Monetary Policy Through Production Networks: Evidence from the Stock Market

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Motivation

Understanding how monetary policy affects the broader economy necessarily entails understanding both how policy actions affect key financial markets, as well as how changes in asset prices and returns in these markets in turn affect the behavior of households, firms, and other decision makers.

Ben Bernanke (2003)

- Central banks' targets: stabilize real consumption, investment, GDP
- Only indirect effect of monetary policy on real outcomes
- Immediate effect on financial markets

Motivation cont.

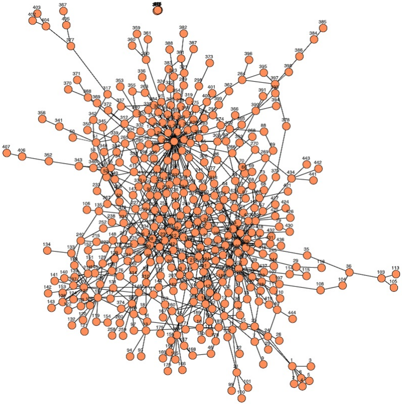
- Policy influences prices via interest rates & risk premia
- Empirically: immediate & strong reaction (Bernanke & Kuttner (2005)
- 25 bps surprise cut $\Rightarrow$ 1% increase in S&P500 within minutes
- Effect permanent; does not revert
- Size hard to rationalize w/ standard amplification mechanisms

Motivation cont.

- US economy: specialization and tightly-linked production networks
- Macro models ignore input-output linkages across sectors
- Traditional view: idiosyncratic shocks irrelevant: law of large numbers
  Lucas (1977)
- Growing literature: micro shocks contribute to aggregate fluctuations
- Central to argument: fat-tailed size distribution of firms/sectors
  Acemuglu et al (2012), Gabaix (2011)

Motivation cont.

Production Network corresponding to US Input-Output Data



- Network is sparse
- Few large suppliers to whole economy

This Paper

- Idea: policy shocks directly affect the demand of end producers
- End producers increase production and require more inputs
- Use stylized model of production to motivate empirical specification
- Spillover effects via intermediate production

Main Finding

- Link input-output tables to industry returns
- Estimate high-frequency event study around FOMC announcements
- “Spatial autoregressions”: introduce network lag in regression
- Decompose overall effect into direct effects and network effects
    - Definition of effects consistent with average partial derivatives

50% to 80% of the overall effect due to indirect effects

Building Blocks

- Simplest model with heterogeneous effects of monetary policy
- One period model
- Stock price determined by net income
- Constant discount rate normalized to 0
- Intermediate inputs only production factor

Firm Problem

Maximize profits

$$\max \pi_i = p_i y_i - \sum_{j=1}^{N} p_j x_{ij} - f_i$$

Subject to the production function

$$y_i = z_i \left(\prod_{j=1}^{N} x_{ij}^{\omega_{ij}} \right)^{\alpha}$$

Substitute first-order condition in objective function to get

$$\pi_i = (1 - \alpha) R_i - f_i$$

π: net income
p_i: product price
y_i: level of output
x_{ij}: intermediate input from firm j
f_i: fixed cost of production
N: number of firms
ω_{ij}: input share from firm j in production of firm i
α: factor share

Household Problem

Maximize utility

$$\max \sum_{i=1}^{N} \log(c_i)$$

subject to the budget constraint

$$\sum_{i=1}^{N} p_i c_i = \sum_{i=1}^{N} \pi_i + \sum_{i=1}^{N} f_i.$$

The first-order condition is given by

$$c_i = \frac{(1-\alpha)\sum_{i=1}^{N} R_i}{N p_i}$$

Goods Market Clearing

$$y_i = c_i + \sum_{j=1}^{N} x_{ji} \Rightarrow y_i = \frac{(1-\alpha)\sum_{i=1}^{N} R_i}{Np_i} + \frac{\alpha \sum_{j=1}^{N} \omega_{ji} p_j y_j}{p_i},$$

which simplifies to

$$R_i = (1-\alpha)\frac{\sum_{i=1}^{N} R_i}{N} + \alpha \sum_{j=1}^{N} \omega_{ji} R_j,$$

Money Supply

- Intermediate input: financed through trade credit
- Consumption goods: purchased with cash

$\Rightarrow$ cash in advance constraint:

$$\sum_{i=1}^{N} p_i c_i = \sum_{i=1}^{N} R_i = M$$

Use market clearing condition to get

$$(I - \alpha W')R = \begin{pmatrix} M/N \\ \vdots \\ M/N \end{pmatrix}_{N\times 1} = m$$

$W = [\omega_{ij}]$: matrix of factor shares
$R = (R_1, ..., R_N)'$: vector of revenues

Equilibrium Prices

Firm profits are given by

$$\begin{aligned}\pi &= (1-\alpha)R - f \\ &= \left(I - \alpha W'\right)^{-1}(1-\alpha)m - f,\end{aligned}$$

Log-linearize

$$\hat{\pi} = \beta \times \hat{M} + \alpha \times W' \times \hat{\pi}$$

$\beta_i = \frac{(1-\alpha)\bar{m}}{\bar{\pi}_i}$

Variables without $_i$: vector of firm-specific variables

Spatial Autoregressions

The spatial autoregressive (SAR) model is given by

$$y = X\beta + \rho W' y + \varepsilon$$

With data generating process

$$y = (\mathbb{I}_n - \rho W')^{-1} X\beta + (\mathbb{I}_n - \rho W')^{-1}\varepsilon$$
$$\varepsilon \overset{N}{\sim} (0, \sigma^2 \mathbb{I}_n),$$

y: vector of returns
X: matrix of covariates
W': row normalized spatial-weighting matrix
W: BEA input-output matrix

Spatial Autoregressions

- Estimate model using maximum likelihood
- Bootstrap standard errors sampling events at random
- 1,000 samples with same number of events as empirical sample

Parameter Interpretation

- OLS: β partial derivatives of dependent wrt independent variable
- Spatial model: incorporates information from related industries

$$
\begin{aligned}
(\mathbb{I}_n - \rho W')y &= X\beta + \varepsilon \\
y &= S(W')X + V(W')\varepsilon,
\end{aligned}
$$

where

$$
\begin{aligned}
S(W') &= V(W')\mathbb{I}_n\beta \\
V(W') &= (\mathbb{I}_n - \rho W')^{-1} = \mathbb{I}_n + \rho W' + \rho^2 (W')^2 + \ldots
\end{aligned}
$$

Parameter Interpretation cont.

Example with three industries and one covariate

$$\begin{pmatrix} y_1 \\ y_3 \\ y_3 \end{pmatrix} = \begin{pmatrix} S(W')_{11} & S(W')_{12} & S(W')_{13} \\ S(W')_{21} & S(W')_{22} & S(W')_{23} \\ S(W')_{31} & S(W')_{32} & S(W')_{33} \end{pmatrix} \times \begin{pmatrix} v \\ v \\ v \end{pmatrix} + V(W)\varepsilon,$$

$S(W')_{ij}$: i, j th element of $S(W')$

Parameter Interpretation cont.

Focus on industry 1

$$y_1 = S(W')_{1,1} v + S(W')_{1,2} v + S(W')_{1,3} v + V(W')_1 \varepsilon$$

$S(W')_i$: i the row of $S(W')$

Parameter Interpretation cont.

Response of industry 1 (y_1) depends on other industries

- Input-output matrix W via effect on intermediate production
- Parameter ρ through the strength of spillover effects
- Parameter β

Decomposition

- Diagonal elements of $S(W')$: direct effect
- Off-diagonal elements: indirect effects

Define

Average direct effect: $1/3tr(S(W'))$

Average total effect: $1/3\iota_3' c_r$ ($c_r = S(W')\iota_3$)

Average indirect effect: difference btw effects

- Definition of effects corresponds to average partial derivatives
- Average direct effect includes spillover effects of other industries

Data and Sample Period

- 129 event dates between February 1994 and December 2008
- 30min event windows around the press releases of the FOMC
- Time stamps of press releases from FOMC
- Stock returns for common stocks from NYSE taq

Input–Output Tables

- Bureau of Economic Analysis (BEA)
- Dollar flows between all producers and purchasers in the US
- Based on NAICS industry codes; before 1997, SIC codes
- “Make” table: production of commodities by industries
- “Use” table: input uses of commodities by intermediate and final users

Industry-by-Industry Matrix

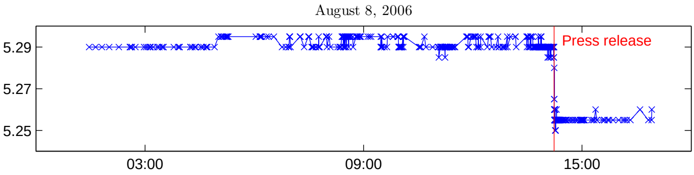
Cross-multiply make and use tables

- *SHARE*: share of each commodity c each industry i produces
- *REVSHARE*: dollar amount industry i sells to industry j
- *SUPPSHARE*: *REVSHARE* over intermediate inputs of industry j
- $SUPPSHARE'$ corresponds to W matrix in model

Monetary Policy Shocks

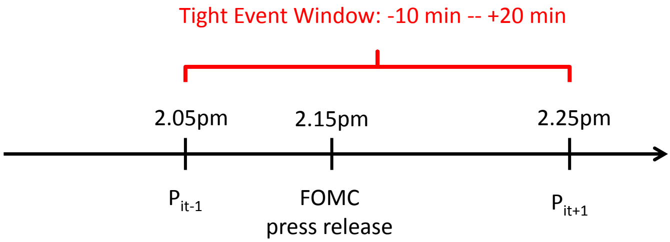
- High-frequency identification of monetary policy shocks
- Tick-by-tick federal funds futures (FFF) Globex data from CME
- FFF ff^0 settles on average effective fed funds rate: use scaled change

$$v_t = \frac{D}{D-t}(ff^0_{t+\Delta t^+} - ff^0_{t-\Delta t^-}) \qquad \text{where } D \text{ is \# of days in month}$$



- High trading activity with immediate market reaction

Event Returns

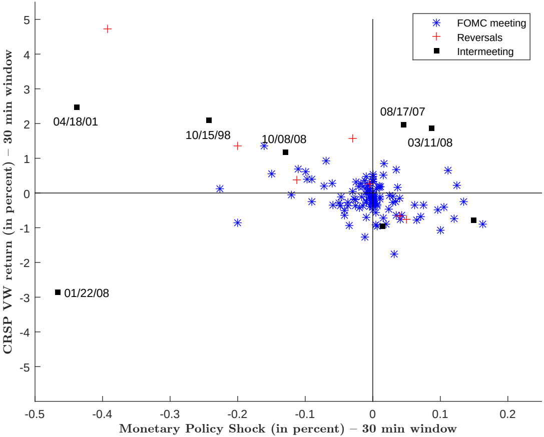


- All common stocks trading on Amex, Nyse, and Nasdaq
- Use tick-by-tick data from NYSE taq
- Last trade before (P_{it-1}) and first trade after (P_{it+1}) event window

taq Trade Prices

	Stock Symbol	Transaction Date	Trade Time	Actual Trade Price per Share	Exchange on which the Trade occurred	Number of Shares Traded
43394	GE	20130131	14:04:46	22.31	K	100
43395	GE	20130131	14:04:46	22.31	K	100
43396	GE	20130131	14:04:46	22.31	K	100
43397	GE	20130131	14:04:46	22.31	K	200
43398	GE	20130131	14:04:46	22.31	K	100
43399	GE	20130131	14:04:46	22.31	K	100
43400	GE	20130131	14:04:46	22.31	K	100
43401	GE	20130131	14:04:46	22.3	D	600
43402	GE	20130131	14:04:46	22.31	K	100
43403	GE	20130131	14:04:46	22.31	K	100
43404	GE	20130131	14:04:46	22.31	K	100
43405	GE	20130131	14:04:46	22.31	K	400
43406	GE	20130131	14:04:46	22.31	K	100
43407	GE	20130131	14:04:46	22.31	K	100
43408	GE	20130131	14:04:46	22.305	D	100
43409	GE	20130131	14:04:46	22.31	K	100
43410	GE	20130131	14:04:46	22.31	K	100
43411	GE	20130131	14:04:46	22.31	K	100
43412	GE	20130131	14:04:46	22.31	K	200
43413	GE	20130131	14:04:46	22.31	C	100
43414	GE	20130131	14:04:46	22.31	C	500
43415	GE	20130131	14:04:46	22.31	K	200
43416	GE	20130131	14:04:47	22.3	D	1000
43417	GE	20130131	14:04:53	22.305	D	100
43418	GE	20130131	14:04:53	22.305	D	100
43419	GE	20130131	14:04:53	22.305	D	450
43420	GE	20130131	14:04:55	22.3	W	600
43421	GE	20130131	14:04:58	22.3	D	200
43422	GE	20130131	14:05:05	22.3	Z	800
43423	GE	20130131	14:05:05	22.3	Z	300
43424	GE	20130131	14:05:05	22.3	Z	500
43425	GE	20130131	14:05:05	22.305	D	100
43426	GE	20130131	14:05:07	22.3	N	200
43427	GE	20130131	14:05:09	22.3055	D	100
43428	GE	20130131	14:05:10	22.3	B	100
43429	GE	20130131	14:05:10	22.3	B	100
43430	GE	20130131	14:05:10	22.3	B	100
43431	GE	20130131	14:05:10	22.3	J	200
43432	GE	20130131	14:05:10	22.3	W	100

Return of CRSP VW Index vs Monetary Policy Surprises



- Negative relationship between stock returns and monetary policy surprises
- *Anything goes* on unscheduled policy decisions

Baseline Analysis

- Estimate spatial autoregressions via MLE
- Empirical Specification:

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

ret_{it}: return of industry i at time t

W': row-normalized transpose of input-output matrix

v_t monetary policy surprise

Predictions: *Monetary policy shocks decrease returns* ($\beta_1 < 0$).

The input-output structure amplifies this effect ($\rho > 0$).

- Bootstrap standard errors

Baseline Results: Point Estimates

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	OLS	SAR: 1992 codes	
		equally-weighted	value-weighted
	(1)	(2)	(3)
β_1	$-3.96***$	$-0.63***$	$-0.58***$
	(0.11)	(0.19)	(0.18)
ρ		0.82***	0.87***
		(0.04)	(0.03)
Constant	$-0.07***$	-0.01	-0.01
	(0.01)	(0.01)	(0.01)
adj R^2	14.38%	7.20%	14.20%
Observations	7,890	7,890	7,890

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- OLS: 100 bps monetary policy surprise leads to decrease in returns of 4%
- SAR: β_1 negative and significant; ρ positive and significant

Baseline Results: Decomposition

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	OLS	SAR: 1992 codes	
		equally-weighted	value-weighted
	(1)	(2)	(3)
Direct Effect		−0.79***	−0.76***
		(0.13)	(0.09)
Indirect Effect		−2.78***	−3.59***
		(0.44)	(0.43)
Total Effect	−3.96***	−3.57***	−4.35***
	(0.11)	(0.56)	(0.52)

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- Total effect: 100 bps monetary policy surprise leads to decrease in returns of 4%
- Indirect effect: around 80% of total effect

Time-varying Spatial-weighting Matrix: Point Estimates

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	SAR: 1997 codes (1)	SAR: 2002 codes (2)	SAR: time-varying (3)
β_1	-1.70^{***}	-1.16^{***}	-1.41^{***}
	(0.35)	(0.28)	(0.36)
ρ	0.59^{***}	0.67^{***}	0.67^{***}
	(0.06)	(0.05)	(0.07)
Constant	$-0.04**$	$-0.03**$	$-0.03**$
	(0.02)	(0.01)	(0.01)
adj R^2	10.74%	7.05%	12.37%
Observations	9,153	9,130	8,781

Standard errors in parentheses

$*p < 0.10, **p < 0.05, ***p < 0.01$

- β_1 negative and significant
- ρ positive and significant

Time-varying Spatial-weighting Matrix: Decomposition

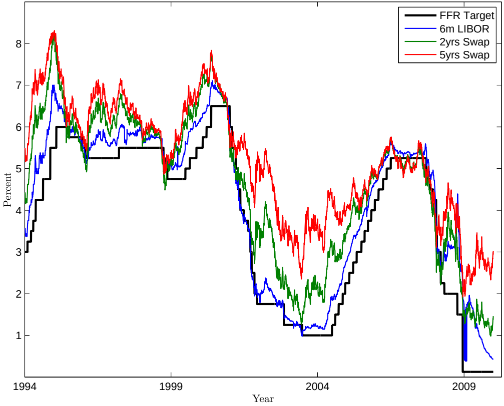
$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	SAR: 1997 codes (1)	SAR: 2002 codes (2)	SAR: time-varying (3)
Direct Effect	−1.79***	−1.24***	−1.54***
	(0.11)	(0.12)	(0.10)
Indirect Effect	−2.35***	−2.30***	−2.70***
	(0.15)	(0.23)	(0.18)
Total Effect	−4.14***	−3.54***	−4.24***
	(0.26)	(0.35)	(0.28)

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- Total effect: 100 bps monetary policy surprise leads to decrease in returns of 4%
- Indirect effect: 60% of total effect

Time Series of Interest Rates



- Policy inertia and interest rate smoothing
- Turning points contain valuable information on future policy stance

Different Event Types: Point Estimates

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	Reversals (1)	Large Shocks (2)	Positive Shocks (3)	Negative Shocks (4)
β_1	-1.56^{***}			
	(0.38)			
ρ	0.77^{***}			
	(0.03)			
Constant	0.03			
	(0.03)			
adj R^2	55.32%			
Observations	676			

Standard errors in parentheses

$*p < 0.10, **p < 0.05, ***p < 0.01$

- β_1 negative and significant
- ρ positive and significant

Different Event Types: Decomposition

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	Reversals (1)	Large Shocks (2)	Positive Shocks (3)	Negative Shocks (4)
Direct Effect	$-1.84***$			
	(0.26)			
Indirect Effect	$-5.07***$			
	(0.60)			
Total Effect	$-6.90***$			
	(0.76)			

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- Total effect: 100 bps monetary policy surprise leads to decrease in returns of 7%
- Indirect effect: 75% of total effect

Large Shocks

- Increased transparency and communication by the Fed
- Monetary policy has become more predictable over time
- Many policy shocks are small in size
- Focus shocks larger than 0.05 in absolute value

Different Event Types: Point Estimates

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	Reversals (1)	Large Shocks (2)	Positive Shocks (3)	Negative Shocks (4)
β_1	−1.56***	−0.61*		
	(0.38)	(0.33)		
ρ	0.77***	0.86***		
	(0.03)	(0.03)		
Constant	0.03	0.00		
	(0.03)	(0.02)		
adj R^2	55.32%	28.16%		
Observations	676	2,233		

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- β_1 negative and significant
- ρ positive and significant

Different Event Types: Decomposition

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	Reversals (1)	Large Shocks (2)	Positive Shocks (3)	Negative Shocks (4)
Direct Effect	−1.84***	−0.80***		
	(0.26)	(0.12)		
Indirect Effect	−5.07***	−3.58***		
	(0.60)	(0.52)		
Total Effect	−6.90***	−4.38***		
	(0.76)	(0.62)		

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- Total effect: 100 bps monetary policy surprise leads to decrease in returns of 4%
- Indirect effect: 80% of total effect

Different Event Types: Point Estimates

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	Reversals (1)	Large Shocks (2)	Positive Shocks (3)	Negative Shocks (4)
β_1	−1.56***	−0.61*	−0.22	−0.83***
	(0.38)	(0.33)	(0.21)	(0.27)
ρ	0.77***	0.86***	0.92***	0.84***
	(0.03)	(0.03)	(0.05)	(0.02)
Constant	0.03	0.00	−0.01	−0.03*
	(0.03)	(0.02)	(0.02)	(0.02)
adj R^2	55.32%	28.16%	1.19%	20.49%
Observations	676	2,233	2,998	3,611

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- Asymmetric effect: β_1 negative and significant only for policy easing
- ρ positive and significant

Different Event Types: Decomposition

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	Reversals (1)	Large Shocks (2)	Positive Shocks (3)	Negative Shocks (4)
Direct Effect	−1.84***	−0.80***	−0.32	−1.04***
	(0.26)	(0.12)	(0.30)	(0.14)
Indirect Effect	−5.07***	−3.58***	−2.39	−4.21***
	(0.60)	(0.52)	(2.24)	(0.54)
Total Effect	−6.90***	−4.38***	−2.71	−5.26***
	(0.76)	(0.62)	(2.53)	(0.66)

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- Total effect: 100 bps surprise easing leads to increase in returns of 5%
- Total effect: statistically insignificant effect of surprise tightening
- Indirect effect: 80% of total effect

Diagonal of Input–Output Matrix

- Focus on industry returns
- Car manufacturer purchases tires from suppliers in same industry
- Concern: within industry effects drive findings
- Constrain diagonal input-output matrix to 0

Robustness Test: Point Estimates

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	zero diagonal W (1)	industry-demeaned (2)	Simulation (3)
β_1	$-1.92***$		
	(0.47)		
ρ	$0.51***$		
	(0.06)		
Constant	$-0.03*$		
	(0.02)		
adj R^2	14.38%		
Observations	7,890		

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- β_1 negative and significant
- ρ positive and significant

Robustness Test: Decomposition

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	zero diagonal W (1)	industry-demeaned (2)	Simulation (3)
Direct Effect	$-1.94***$		
	(0.10)		
Indirect Effect	$-2.00***$		
	(0.11)		
Total Effect	$-3.94***$		
	(0.21)		

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- Total effect: 100 bps monetary policy surprise leads to decrease in returns of 4%
- Indirect effect: 50% of total effect

Industry Heterogeneity

- Constrain sensitivity to be the same across industries
- Industries might differ due to cyclicality of demand or durability
- Use industry-adjusted returns

Robustness Test: Point Estimates

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_{it}$$

	zero diagonal W (1)	industry-demeaned (2)	Simulation (3)
β_1	$-1.92{*}{*}{*}$	$-0.59{*}$	
	(0.47)	(0.33)	
ρ	$0.51{*}{*}{*}$	$0.86{*}{*}{*}$	
	(0.06)	(0.04)	
Constant	$-0.03{*}$		
	(0.02)		
adj R^2	14.38%	14.12%	
Observations	7,890	7,890	

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- β_1 negative and significant
- ρ positive and significant

Robustness Test: Decomposition

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_{it}$$

	zero diagonal W (1)	industry-demeaned (2)	Simulation (3)
Direct Effect	-1.94^{***}	-0.77^{***}	
	(0.10)	(0.09)	
Indirect Effect	-2.00^{***}	-3.46^{***}	
	(0.11)	(0.41)	
Total Effect	-3.94^{***}	-4.23^{***}	
	(0.21)	(0.49)	

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- Total effect: 100 bps monetary policy surprise leads to decrease in returns of 4%
- Indirect effect: 80% of total effect

Simulated Heterogeneity

- Estimate common β across industries
- Baseline point estimates: β = -0.58 and ρ = 0.87
- Simulate $\beta_i \sim$ U $[-0.4, -0.8]$ and $\rho = 0.87$
- $\epsilon_{it} \sim$ N $(0, \hat{\sigma})$
- Re-estimate baseline to check for bias

Robustness Test: Point Estimates

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_{it}$$

	zero diagonal W (1)	industry-demeaned (2)	Simulation (3)
β_1	-1.92^{***}	-0.59^{*}	-1.24^{***}
	(0.47)	(0.33)	(0.27)
ρ	0.51^{***}	0.86^{***}	0.79^{***}
	(0.06)	(0.04)	(0.01)
Constant	-0.03		-0.02
	(0.02)		(0.03)
adj R^2	14.38%	14.12%	2.26%
Observations	7,890	7,890	7,873

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- β_1 negative but larger than baseline
- ρ positive and similar to baseline

Robustness Test: Decomposition

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_{it}$$

	zero diagonal W (1)	industry-demeaned (2)	Simulation (3)
Direct Effect	-1.94^{***}	-0.77^{***}	-1.75^{***}
	(0.10)	(0.09)	(0.37)
Indirect Effect	-2.00^{***}	-3.46^{***}	-4.26^{***}
	(0.11)	(0.41)	(0.85)
Total Effect	-3.94^{***}	-4.23^{***}	-6.00^{***}
	(0.21)	(0.49)	(1.21)

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- Total effect: 100 bps monetary policy surprise leads to decrease in returns of 6%
- Indirect effect still economically large

Model and Data

- $\beta_i = \frac{(1-\alpha)\bar{m}}{\bar{\pi}_i}$
- Model: sensitivity lower for industries with higher average profitability
- Construct value-weighted average industry profitability
- Profitability: (Sales - COGS) / Total Assets
- Add profitability and interaction with policy shocks to SAR

Model and Data cont.

$$r_{it} = \beta_0 + \underbrace{\beta_1}_{\substack{-1.31\\(0.45)}} \times v_t + \underbrace{\beta_2}_{\substack{0.00\\(0.12)}} \times prof_i + \underbrace{\beta_3}_{\substack{4.25\\(1.71)}} \times prof_i \times v_t + \underbrace{\rho}_{\substack{0.85\\(0.03)}} \times W' \times r_t + \varepsilon_{it}$$

- Returns fall following contractionary monetary policy
- Effect propagated through production network
- Lower sensitity for industries with higher profitability

Pseudo Weighting Matrix

- Regress industry returns on weighted average of industry returns
- Concern: mechanical relationship and large network effets
- Test: construct “pseudo-weighting” matrix
- Sparse as empirical counterpart (same number of non-zeros entries)
- Few sectors important suppliers of economy
- Draw random numbers from a generalized Pareto distribution
- Min squared distance between the empirical & fitted distribution

Placebo Test: Point Estimates

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_{it}$$

	pseudo W (1)	permute columns (2)	permute rows (3)	scaled returns (4)
β_1	-3.24^{***}			
	(1.23)			
ρ	0.19^{***}			
	(0.05)			
Constant	-0.06			
	(0.07)			
adj R^2	14.38%			
Observations	7,890			

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- β_1 negative and significant
- ρ positive and significant but reduced by factor of 5 compared to baseline

Placebo Test: Decomposition

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_{it}$$

	pseudo W (1)	permute columns (2)	permute rows (3)	scaled returns (4)
Direct Effect	-3.23^{***}			
	(0.10)			
Indirect Effect	-0.74^{***}			
	(0.02)			
Total Effect	-3.97^{***}			
	(0.13)			

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- Total effect: 100 bps monetary policy surprise leads to decrease in returns of 4%
- Indirect effect: less than 20% of total effect

Permutation of Rows and Columns

- Sectors have different sizes and outdegrees
- Pseudo W does not take feature of data into account
- Permute rows and colums of actual W matrix
- Keeps economic linkages intact

Placebo Test: Point Estimates

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_{it}$$

	pseudo W (1)	permute columns (2)	permute rows (3)	scaled returns (4)
β_1	-3.24^{***}	-2.26^{***}	-2.44^{***}	
	(1.23)	(0.68)	(0.72)	
ρ	0.19^{***}	0.40^{***}	0.36^{***}	
	(0.05)	(0.07)	(0.07)	
Constant	-0.06	-0.05	-0.05	
	(0.07)	(0.02)	(0.03)	
adj R^2	14.38%	14.59%	14.59%	
Observations	7,890	7,873	7,873	

Standard errors in parentheses

$*p < 0.10, **p < 0.05, ***p < 0.01$

- β_1 negative and significant
- ρ only 40% of baseline

Placebo Test: Decomposition

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_{it}$$

	pseudo W (1)	permute columns (2)	permute rows (3)	scaled returns (4)
Direct Effect	-3.23^{***}	-2.82^{***}	-2.46^{***}	
	(0.10)	(0.68)	(0.72)	
Indirect Effect	-0.74^{***}	-1.48^{***}	-1.34^{***}	
	(0.02)	(0.47)	(0.42)	
Total Effect	-3.97^{***}	-3.76^{***}	-3.79^{***}	
	(0.13)	(1.01)	(1.01)	

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- Total effect: 100 bps surprise leads to decrease in returns of 4%
- Indirect effect only 35% of total effect

Scaled Returns

- Errors themselves might follow SAR structure
- Sectoral returns correlated over non-FOMC days as well
- Construct pseudo event in between two actual events
- Scale event returns by previous pseudo-event returns
- H_0: $\rho = 0$

Scaled Returns: Point Estimates

$$\frac{ret_{it}}{ret_{it-}} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times \frac{ret_t}{ret_{t-}} + error_{it}$$

	pseudo W (1)	permute columns (2)	permute rows (3)	scaled returns (4)
β_1	-3.24^{***}	-2.26^{***}	-2.44^{***}	-0.40^{***}
	(1.23)	(0.68)	(0.72)	(0.17)
ρ	0.19^{***}	0.40^{***}	0.36^{***}	0.85^{***}
	(0.05)	(0.07)	(0.07)	(0.03)
Constant	−0.06	−0.05	−0.05	−0.02
	(0.07)	(0.02)	(0.03)	(0.01)
adj R^2	14.38%	14.59%	14.59%	2.58%
Observations	7,890	7,873	7,873	6,820

Standard errors in parentheses
$*p < 0.10, **p < 0.05, ***p < 0.01$

- β_1 negative and significant
- ρ positive and close to baseline

Scaled Returns

$$\frac{ret_{it}}{ret_{it-}} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times \frac{ret_t}{ret_{t-}} + error_{it}$$

	pseudo W	permute columns	permute rows	scaled returns
	(1)	(2)	(3)	(4)
Direct Effect	-3.23^{***}	-2.82^{***}	-2.46^{***}	-0.61^{***}
	(0.10)	(0.68)	(0.72)	(0.24)
Indirect Effect	-0.74^{***}	-1.48^{***}	-1.34^{***}	-2.03^{***}
	(0.02)	(0.47)	(0.42)	(0.71)
Total Effect	-3.97^{***}	-3.76^{***}	-3.79^{***}	-2.64^{***}
	(0.13)	(1.01)	(1.01)	(0.91)

Standard errors in parentheses

$*p < 0.10, **p < 0.05, ***p < 0.01$

- Total effect: 100 bps surprise leads to decrease in scaled returns of 2.64%
- Indirect effect: 77% of total effect

Closeness to End-Consumers

- Monetary policy shocks: demand shocks
- I/O structure predictions on importance of direct and indirect effects
- Industries close to end-consumers: bigger importance of direct effects
- Layers by fraction of output sold directly and indirectly to consumers
  - Layer 1: $>$ 90% of output sold to consumers
  - Layer 2: $>$ 90% of output directly or indirectly and not in Layer 1
- Layers 1 to 4: "close to end-consumers"
- Layers 5 to 8: "far from end-consumers"

Closeness to End-Consumers: Decomposition

$$ret_{it} = \beta_0 + \beta_1 \times v_t + \rho \times W' \times ret_t + error_t$$

	Baseline Estimates	Close to Endconsumer		Far from Endconsumer	
		Re-estimated	Implied	Re-estimated	Implied
	(1)	(2)	(3)	(4)	(5)
Direct Effect	−1.21	−2.37	−2.03	−1.08	−1.10
Indirect Effect	−3.02	−2.77	−2.20	−3.05	−3.12
Total Effect	−4.23	−5.14	−4.23	−4.12	−4.23
Direct Effect [%]	28.65%	46.09%	47.91%	26.11%	26.11%
Indirect Effect [%]	71.35%	53.91%	52.09%	73.89%	73.89%

- Unconditional: 30% direct effects
- Close to end-consumer: 45% direct effects
- Far from end-consumer: 25% direct effects

Cash Flow Fundamentals

- Large indirect effects on monetary policy on stock returns
- Demand interpretation $\Longrightarrow$ network effects in ex-post fundamentals
- Sum monetary policy shocks v_t within quarter: $\tilde{v}_t$
- Change btw previous 4 quarters and quarters from $t+H$ to $t+H+3$:

$$\Delta sale_{it,H} = \frac{\frac{1}{4}\sum_{s=t+H}^{t+H+3} sale_{is} - \frac{1}{4}\sum_{s=t-4}^{t-1} sale_{is}}{TA_{it-1}} \times 100$$

- Estimate SAR model on changes in fundamentals

Cash Flow Fundamentals: Decomposition

$$\Delta sale_{t,H} = \beta_0 + \beta_1 \times \tilde{v}_t + \rho \times W' \times \Delta sale_{t,H} + error_t$$

Horizon	0	1	2	3	4	5	6	7	8
				Panel A. Value-weighted Sales					
Direct Effect	1.28**	1.45*	1.76**	1.82*	1.68	1.43	1.36	1.31	1.46
Indirect Effect	1.87**	2.13*	2.38**	2.61*	2.35	2.18	1.94	1.86	2.25
				Panel B. Value-weighted Operating Income					
Direct Effect	0.36**	0.43***	0.46**	0.43**	0.39*	0.32	0.25	0.30	0.35
Indirect Effect	0.57**	0.68***	0.70**	0.65**	0.57*	0.48	0.39	0.45	0.54

Standard errors in parentheses

$*p < 0.10, **p < 0.05, ***p < 0.01$

Indirect effect:

- 60% of impact effect of monetary policy
- Increases up to 7 quarters
- No significance after 8 quarters

Additional Results

- Identification via heteroskedasticity a la Rigobon & Sack
- SAR on simulated data from dynamic model with nominal ridigities
- More subsample tests and different time periods

Conclusion

- Monetary policy has a large and immediate effect on financial markets
- Develop model of production w/ intermediate inputs to guide empirics
- Network effects responsible for a large part of overall effect
- First evidence networks important for propagation of macro shocks