Network Factors for Idiosyncratic Volatility Spillover

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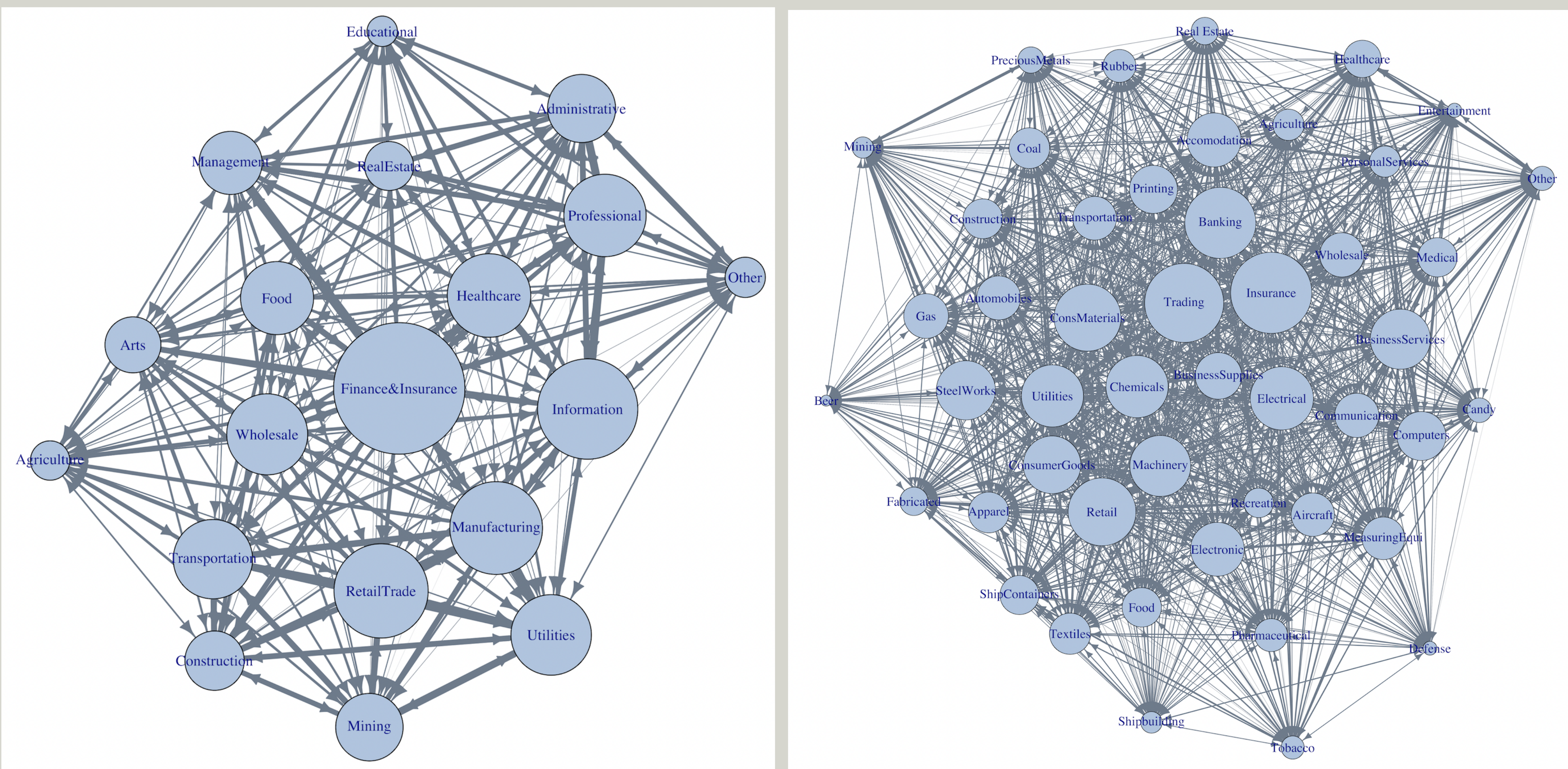
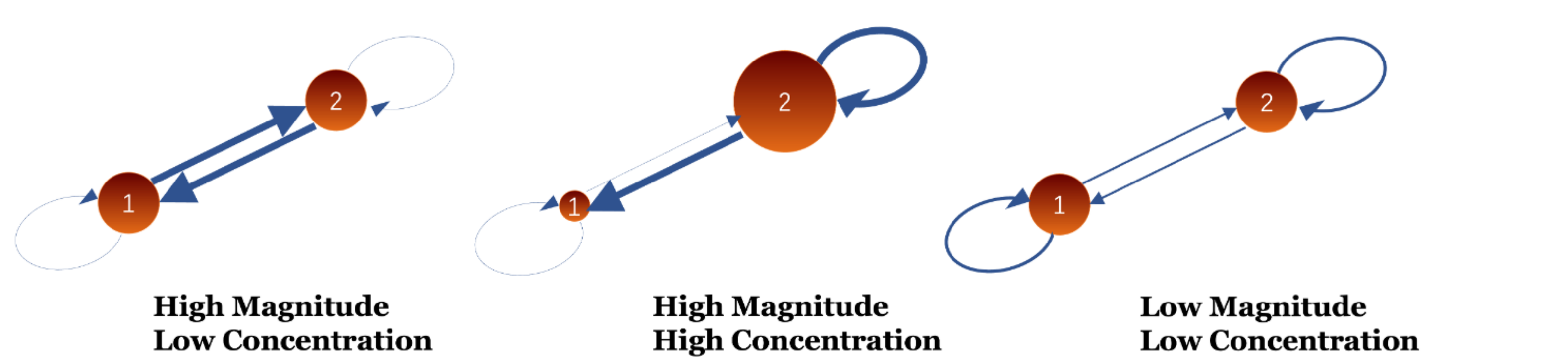
Abstract



This paper studies the network structure change of idiosyncratic volatility spillover among sectors. Changes in the network structure are captured by two asset pricing factors: Concentration factor and Magnitude factor. The two factors determine the node size distribution and linkage thickness distribution respectively and they contain distinct sources of systematic risk. Sectors' positions in the network can predict their future returns. A multisector model links the idiosyncratic structure change to the aggregate volatility: conditionally, a higher Concentration and a lower Magnitude can increase the cross-sectional decay rate of aggregate volatility when sector n $\to \infty$.

Main Structure



- Concentration Factor (Node)
  - Fewer potential sources to contaminate the economy
  - Less likely to cause systematic risk
- Magnitude Factor (Linkage)
  - Higher spillover probability on average
  - More likely to cause systematic risk

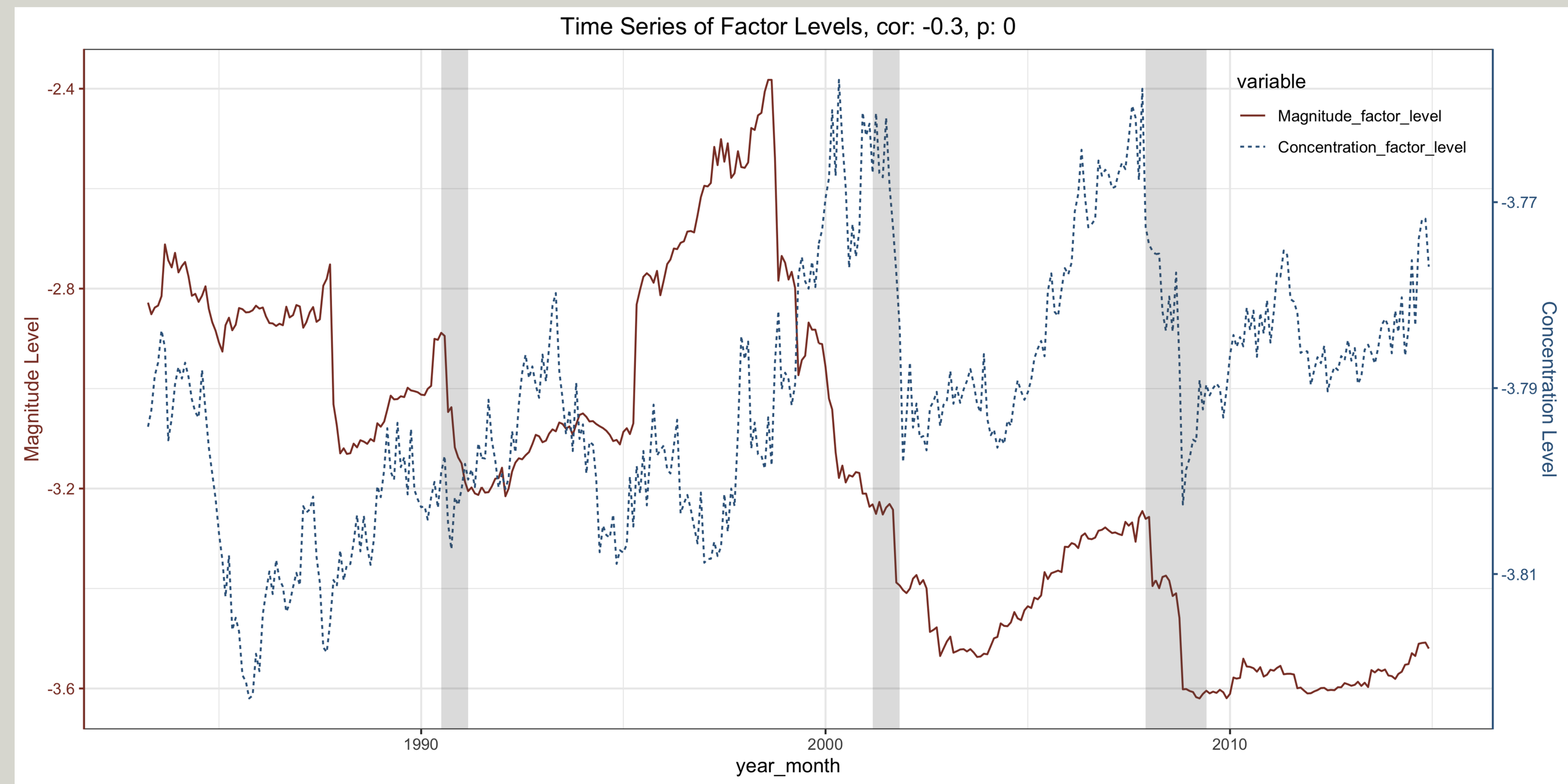
Empirical Procedures

1. Industry-level Idiosyncratic Volatility.
2. Rolling Window Lasso VAR(1) and GVD of Forecasting Error.

	IND_1	IND_2	...	IND_{48}	From others (Indegree)	
IND_1	$d_{1,1}$	$d_{1,2}$	...	$d_{1,48}$	$In_1 = \sum_{j=1}^{48} d_{1,j},$	$j \neq 1$
IND_2	$d_{2,1}$	$d_{2,2}$	...	$d_{2,48}$	$In_2 = \sum_{j=1}^{48} d_{2,j},$	$j \neq 2$
...		...				...
IND_{48}	$d_{48,1}$	$d_{48,2}$	...	$d_{48,48}$	$In_{48} = \sum_{j=1}^{48} d_{48,j},$	$j \neq 48$
To others (Outdegree)	$O_1 = \sum_{i=1}^{48} d_{i,1}$ $i \neq 1$	$O_2 = \sum_{i=1}^{48} d_{i,2}$ $i \neq 2$	... ..	$O_{48} = \sum_{i=1}^{48} d_{i,48}$ $i \neq 48$	total connectedness	$\frac{1}{48}\sum_{i=1}^{48} d_{i,j}$ $i \neq j$

3. Network Factors. $CON = \sum_{i=1}^{48} O_i \times \log O_i$, $MAG = \frac{1}{48}\sum_{i=1}^{48}\sum_{j=1}^{48} d_{ij} \times \log d_{ij}$

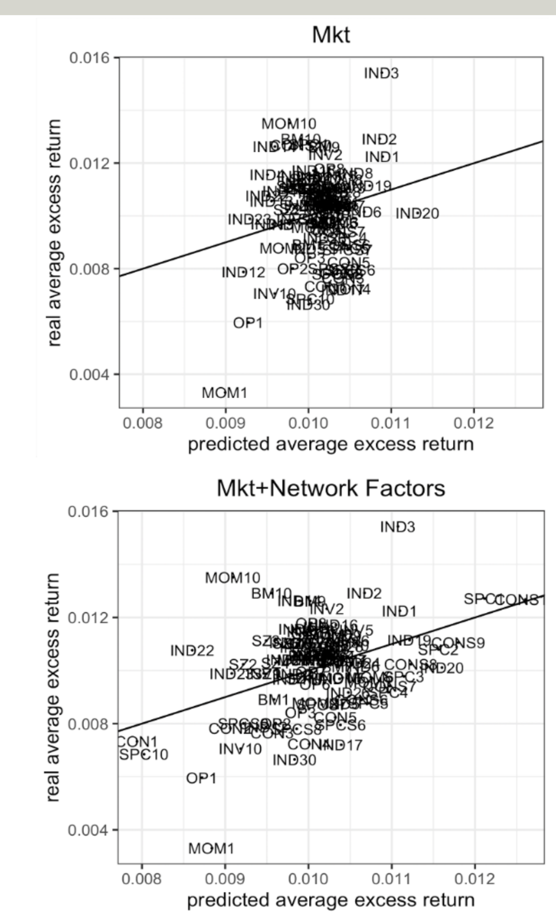
Empirical Findings



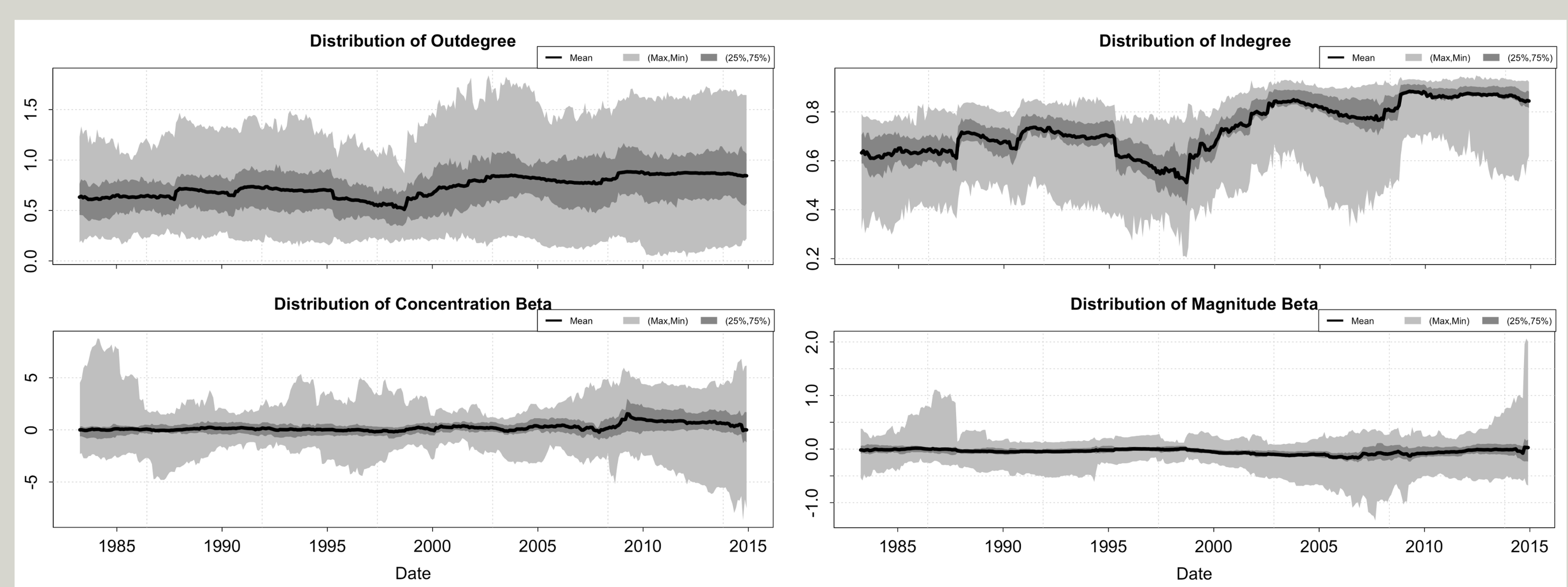
- Business cycle and market power story.
- Stocks more exposed to Concentration factor are riskier.
  - An annual return spread of +5% unexplained by factor models.
- Stocks more exposed to Magnitude factor are hedges.
  - An annual return spread of -4% unexplained by factor models.

Magnitude Factor	1	2	3	H-L	t	grs stat	grs p
Ave.Exc.Ret	0.129	0.107	0.091	-0.038	-2.558		
volatility	0.166	0.139	0.159	0.092			
Sharpe ratio	0.779	0.767	0.569	-0.419			
α_{CAPM}	0.005	0.004	0.002	-0.003	-2.139	4.576	0.033
α_{FF3}	0.003	0.002	0.000	-0.003	-2.389	5.710	0.017
$\alpha_{4factor}$	0.004	0.002	0.000	-0.004	-2.900	8.412	0.004
$\alpha_{5factor}$	0.004	0.002	0.001	-0.004	-2.765	7.645	0.006

Concentration Factor	1	2	3	H-L	t	grs stat	grs p
Ave.Exc.Ret	0.089	0.103	0.135	0.046	2.023		
volatility	0.155	0.141	0.167	0.090			
Sharpe ratio	0.571	0.728	0.807	0.513			
α_{CAPM}	0.002	0.003	0.005	0.003	2.533	6.414	0.012
α_{FF3}	0.000	0.001	0.003	0.003	2.296	5.273	0.022
$\alpha_{4factor}$	0.001	0.002	0.005	0.004	3.014	9.087	0.003
$\alpha_{5factor}$	0.001	0.002	0.005	0.004	2.988	8.933	0.003



- FM: Defeat "CIV" factor and production-based network factors.
- Factor betas are other measurements of systemic risk.



Theoretical Framework

Cobb-Douglas production function: $y_{i,t} = e^{z_{i,t}}\zeta_i l_{i,t}^{\alpha} \prod_{j=1}^{n} x_{ij,t}^{(1-\alpha)\omega_{ij}}$

Representative household: $U_t = \left[(1-\beta)C_t^{1-\rho} + \beta\left(\mathbb{E}_t\left(U_{t+1}^{1-\gamma}\right)\right)^{\frac{1-\rho}{1-\gamma}}\right]^{\frac{1}{1-\rho}}$

Equilibrium: $\mathbb{E}_t\left[\underbrace{\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\rho}\frac{\frac{\partial C_{t+1}}{\partial c_{1,t+1}}/P_{1,t+1}}{\frac{\partial C_t}{\partial c_{1,t}}/P_{1,t}}\left(\frac{J_{t+1}}{\mathbb{E}_t\left(J_{t+1}^{1-\gamma}\right)^{\frac{1}{1-\gamma}}}\right)^{\rho-\gamma}}_{\equiv M_{t+1}}\underbrace{\frac{D_{i,t+1}+Q_{i,t+1}}{Q_{i,t}}}_{\equiv R_{i,t+1}}\right] = 1$

Theoretical Results

- Proposition 1: The spot price vector is given by

$$\ln \mathsf{P}_t = \tilde{\mathsf{L}}\left[-ln\alpha^{\alpha}(1-\alpha)^{1-\alpha} - (1-\alpha)\sum_{j=1}^{n}\omega_{ij}\ln\omega_{ij} + \alpha\ln h_t\mathbf{1} - \mathsf{z}_t\right]$$

Conditional relationship: production network vs. idiosyncratic vol spillover

$$\Delta_{t\to t+1} = \begin{bmatrix} \frac{(1+(1-\alpha)\omega_{1,1})^2}{denom_1} & \frac{((1-\alpha)\omega_{1,2})^2}{denom_1} & \cdots & \frac{((1-\alpha)\omega_{1,n})^2}{denom_1} \\ \frac{((1-\alpha)\omega_{2,1})^2}{denom_2} & \frac{(1+(1-\alpha)\omega_{2,2})^2}{denom_2} & \cdots & \frac{((1-\alpha)\omega_{2,n})^2}{denom_2} \\ & \cdots & \cdots & \\ \frac{((1-\alpha)\omega_{n,1})^2}{denom_n} & \frac{((1-\alpha)\omega_{n,2})^2}{denom_n} & \cdots & \frac{(1+(1-\alpha)\omega_{n,n})^2}{denom_n} \end{bmatrix}$$

- Proposition 2. The existence of the idiosyncratic volatility network structure has a defining influence on the (cross-sectional) decay rate of the aggregate volatility.

$$\sqrt{var(\xi_{t\to t+1})} = \Omega\left(\frac{1}{n}\sqrt{\frac{CON_{t\to t+1}}{MAG_{t\to t+1}}}\right)$$

The decay rate of aggregate volatility depends on the distribution of the CON and MAG factors and it is possible to be much slower than $\sqrt{n}$. This rejects the classical diversification argument where idiosyncratic volatility averages out and the aggregate volatility concentrates to its mean at a very fast speed, proportional to $\sqrt{n}$.

- Proposition 3. Aggregate output is a linear combination of the idiosyncratic shocks:

$$\ln\xi_t = \alpha'\ln\alpha + \alpha'\tilde{\mathbf{L}}\mathbf{z_t}$$

The simulated aggregate output is 0.3 (p=0) correlated with CON factor and -0.2 (p=0) correlated with MAG factor, which is consistent with the empirical price of risk.

References

[1] Francis X Diebold and Kamil Yilmaz. On the network topology of variance decompositions: Measuring the connectedness of financial firms. *Journal of econometrics*, 182(1):119–134, 2014.

[2] Bernard Herskovic. Networks in production: Asset pricing implications. *The Journal of Finance*, 73(4):1785–1818, 2018.

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