Upstream, Downstream & Common Firm Shocks

Everett Grant
Federal Reserve Bank of Dallas

Julieta Yung
Bates College

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Motivation

Recent shocks have had widespread effects across firms & industries
(e.g., U.S. Sub-Prime Mortgage Crisis, Eurozone Debt Crisis,
2011 Tohoku Quake in Japan, Brexit)

In this Paper

We investigate the relative importance of firm exposure to

- upstream (supplier-to-user) shocks
- downstream (user-to-supplier) shocks
- common (aggregate) shocks

Upstream & Downstream Transmission: An Example

In April 2018, U.S. Commerce Department announced a prohibition on domestic firms selling to Chinese telecommunications firm ZTE (failed to comply with a settlement for allegedly selling sanctioned telecommunications equipment to North Korea & Iran)

- **Upstream Exposure:** A shock to U.S. companies supplying ZTE (ZTE's equity price declined over 60% & it neared insolvency)
- **Downstream Exposure:** Shock spread to ZTE suppliers (including Qualcomm Inc, Microsoft Corp and Intel Corp)

Understanding upstream & downstream shock propagation and influence of common factors would help contend with future contagion and inform other policies that might affect supply chains

Overview

1. Present a DSGE model that maps (sector-specific) productivity and consumer-taste shocks to firm profit and equity returns
   - Equity prices reflect common and idiosyncratic components
   - Idiosyncratic changes reflect up/downstream exposure to shocks

2. Estimate equity return dynamics as a function of common and idiosyncratic components (524-1,600 U.S. firms 1989-2017)
   - Three significant common (latent) factors
     (growth; price level; supply of raw inputs)
     explain 11.7% of return variation first 10 yrs; 35.0% final 10 yrs

3. Compare idiosyncratic network exposure to Input/Output tables
   - Exposure to upstream shocks is more important than downstream
   - Important role for market structure
     (elasticity of substitution across inputs)

DSGE Model

DSGE Model Setup

- Extend Baqaee (2018) to a multi-period setting with infinite-horizon representative hhold (supplies labor & rents capital to firms) $\Longrightarrow$ equity prices are derived from standard Euler equation

- Household utility:

$$U_t = \left(\sum_{k=1}^{N} \beta_{tk}^{\frac{1}{\sigma}} c_{tk}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \text{ and } c_{tk} = \left(\int c_t(k,i)^{\frac{\epsilon_k-1}{\epsilon_k}} di\right)^{\frac{\epsilon_k}{\epsilon_k-1}}$$

- Production decisions are static and markups are constant (monopolistically competitive unit continuum of firms in N sectors)

- Firm production function:

$$y_t(k,i) = \left[v_{tk}^{\frac{1}{\sigma}} \left(K_t(k,i)^{\gamma} L_t(k,i)^{1-\gamma}\right)^{\frac{\sigma-1}{\sigma}} + \sum_{l=1}^{N} \omega_{kl}^{\frac{1}{\sigma}} x_t(k,i,l)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

- Products can be sold to households or as intermediate inputs

Firm Centralities

Consumer Centrality

The degree to which a firm consumes raw inputs (and its exposure to upstream productivity shocks)

$$P_t^{1-\sigma} = \underbrace{\left[I_N - \mu^{1-\sigma}\Omega\right]^{-1} \mu^{1-\sigma}}_{\equiv \Psi^d} v_t \tilde{z}_t^{\sigma-1} R_t^{1-\sigma}$$

$\tilde{\alpha}_t \equiv \Psi^d v_t$ are the consumer centralities for the labor-capital aggregate

Supplier Centrality

Degree to which a firm supplies its output (and its exposure to demand shocks)

$$\left(P_t^{\sigma} y_t\right)' = \beta_t' \underbrace{\left[I_N - \mu^{-\sigma}\Omega\right]^{-1}}_{\equiv \Psi^S} P_{ct}^{\sigma} U_t$$

$\tilde{\beta}_t \equiv \Psi^{S'} \beta_t$ are the supplier centralities

Firm Profits

- Multiplying supplier & consumer centralities and given that firms' profits are a fixed share of revenue:

$$\pi_t(k,i) = \underbrace{\underbrace{P_{ct}U_t}_{\text{GDP}} \underbrace{\left(\frac{P_{ct}}{R_t}\right)^{\sigma-1}}_{\text{Real Price Level}} \underbrace{\tilde{z}_t^{\sigma-1}}_{\text{Raw Input Supply}}}_{\text{Aggregate Exposure}} \quad \underbrace{\underbrace{\frac{1}{\epsilon_k}}_{\text{Market Structure}} \underbrace{\tilde{\alpha}_{tk}}_{\text{Consumer Centrality}} \underbrace{\tilde{\beta}_{tk}}_{\text{Supplier Centrality}}}_{\text{Industry Specific Exposures}}$$

- The steady-state log equity price for firm i in industry k is:

$$ln(q_t(k,i)) = ln\left(\frac{1}{\epsilon_k(1-\rho)}\right) + ln\left(P_{ct}U_t\left(\frac{P_{ct}}{R_t}\right)^{\sigma-1}\tilde{z}_t^{\sigma-1}\right) + ln\tilde{\alpha}_{tk} + ln\tilde{\beta}_{tk}$$

Equity Price Dynamics

- Idiosyncratic equity response for industry k firms to industry s shocks:

$$dln(q_t^*(k,i)) = \underbrace{\frac{\Psi_{ks}^{d}}{\tilde{\alpha}_{tk}}}_{\substack{\mathcal{U}_{ks} \equiv \text{Upstream} \\ \text{Exposure}}} dv_s + \underbrace{\frac{\Psi_{ks}^{S'}}{\tilde{\beta}_{tk}}}_{\substack{\mathcal{D}_{ks} \equiv \text{Downstream} \\ \text{Exposure}}} d\beta_s$$

$\Longrightarrow$ Shocks flow through the firm network in direct proportion to the centrality of the source of a shock to target firm

- We match the model to U.S. input-output use tables from the BEA to calculate the $\mathcal{U}$ and $\mathcal{D}$ exposure matrices.

Econometric Model

Estimating Equity Return Dynamics

1. Decompose firm returns (R_t^A) into influences from common factors (F_t) & firms' idiosyncratic returns (R_t^I):

$$R_t^A = \Lambda F_t + R_t^I$$

F_t reflect system-wide shocks directly recovered from the data

2. R_t^I may influence one another reflecting the interconnectedness of the system & are subject to firm-specific innovations (ϵ_t):

$$R_t^I = \beta_0 + \beta R_{t-1}^I + \epsilon_t; \quad \epsilon_t \overset{iid}{\sim} \mathcal{N}(0, \Sigma)$$

3. Individual firms assumed small enough that they do not influence aggregate factors, which follow a VAR process:

$$F_t = \Gamma(L) F_{L,t-1} + \eta_t; \quad \eta_t \overset{iid}{\sim} \mathcal{N}(0, \Upsilon)$$

Estimation Procedure

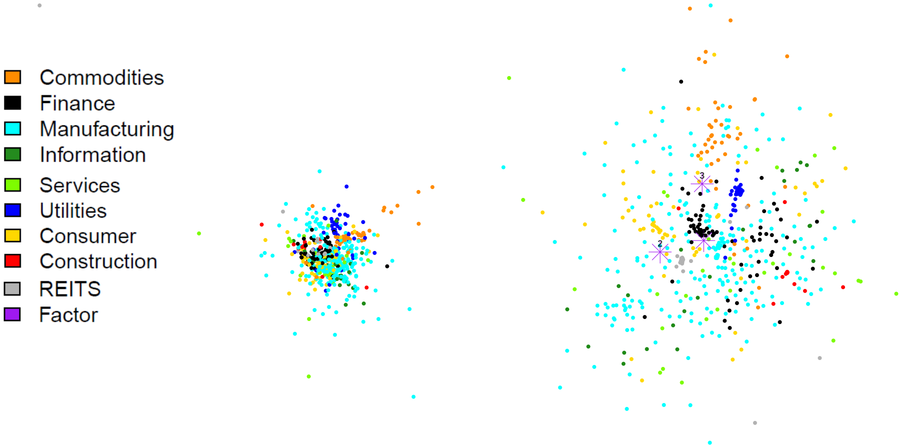
1. Sample: 524 daily U.S. firm log equity returns (1989–2017)
2. Estimate factors with PCA, using Bai and Ng (2002) criteria
3. Remove common factors from returns to get R_t^I series
4. Estimate R_t^I VAR
   - Use Chudik et al. (2018) OCMT variable selection procedure to contend with curse of dimensionality & over-fitting
   - Run individual OLS regressions of dependent variable on each potential explanatory one, adjusting statistical significance since test is repeated
5. Estimate factor VAR
6. Calculate network edges as generalized forecast error variance contributions (similar to Pesaran and Shin, 1998)

U.S. Inter-Firm Networks

Firm Network Spring Plots by BEA Sector

R^A to R^A

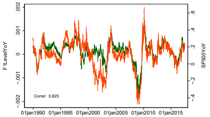
R^I & Factors to R^A & Factors



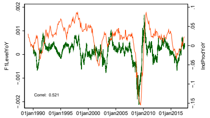
1st Factor & Growth of the U.S. Economy

Year-over-Year Change

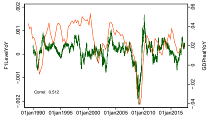
SP500



Industrial Production

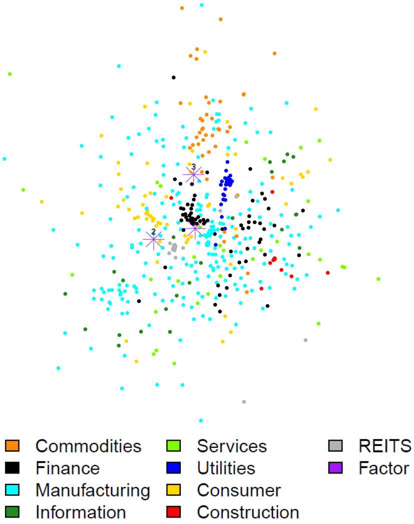


Real GDP



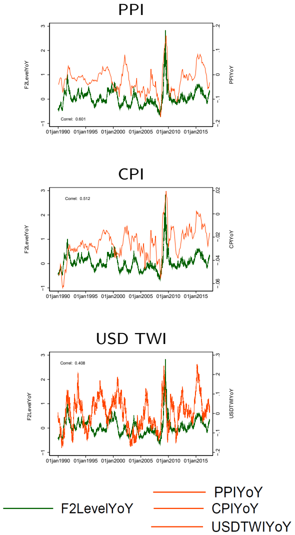
F1LevelYoY — SP500YoY, IndProdYoY, GDPrealYoY

R^I & Factors to R^A & Factors

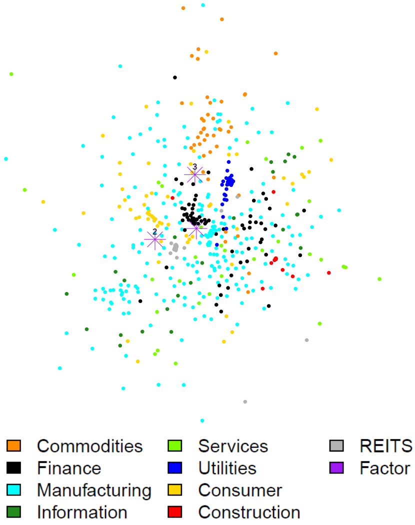


2^{nd} Factor & Prices

Year-over-Year Change

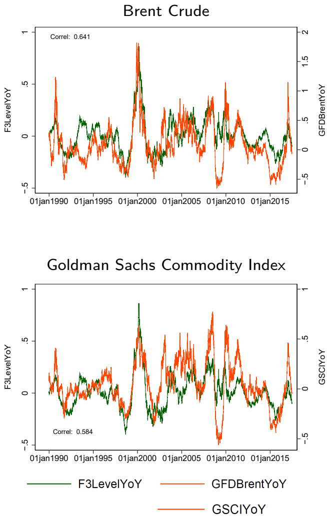


R^I & Factors to R^A & Factors

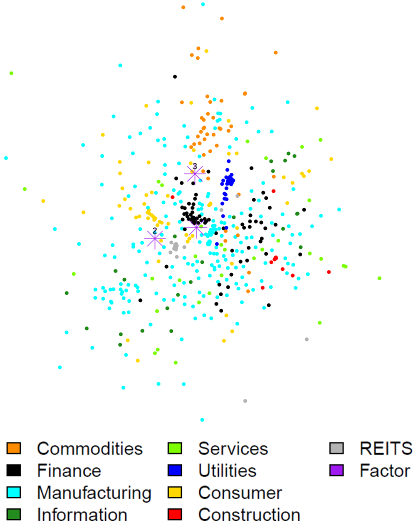


3^{rd} Factor & Commodities

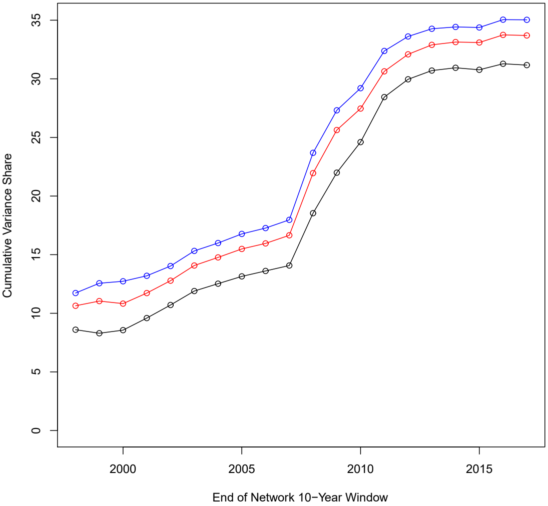
Year-over-Year Change



R^I & Factors to R^A & Factors

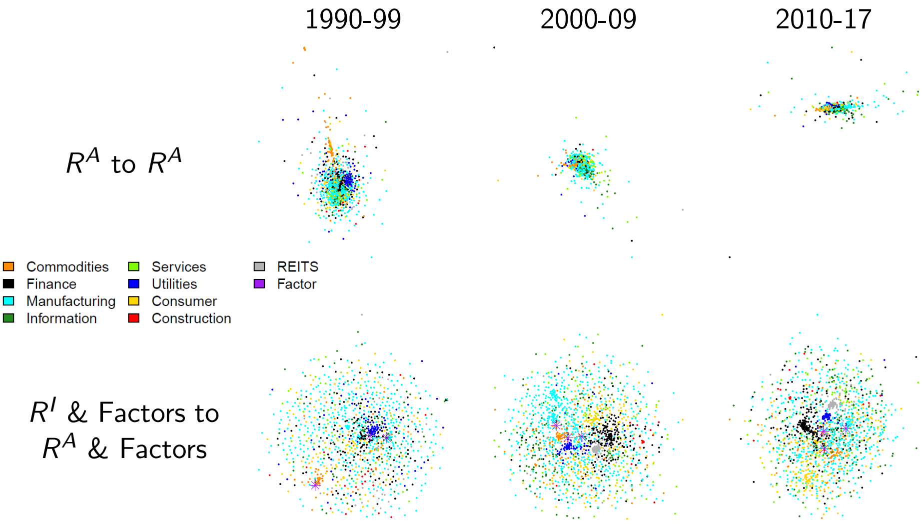


Variance Share of Top 3 Common Factors



Note: Factor variances for rolling 10-year samples with all firms continuously traded within each time period, with factors extracted by PCA on the variance-covariance matrix of the daily log equity returns.

Evolution of the U.S. Firm Network



Assessing Upstream vs. Downstream Exposures

- Compare firm equity response networks aggregated at BEA sector level with U.S. I/O use table based networks:
  - Raw I/O tables
  - Industry output normalized I/O tables
  - Leontief inverses
  - DSGE upstream & downstream exposure matrices

- Treat tables as sectoral network adjacency matrices & calculate correlations
  - Use Quadratic Assignment Procedure to bootstrap correlation distributions of similarly structured networks for statistical significance

Firm Equity vs. Input-Output Based Networks

Panel A: 1989-2017 Network

Equity Network Type	Raw IO	IO Output Normalized	Leontief Inverse	Upstream Exposure	Downstream Exposure
R^A to R^A	0.83***	0.49**	0.39**	0.45***	0.04
R^I to R^I	0.89***	0.54**	0.61**	0.62***	0.21

- Exposure from upstream/suppliers economically & statistically significant
- Exposure to downstream firms is lower & not statistically significant

  $\Longrightarrow$ Low short-term elasticity of substitution across inputs passes shocks from upstream/suppliers, but greater flexibility on the customer side
- Common factors distort these results

Panel B: Average Across Rolling 10-Year Networks with Maximum Number of Firms Ending 1998-2017

Equity Network Type	Raw IO	IO Output Normalized	Leontief Inverse	Upstream Exposure	Downstream Exposure
R^A to R^A	0.78	0.47	0.38	0.44	0.04
R^I to R^I	0.88	0.56	0.59	0.61	0.19

Firm Equity vs. Input-Output Based Networks Over Time

		R^A to R^A Network Correlations				R^I to R^I Network Correlations			
EQ Network Period	IO Year	IO Output Normalized	Leontief Inverse	Upstream Exposure	Downstream Exposure	IO Output Normalized	Leontief Inverse	Upstream Exposure	Downstream Exposure
1989-1998	1997	0.55**	0.46**	0.50***	0.08	0.58**	0.60**	0.61***	0.20
1990-1999	1997	0.55**	0.47**	0.51***	0.10	0.57**	0.59**	0.60***	0.19
1991-2000	1997	0.55**	0.48**	0.52***	0.11	0.57**	0.59**	0.60***	0.19
1992-2001	1997	0.55**	0.47**	0.51***	0.11	0.57**	0.59**	0.60***	0.20
1993-2002	1998	0.54**	0.45**	0.49***	0.09	0.57**	0.59**	0.61***	0.20
1994-2003	1999	0.53**	0.43**	0.47***	0.07	0.56**	0.60**	0.61***	0.19
1995-2004	2000	0.52**	0.43**	0.47***	0.07	0.55**	0.59**	0.60***	0.19
1996-2005	2001	0.50**	0.42**	0.45***	0.07	0.54**	0.59**	0.60***	0.19
1997-2006	2002	0.51**	0.41**	0.45***	0.07	0.54**	0.59**	0.60***	0.20
1998-2007	2003	0.50**	0.41**	0.45***	0.07	0.53**	0.59**	0.60***	0.21
1999-2008	2004	0.49**	0.40**	0.45***	0.05	0.54**	0.60**	0.62***	0.22
2000-2009	2005	0.48**	0.39**	0.46***	0.03	0.53**	0.61**	0.63***	0.21
2001-2010	2006	0.48**	0.38**	0.45***	0.03	0.53**	0.61**	0.63***	0.21
2002-2011	2007	0.47**	0.38**	0.45***	0.02	0.53**	0.61**	0.63***	0.22
2003-2012	2008	0.45**	0.37**	0.44***	0.03	0.51**	0.61**	0.63***	0.22
2004-2013	2009	0.44**	0.35**	0.41***	0.03	0.51**	0.60**	0.62***	0.23
2005-2014	2010	0.45**	0.35**	0.42***	0.02	0.50**	0.60**	0.63***	0.25
2006-2015	2011	0.46**	0.36**	0.43***	0.03	0.50**	0.61**	0.63**	0.29
2007-2016	2012	0.45**	0.36**	0.44***	0.03	0.50**	0.61**	0.63**	0.30
2008-2017	2013	0.46**	0.36**	0.44***	0.03	0.50**	0.61**	0.63**	0.30
Average		0.50	0.41	0.46	0.06	0.54	0.60	0.62	0.22
Std. Dev.		0.04	0.04	0.03	0.03	0.03	0.01	0.01	0.04

$\Longrightarrow$ Prior slide's patterns hold across time

$\Longrightarrow$ Defactored network correlations 34% higher with upstream exposures

$\Longrightarrow$ Increased factor importance appears to skew R^A networks

$\Longrightarrow$ Results extremely consistent over time when remove factors in R^I networks

Further Analysis

- DSGE model extension with industry TFP, credit, varied market size, and commodity price shocks
- **Theoretical Networks:** Simulated equity responses to productivity and demand shocks under different structures: Star, Y, Nested, Parallel, Linear, Dense linear, Diamond, Circle, Dense circle, 1-2-2-1, 2 nests
- **Econometric Model:** up to 10 lags in idiosyncratic VAR; non-zero constant in factor VAR; 1–5 common factors; lower frequency; balanced sample; rolling samples
- **Econometric Networks:** GIRFs and GFEVDs; by decades; simulations to show effect of removing common factors (GIRF, GFEVD, GFEVC, AEN, w/ w/o standardization); application to GDP positive growth shock and commodity negative shock (1989–2017 and 2008–2017)

Conclusion

- Both theoretical & empirical approaches yield three common factors that influence equity returns: growth/market beta, price level, and supply of raw inputs.
  - Factors increasingly important over our sample period
  - Equity returns net of common factors represent upstream/downstream exposures of firms in network experiencing productivity and demand shocks
- Macroeconomic linkages can be proxied with financial market data, potentially allowing for the real-time monitoring of the network at high frequency
- Follow up work
  - Study implications for policy decisions.
  - Pair analysis with firm level micro data.
  - Longer run analysis of networks over business cycles & around crises.