2.74	-2.454	-2.533	-3.110
	(0.208)	(1.303)	(1.311)	(0.320)	(0.266)	(1.046)
Constant	0.993	0.993	0.992	0.893	1.013	0.526
	(0.013)	(0.090)	(0.091)	(0.029)	(0.026)	(0.086)
Estimator	OLS	OLS	LS	Random coeffs	Mean Group	LS - country
Fixed effects	None	None	*mi*	Random	*mi*	*m*
St. errors	Regular	Clustered on *t*		Conventional	Group-specific	Clustered on *t*

Notes: There are 49,667 observations in columns (1)-(5), and 1,716 observations in column (6). Standard errors are in parentheses.

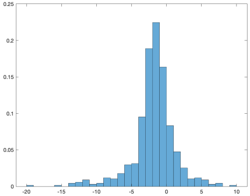
- International β^{LS}: -2.63 (3); -2.41 (5); -3.11 (6)
- U.S. β^{LS}: -4.31 (3); -4.42 (5); -2.99 (6)

Baseline SAR results

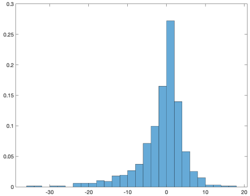
Distributions of decompositions across country-sectors



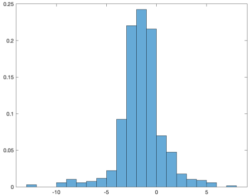
(a) Direct, AAK



(b) Network, AAK



(a) Direct, LP



(b) Network, LP

Baseline SAR results

Robustness of panel SAR

$$\widehat{\boldsymbol{q}}_t = \boldsymbol{\alpha} + (I - \mathrm{diag}(\boldsymbol{\rho})\,\mathrm{W})^{-1}\,\boldsymbol{\beta}\,\widehat{\mathcal{M}}_{US,t} + \boldsymbol{\varepsilon}_t$$

Time period	Year for W	Share of network effect		
		Full sample	International	USA
2000-07	Avg. 2000-07	0.668	0.679	0.588
		(0.056)	(0.060)	(0.068)
2000-16	2000	0.748	0.758	0.661
		(0.056)	(0.059)	(0.034)
2000-16	Avg. 2000-16	0.765	0.772	0.707
		(0.050)	(0.054)	(0.032)
2000-07,09-16	2000	0.723	0.734	0.625
		(0.051)	(0.054)	(0.041)
2000-07,09-16	Avg. 2000-16	0.747	0.756	0.670
		(0.052)	(0.055)	(0.043)
2000-08,10-16	2000	0.743	0.748	0.693
		(0.044)	(0.046)	(0.059)
2000-08,10-16	Avg. 2000-16	0.759	0.762	0.737
		(0.062)	(0.064)	(0.073)

Baseline SAR results

Other definitions of MP shock

$$\widehat{\boldsymbol{q}}_t = \boldsymbol{\alpha} + (I - \text{diag}(\boldsymbol{\rho})\,W)^{-1}\,\boldsymbol{\beta}\,\widehat{\mathcal{M}}_{US,t} + \boldsymbol{\varepsilon}_t$$

	Share of network effect		
Specification	Full sample	International	USA
Excess returns	0.799	0.813	0.693
	(0.107)	(0.119)	(0.046)
Domestic currency returns	0.678	0.684	0.629
	(0.060)	(0.062)	(0.074)
Real domestic currency returns	0.665	0.675	0.594
	(0.084)	(0.087)	(0.082)
USD returns, OW shock	0.663	0.668	0.606
	(0.050)	(0.052)	(0.103)
USD returns, NS shock	0.672	0.678	0.612
	(0.060)	(0.063)	(0.074)
USD returns, BRW shock	0.609	0.606	0.655
	(0.102)	(0.104)	(0.122)

Baseline SAR results

Baseline SAR with foreign monetary policy shocks

$$\widehat{\boldsymbol{q}}_t = \boldsymbol{\alpha} + (I - \text{diag}(\boldsymbol{\rho})\,\mathrm{W})^{-1}\left(\boldsymbol{\beta}\,\widehat{\mathcal{M}}_{US,t} + \sum_{k=1}^{K}\gamma_k\,\widehat{\mathcal{M}}_{kt}\right) + \boldsymbol{\varepsilon}_t$$

	Full Sample			International	United States
	(1)	(2)	(3)	(4)	(5)
Direct effect of US MP	-0.877	-0.889	-0.883	-0.804	-1.848
	(0.314)	(0.317)	(0.291)	(0.088)	(0.301)
Network effect of US MP	-1.974	-1.897	-1.912	-1.863	-2.501
	(0.347)	(0.357)	(0.328)	(0.333)	(0.474)
Total effect of BOE MP	-0.599		-0.572	-0.644	0.302
	(0.274)		(0.293)	(0.196)	(0.408)
Total effect of ECB MP		0.014	-0.118	-0.114	-0.165
		(0.247)	(0.243)	(0.190)	(0.381)

Baseline SAR results

Least-squares with global financial cycle variables

$$\widehat{q}_{mi,t} = \alpha_{mi} + \beta^{LS}_{MP}\widehat{\mathcal{M}}_{US,t} + X_t \beta'^{LS}_X + \varepsilon_{mi,t}$$

	Full Sample				International	United States
	(1)	(2)	(3)	(4)	(5)	(6)
MP shock	-3.320	-3.514	-3.184	-3.465	-3.339	-4.472
	(0.888)	(0.875)	(0.903)	(0.848)	(0.872)	(0.710)
Δ lnVIX	-0.018			-0.016	-0.016	-0.013
	(0.003)			(0.004)	(0.004)	(0.003)
ΔT2y		0.551		0.209	0.220	0.061
		(0.383)		(0.363)	(0.380)	(0.305)
Δ lnUSD			-0.476	-0.438	-0.443	-0.357
			(0.574)	(0.542)	(0.560)	(0.448)
R^2	0.075	0.069	0.067	0.076	0.074	0.08
Observations	49,667				46,357	3,310
Cty-sec FE	Yes	Yes	Yes	Yes	Yes	Yes

Panel SAR estimates

First-Stage Residual Regression Estimation: Controlling for Global Financial Variables

$$\widehat{q}_t = \alpha + \gamma_1 \Delta \ln \text{VIX}_t + \gamma_2 \Delta \ln \text{USD}_t + \gamma_3 \Delta \text{T2y}_t + \varepsilon_t$$

	OLS (1)	RC (2)	MG (3)
Δ lnVIX	-0.057	-0.052	-0.057
	(0.019)	(0.004)	(0.003)
ΔT2y	0.037	0.065	0.035
	(0.395)	(0.079)	(0.064)
Δ lnUSD	-2.404	-2.376	-2.389
	(0.599)	(0.142)	(0.116)
Constant	1.087	0.983	1.105
	(0.078)	(0.030)	(0.028)
Observations	49,667	49,641	49,641
Adjusted R^2	0.023		
Wald χ^2		542.03	881.78

Panel SAR estimates