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

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

Recent era of globalization

- Rise of international integration of firms' production chains (e.g., Hummels et al., 2001; Yi, 2003)
- Increased correlation of world stock markets (e.g., Dutt et al., 2013)
- 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?

Our question

What is the role of the global production network in transmitting U.S. monetary policy shocks across stock markets?

We answer it in four steps:

- Extend a simple network model to multi-country setting
  - Acemoglu et al. (2012), Ozdagli and Weber (2017)
- Construct 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
- Document relationship between country-sector distance in production network and stock return correlations
- Estimate 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

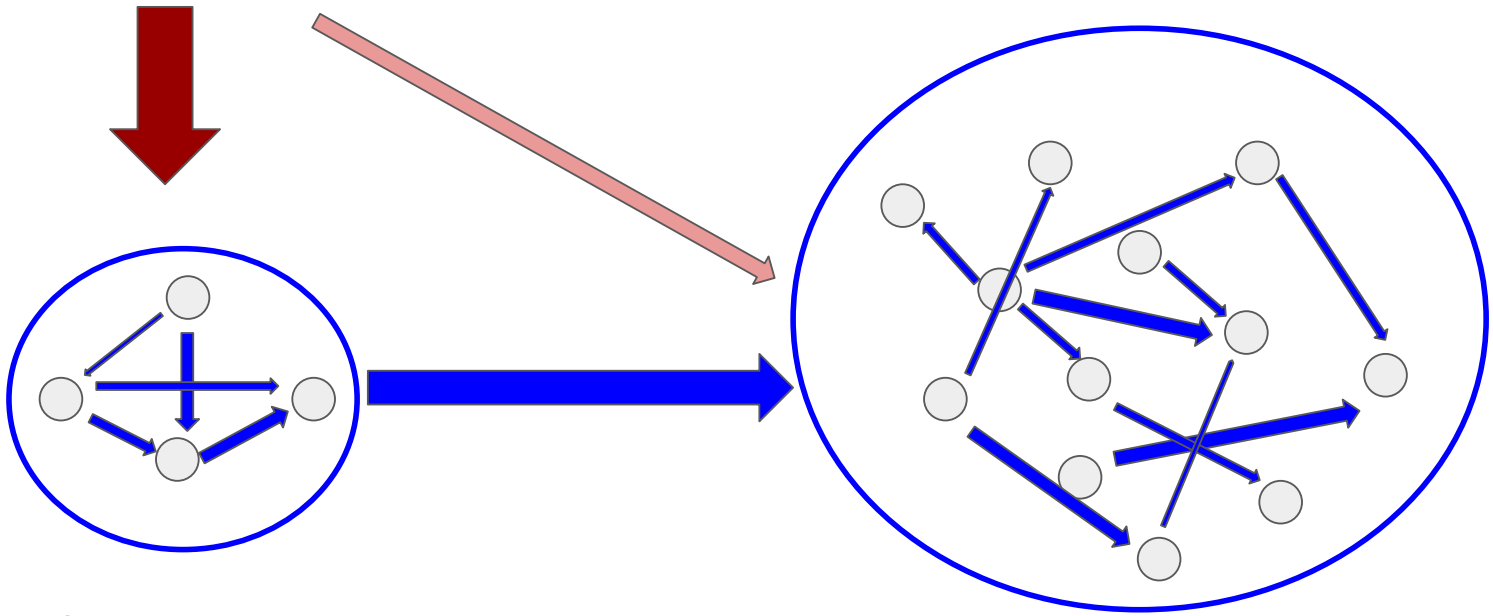
2. Global product network accounts for at least *60%* of the total impact of U.S. MP shocks on stock returns via demand (upstream) channel
   - Baseline analysis 2000–07, but robust to other time periods

3. *Direct* impact greater for U.S. sectors, while *network* impact greater for foreign markets

4. Results robust to controlling for global financial cycle variables, which tend to impact returns more directly

Story in a nutshell

U.S.monetary policy shock



U.S. stock returns

Foreign stock returns

Related literature

- Transmission of shocks through production linkages
  - **International:** Burstein et al. (2008), Bems et al. (2010), Johnson (2014), Eaton et al. (2016), di Giovanni et al. (2018), Baqaee and Farhi (2019b), Huo et al. (2020)
  - **Domestic:** Foerster et al. (2011), Acemoglu et al. (2012), Carvalho et al. (2016), Atalay (2017), Grassi (2017), Ozdagli and Weber (2017), Boehm et al. (2019), Baqaee and Farhi (2019a)
- International transmission of U.S. monetary policy shocks
  - **Effect on asset prices:** Many papers starting with Rey (2013), Miranda-Argippino and Rey (2020)
  - **Through banking:** Cetorelli and Goldberg (2012), Bruno and Shin (2015b), Avdjiev et al. (2018), Temesvary et al. (2018), Buch et al. (2019), Morais et al. (2019)
  - **Effect on capital flows:** Bruno and Shin (2015a), Avdjiev and Hale (2019)
  - **Through trade:** Brooks and Del Negro (2006), Todorova (2018), Du et al. (2019)

Theoretical framework: main ingredients

- Based on a static multi-sector model of Ozdagli and Weber (2017), who adapt Acemoglu et al. (2012):
  - Firms: decreasing returns to scale, fixed costs ▸ Firms
  - Wages: preset, do not adjust to monetary shocks
  - Consumers: cash-in-advance constraint ▸ Consumers
  - Exogenous money supply

  Open economy:
  - Multi-country, multi-sector model of production linkages:

    countries m, n; industries i, j
  - Balanced trade for each country
  - LOOP after adjusting for an iceberg trade cost:

    $p_{mi,n} = \tau_{mi,n} p_{mi}$, $\tau_{mi,n} \geq 1$

Theoretical framework: solution

- Goods market clearing:

$$y_{mi} = \sum_{n=1}^{N} c_{mi,n} + \sum_{j=1}^{J} \sum_{n=1}^{N} x_{mi,nj}$$

- Iceberg trade costs: $p_{mi,n} = \tau_{mi,n} p_{mi}$, $\tau_{mi,n} \geq 1$

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- Iceberg trade costs: $p_{mi,n} = \tau_{mi,n} p_{mi}$, $\tau_{mi,n} \geq 1$
- Combining with FOCs, we get a recursive solution across country-sectors:

$$R_{mi} = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{b_{mi,n}(1-\lambda_{nj})}{\tau_{mi,n}} R_{nj} + \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\lambda_{nj}\omega_{mi,nj}}{\tau_{mi,n}} R_{nj}$$

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- Stacking across nj and express in matrix form:

$$(I - \widetilde{\Omega}\Lambda)\mathrm{R} = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{b_{mi,n}(1-\lambda_{nj})}{\tau_{mi,n}} R_{nj} \qquad (1)$$

▶ Matrices

Money supply

- Cash-in-advance constraint:

$$\sum_{i=1}^{J}\sum_{m=1}^{N} p_{mi,n}c_{mi,n} = \sum_{j=1}^{J}(1-\lambda_{nj})R_{nj} = \mathcal{M}_n,$$

  where $\mathcal{M}_n$ is domestic money supply in country n

- Combining with (1):

$$(I - \widetilde{\Omega}\Lambda)\mathrm{R} = \tilde{\boldsymbol{b}}\boldsymbol{\mathcal{M}}$$

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- Combining with (1):

$$(I - \widetilde{\Omega}\Lambda)\mathrm{R} = \tilde{\boldsymbol{b}}\boldsymbol{\mathcal{M}}$$

- Substituting into profit equation, and log-linearizing around steady state:

$$\widehat{\boldsymbol{\pi}} = \left(I - \widetilde{\Omega}\Lambda\right)^{-1}\boldsymbol{\beta}\widehat{\boldsymbol{\mathcal{M}}},$$

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

$$\widehat{\boldsymbol{\pi}} = \left(I - \widetilde{\Omega}\Lambda\right)^{-1}\boldsymbol{\beta}_{US}\widehat{\mathcal{M}}_{US} \qquad (2)$$

Heterogeneous panel SAR model

- Expressing (2) in spatial autoregressive (SAR) form:

$$\widehat{\boldsymbol{\pi}}_t = \boldsymbol{\beta}\,\widehat{\mathcal{M}}_{US,t} + \boldsymbol{\rho}\mathsf{W}\,\widehat{\boldsymbol{\pi}}_t + \boldsymbol{\varepsilon}_t,$$

  where $\mathsf{W} = \widetilde{\Omega}\Lambda$ is standard input-output coefficient, adjusted for bilateral trade costs

- Or with controls:

$$\widehat{\boldsymbol{\pi}}_t = \boldsymbol{\beta}_1\,\widehat{\mathcal{M}}_{US,t} + \boldsymbol{\beta}_2\,\mathsf{X}_t + \boldsymbol{\rho}\mathsf{W}\,\widehat{\boldsymbol{\pi}}_t + \boldsymbol{\varepsilon}_t$$

- We allow for heterogeneity in β's as well as "resistance" coefficient ρ across country-sectors

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

Decomposition into direct and network effects

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

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

- Following Lesage and Pace (2009) this marginal effect for each *mi* can be decomposed into a direct effect of the shock and the network effect as

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

$$\text{Network} = \text{Total} - \text{Direct}$$

Data

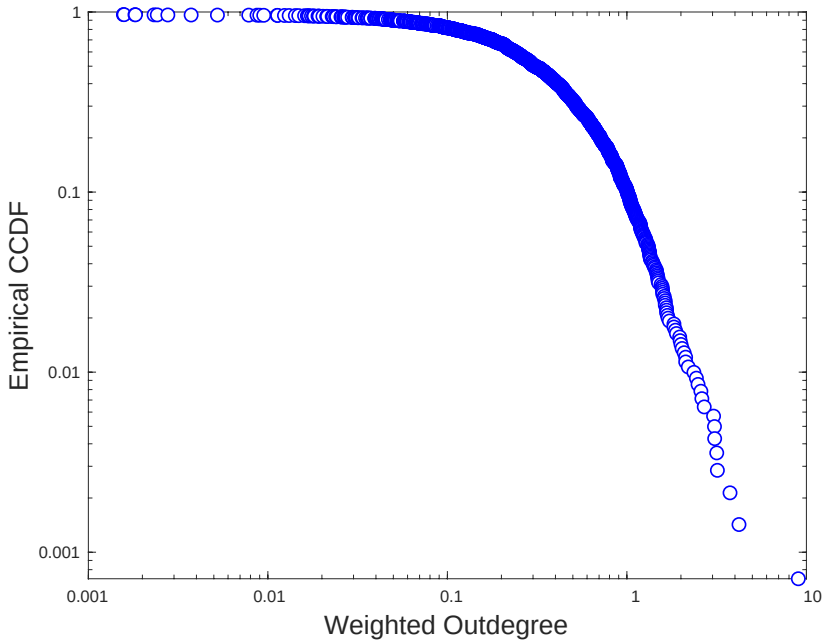
- Input-output: WIOD
  - Input-output linkages for 43 countries 56 sectors for 1996-2014 $\Rightarrow$ We use 26 countries and 54 industries
  - Matrix W:

    $$w_{mi,nj} = \frac{Sales_{mi \to nj}}{Sales_{nj}}$$

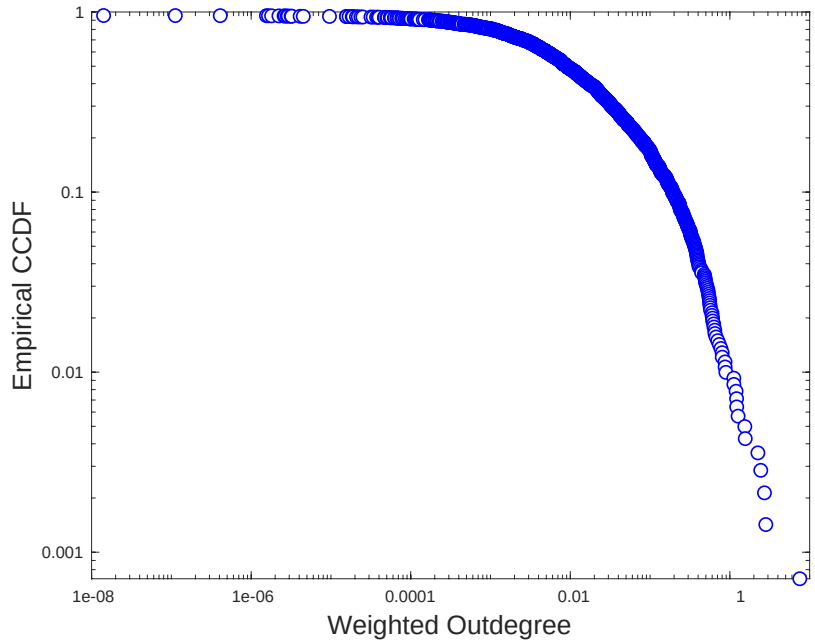
    ▸ Data matrices
  - Trade costs computed using Head-Reis (2001) index at (mi, n) level
- Stock returns: Thompson-Reuters Eikon (TREI)
  - Firm-level stock prices and market capitalization, 2000–16
  - Use NAICS information in Eikon to crosswalk to WIOD industries

  $\Rightarrow$ **Monthly** market-cap weighted stock indexes and returns
- Shocks:
  - Monetary: Jarociński-Karadi (2020); [BRW, NS, OW]
  - Global financial cycle: VIX, 2yr Treas. rate, USD Broad Index

Weighted outdegree of input-output network



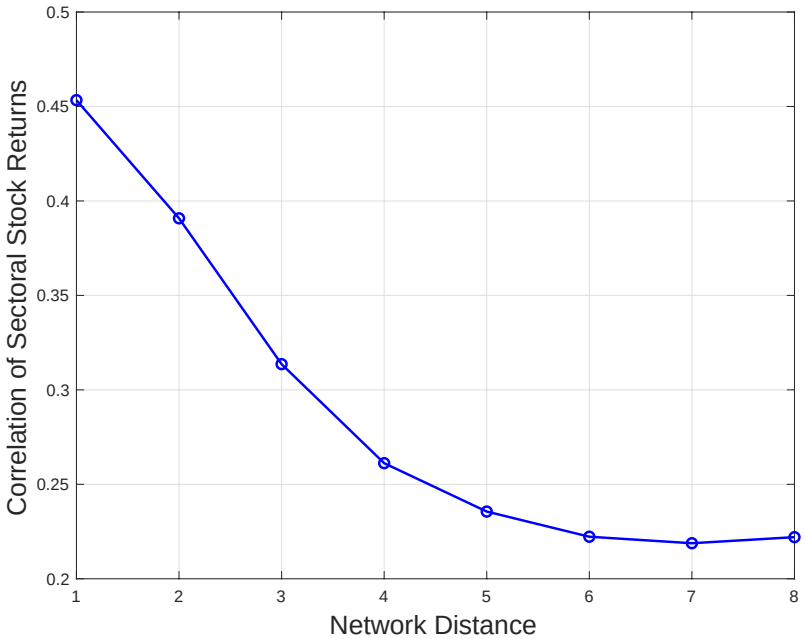
(a) World linkages



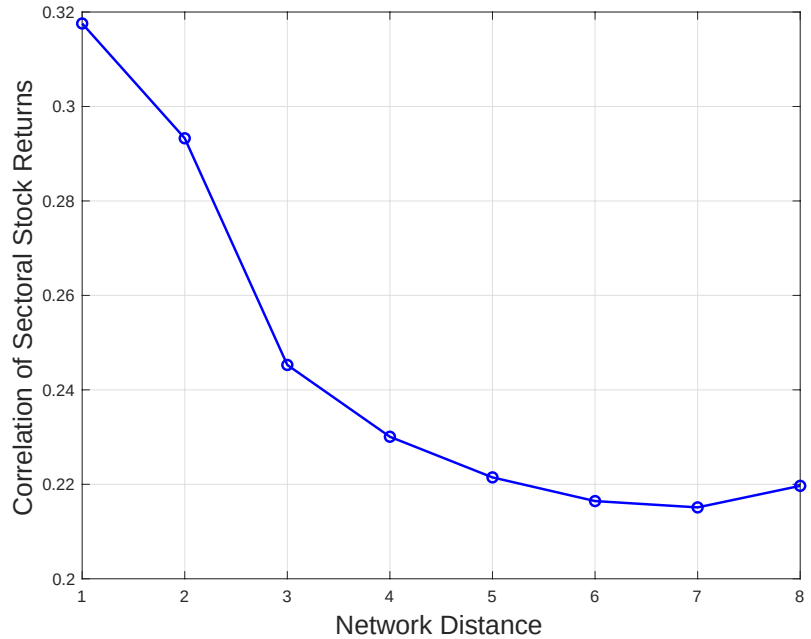
(b) International linkages

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

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

$$\widehat{\pi}_{mi,t} = \boldsymbol{\beta}\,\widehat{\mathcal{M}}_{US,t} + \boldsymbol{\rho}\,\mathrm{W}\widehat{\boldsymbol{\pi}}_t + \varepsilon_{mi,t}$$

	Avg. β (1)	Avg. ρ (2)	Avg. **Direct** (3)	Avg. **Network** (4)	**Network/Total** (5)
Full sample	-0.027*	0.675***	-0.035**	-0.053***	60%***
	(0.020)	(0.157)	(0.020)	(0.012)	(0.164)
International	-0.023	0.681***	-0.031*	-0.052***	62%***
	(0.020)	(0.158)	(0.019)	(0.020)	(0.045)
USA	-0.080***	0.600***	-0.087***	-0.065**	42%***
	(0.034)	(0.154)	(0.034)	(0.034)	(0.008)

▸ OLS results ▸ Distributions of direct and network effects ▸ Time periods ▸ Definitions ▸ No trade costs

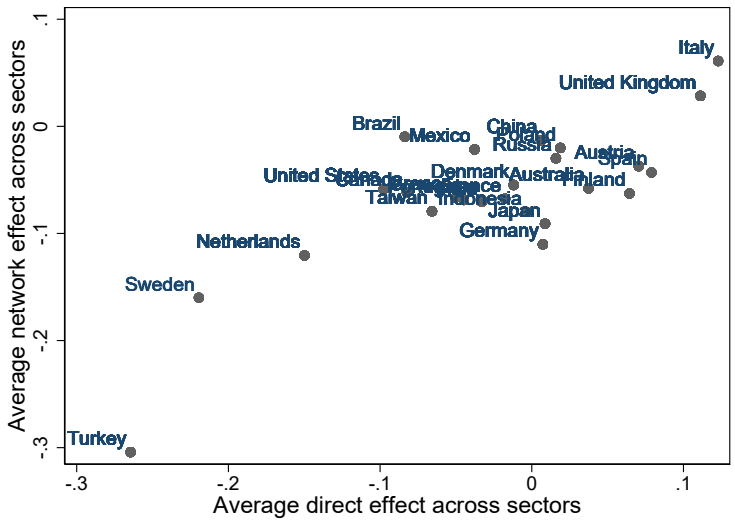
Panel SAR with global financial cycle variables

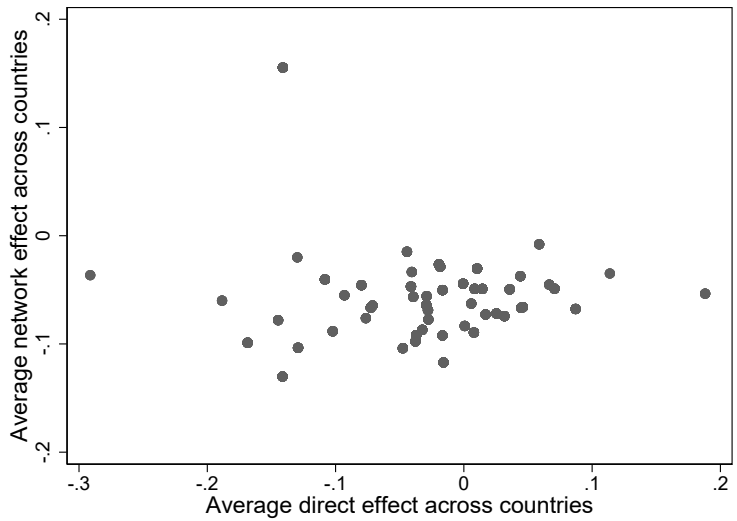
$$\widehat{\pi}_{mi,t} = \boldsymbol{\beta}_{MP}\,\widehat{\mathcal{M}}_{US,t} + \boldsymbol{\beta}_{X}\,\mathrm{X}_t + \boldsymbol{\rho}\,\mathrm{W}\widehat{\boldsymbol{\pi}}_t + \varepsilon_{mi,t}$$

	Full Sample				International	USA
	(1)	(2)	(3)	(4)	(5)	(6)
Direct effect of MP	-0.014	-0.035**	-0.029	-0.020**	-0.014	-0.089***
	(0.010)	(0.017)	(0.023)	(0.011)	(0.011)	(0.019)
Network effect of MP	-0.036***	-0.068***	-0.064***	-0.045***	-0.045***	-0.050***
	(0.013)	(0.019)	(0.015)	(0.018)	(0.018)	(0.020)
Direct effect of VIX	-0.063***			-0.058***	-0.058***	-0.051***
	(0.024)			(0.019)	(0.019)	(0.017)
Network effect of VIX	-0.079***			-0.068***	-0.068***	-0.063***
	(0.016)			(0.016)	(0.016)	(0.016)
Direct effect of T2y		0.060**		0.042***	0.041***	0.051***
		(0.027)		(0.014)	(0.013)	(0.016)
Network effect of T2y		0.077***		0.045***	0.045***	0.048***
		(0.027)		(0.013)	(0.017)	(0.019)
Direct effect of USD			-0.150**	-0.101**	-0.091**	-0.212***
			(0.082)	(0.050)	(0.051)	(0.079)
Network effect of USD			-0.343***	-0.155*	-0.155*	-0.156*
			(0.088)	(0.106)	(0.106)	(0.118)

▸ Least-squares estimates

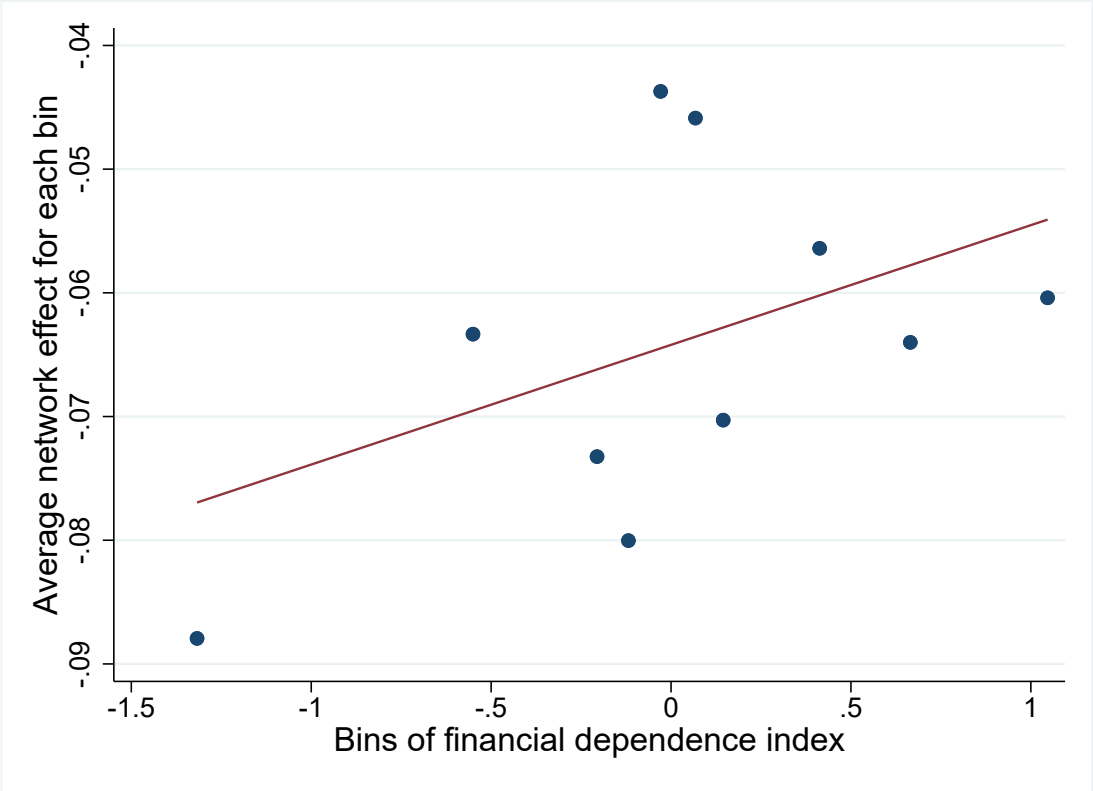
Heterogeneity across countries and sectors





- Neither direct nor network effects correlated with country characteristics, such as country size, financial openness, current account....

Sectoral external financial dependence



- The magnitude of network effect is smaller (in absolute value) for sectors that are more reliant on external finance

▸ No trade costs

Conclusion

- We quantify propagation of the U.S. monetary policy shocks to stock returns worldwide and find an import role for the global production network, via upstream demand channel
- Production network plays a greater role for transmission across countries than within the U.S.
- Results robust numerous to numerous specifications, including global financial cycle variables
- Simple setup that can be extended in numerous ways, including incorporating exchange rate effects (both upstream and downstream)

Consumers

- Representative agent in country n consumes goods from all industries i in all countries m and supplies labor to all industries j in her country

$$\max_{\{c_{mi,n}\},l_n} \sum_{i=1}^{J}\sum_{m=1}^{N} b_{mi,n} \log c_{mi,n} - l_n$$

$$\text{s.t.}$$

$$\sum_{i=1}^{J}\sum_{m=1}^{N} p_{mi,n} c_{mi,n} = w_n l_n + \pi_n + f_n,$$

where $b_{mi,n}$ is a preference parameter for which we assume $\sum_{i=1}^{J}\sum_{m=1}^{N} b_{mi,n} = 1$

Back

Firms

- Cobb-Douglas production function of industry j in country n:

$$y_{nj} = z_{nj} l_{nj}^{\alpha_{nj}} X_{nj}^{\lambda_{nj}}; \qquad \alpha_{nj} + \lambda_{nj} < 1,\ z_{nj} = 1\ \forall\ nj$$

$$X_{nj} = \prod_{i=1}^{J} \prod_{m=1}^{N} x_{mi,nj}^{\omega_{mi,nj}}; \qquad \sum_{i=1}^{J} \sum_{m=1}^{N} \omega_{mi,nj} = 1,$$

  where $\omega_{mn,ij}$ is nj usage of product of mi (viz. total intermediates)

- Firms maximize profit paying wage bill and a fixed costs, f_{nj}:

$$\pi_{nj} = (1 - \lambda_{nj} - \alpha_{nj}) R_{nj} - f_{nj},$$

  where $R_{nj} = p_{nj} y_{nj}$

Back

Matrices

$$\mathrm{R} \equiv (R_{11}, \ldots, R_{NJ})', \qquad NJ \times 1,$$

$$\Lambda \equiv \mathrm{diag}\left(\{\lambda_{nj}\}\right), \qquad NJ \times NJ,$$

$$\widetilde{\Omega} \equiv \tilde{\boldsymbol{\tau}} \circ \Omega, \qquad NJ \times NJ,$$

$$\Omega \equiv \begin{pmatrix} \omega_{11,11} & \cdots & \omega_{11,NJ} \\ \vdots & \ddots & \vdots \\ \omega_{NJ,11} & \cdots & \omega_{NJ,NJ} \end{pmatrix}, \qquad NJ \times NJ,$$

$$\tilde{\boldsymbol{\tau}} \equiv \begin{pmatrix} \left(\frac{1}{\tau_{11,1}}\right) \circ 1_{1\times J} & \cdots & \left(\frac{1}{\tau_{11,N}}\right) \circ 1_{1\times J} \\ \vdots & \ddots & \vdots \\ \left(\frac{1}{\tau_{NJ,1}}\right) \circ 1_{1\times J} & \cdots & \left(\frac{1}{\tau_{NJ,N}}\right) \circ 1_{1\times J} \end{pmatrix}, \qquad NJ \times NJ,$$

◂ Equilibrium

Benchmark linear regressions

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

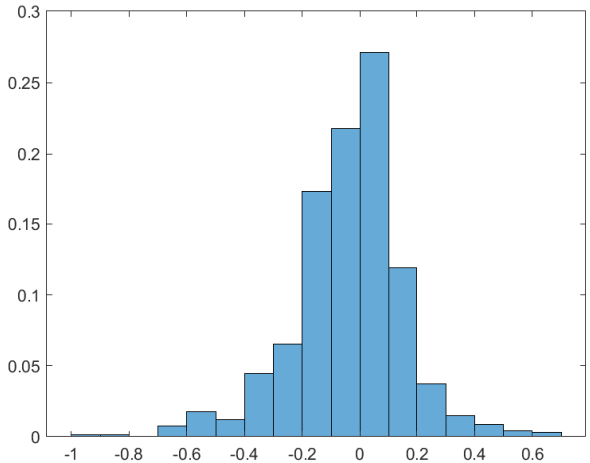
	(1)	(2)	(3)	(4)	(5)	(6)
MP shock	-0.102***	-0.102**	-0.103**	-0.083***	-0.098***	-0.136***
(β^{LS})	(0.008)	(0.044)	(0.044)	(0.011)	(0.009)	(0.049)
Constant	0.010***	0.010**	0.010*	0.010***	0.010***	0.010*
	(0.000)	(0.005)	(0.005)	(0.001)	(0.001)	(0.005)
Estimator	OLS	OLS	LS	Random coeffs	Mean Group	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 with *, **, and *** denoting coefficients significantly different from zero at the 1, 5 and 10% levels, respectively.

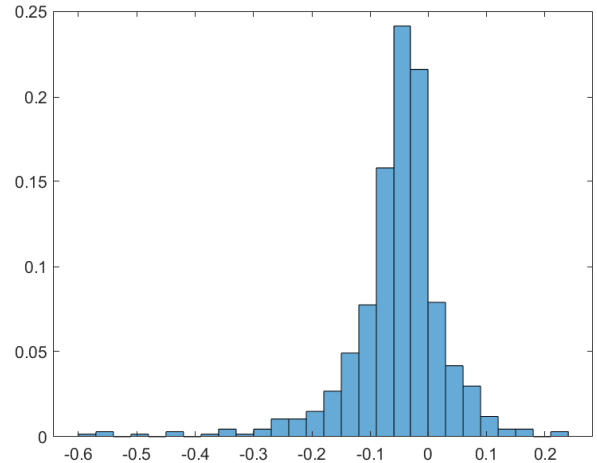
- International β^{LS}: -0.134 (3); -0.092 (5); -0.134 (6)
- U.S. β^{LS}: -0.171 (3); -0.179 (5); -0.173 (6)

◂ Baseline SAR results

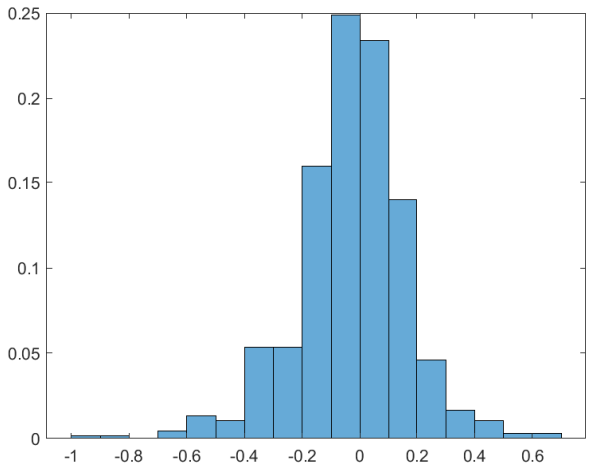
Distributions of decompositions across country-sectors



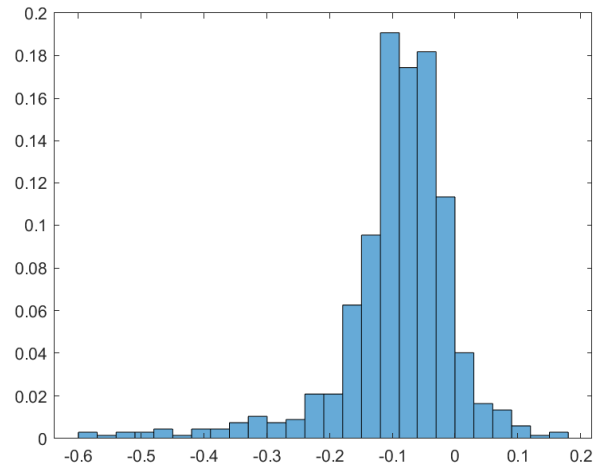
(a) Direct



(b) Network



(a) Direct, $\tau = 1$



(b) Network, $\tau = 1$

◀ Baseline SAR results

Robustness of panel SAR

Time period	Observations	Year for W	Share of network effect		
			Full sample	International	USA
2000–07	44,286	Average 2000–07	59%	62%	40%
			(0.141)	(0.013)	(0.007)
2000–16	92,598	2000	74%	80%	44%
			(0.349)	(0.240)	(0.124)
2000–16	92,598	Average 2000–14	77%	84%	43%
			(0.364)	(0.202)	(0.106)
2000–07,09–16	87,230	2000	65%	68%	45%
			(0.181)	(0.101)	(0.108)
2000-07,09–16	87,230	Average 2000–14	63%	66%	42%
			(0.172)	(0.099)	(0.087)

◂ Baseline SAR results

Other definitions of MP shock

$\widehat{\pi}_{mi,t} = \beta \widehat{\mathcal{M}}_{US,t} + \rho \mathrm{W}\widehat{\pi}_t + \varepsilon_{mi,t}$

Specification	Share of network effect		
	Full sample	International	USA
Real returns, JK shock	66%	69%	48%
	(0.156)	(0.070)	(0.055)
Nominal returns, BRW shock	67%	69%	60%
	(0.247)	(0.204)	(0.177)
Nominal returns, OW shock	57%	58%	54%
	(0.138)	(0.065)	(0.068)
Nominal returns, NS shock	59%	60%	52%
	(0.188)	(0.145)	(0.117)

◀ Baseline SAR results

Baseline SAR without trade costs

$$\widehat{\pi}_{mi,t} = \boldsymbol{\beta}\,\widehat{\mathcal{M}}_{US,t} + \boldsymbol{\rho}\,\mathrm{W}\widehat{\boldsymbol{\pi}}_t + \varepsilon_{mi,t}$$

	Avg. β (1)	Avg. ρ (2)	Avg. **Direct** (3)	Avg. **Network** (4)	**Network/Total** (5)
Full sample	-0.019	0.748***	-0.026*	-0.093***	78%***
	(0.021)	(0.179)	(0.020)	(0.018)	(0.197)
International	-0.016	0.746***	-0.023	-0.091***	80%***
	(0.020)	(0.179)	(0.019)	(0.020)	(0.084)
USA	-0.056*	0.768***	-0.066**	-0.122***	65%***
	(0.035)	(0.212)	(0.033)	(0.035)	(0.047)

◀ Baseline SAR results

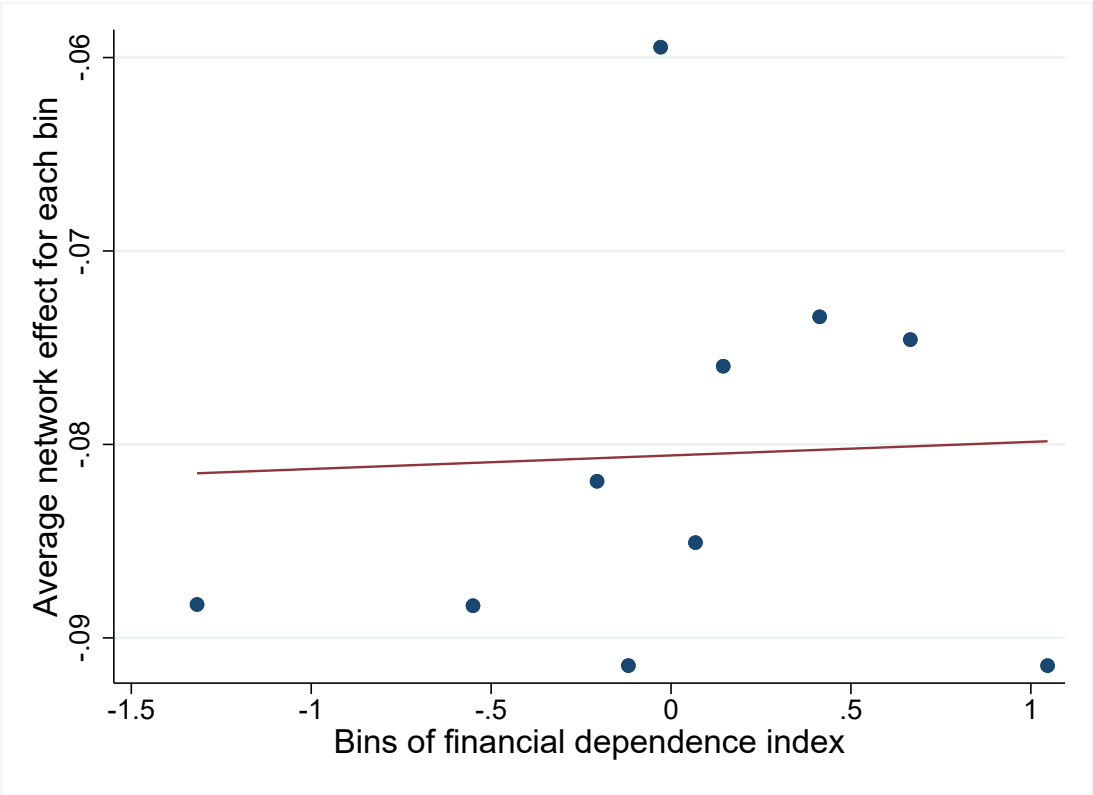
Least-squares with global financial cycle variables

$$\widehat{\pi}_{mi,t} = \beta_{MP}^{LS}\,\widehat{\mathcal{M}}_{US,t} + \boldsymbol{\beta}_{X}^{LS}\,\mathrm{X}_t + \varepsilon_{mi,t}$$

	Full Sample				International	USA
	(1)	(2)	(3)	(4)	(5)	(6)
MP shock	-0.061	-0.117**	-0.107**	-0.076	-0.070	-0.152***
	(0.046)	(0.046)	(0.044)	(0.047)	(0.048)	(0.040)
VIX	-0.162***			-0.146***	-0.148***	-0.123***
	(0.037)			(0.036)	(0.036)	(0.031)
T2y		0.146*		0.091*	0.090*	0.113***
		(0.077)		(0.047)	(0.049)	(0.035)
USD			-0.546	-0.338	-0.332	-0.417
			(0.363)	(0.290)	(0.297)	(0.281)
R^2	0.060	0.030	0.02	0.070	0.070	0.14
Observations	49,667				46,357	3,310

◂ Panel SAR estimates

Sectoral external financial dependence: no trade costs



Back