Production Networks and Stock Returns: The Role of Vertical Creative Destruction

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Contents

Backgrounds & Motivation

- Production takes place in a complex network comprised of long and intertwined supply chains. This multistage production process reflects the vertical organization of production.
- Little is known about this vertical dimension of production in connection to asset prices, especially at the firm-level.
- The strength of the supply effect is heterogeneous across layers.

➢ How do firms' exposures to macroeconomic risks vary with their upstreamness? What is the relation between firms' upstreamness and returns? Do supply chain characteristics affect firms' cost of capital?

Literatures

- creative destruction

creative destruction works horizontally: not all firms benefit equally from innovations

vertical creative destruction: suppliers innovations devalue customer firms

- production networks

stock return predictability via supplier-customer links

contemporaneous return across different layers

- production-based asset pricing

examine asset pricing implications in two-sector economies

account for a multilayer production process

Research Problem

- What is the relation between firms' upstreamness and their expected returns?
  - ➢ Firms farther away from consumers have higher risk premiums and higher exposure to aggregate productivity.
- How to explain these findings?
  - ➢ Using a general equilibrium model featuring a multilayer production process, we find positive productivity shocks to suppliers devalue customers' assets-in-place.
- Anything matters?
  - ➢ Vertical creative destruction varies with competition and firm characteristics.

Contribution

- Introduce vertical creative destruction - suppliers' innovations devalue customer firms
- Empirically document two novel facts that highlight a monotonic relation between a firm's vertical position and their riskiness/return.
- Develop a general equilibrium model with multiple layers of production (supply chain) to explains a new form of creative destruction.

Outline

Mechanism / Idea:
Vertical creative destruction

Empirical facts:
1. Layer portfolio returns
2. Productivity exposure of layer portfolio

Inspiration

Theoretical support

Theoretical Explanation:
DSGE model:
4 properties

Empirical Results

Quantitative Results

Testing the Mechanism

Spread is smaller when firms have greater monopolistic power

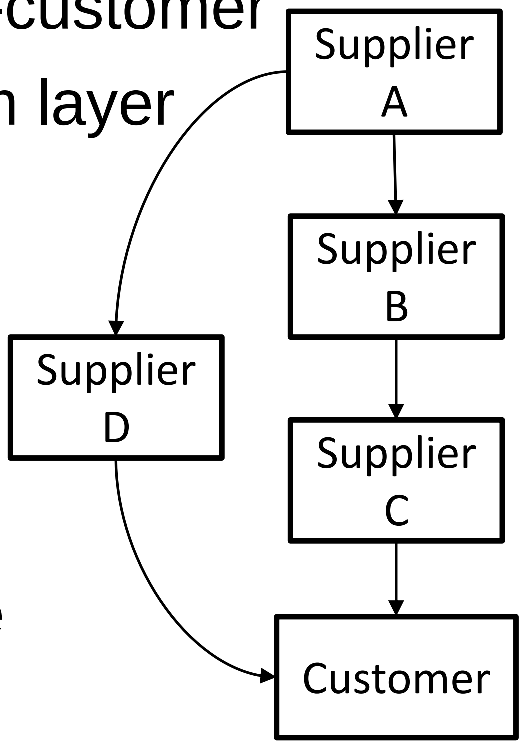
Spread is larger for firms that rely more heavily on installed physical assets

Data

- CRSP stock database (for stock returns)
- Compustat North America database (for accounting data)
- FactSet Revere relationships database (for information about suppliers, customers, and competitors)
- Sample period: April 2003 - December 2012
- Exclude financial firms (GICS code 40), industrial conglomerates (GICS 201050), penny stocks (i.e., stocks with a price of less than $1 in the previous month).
- Combine if the time gap between two consecutive relationships is not longer than 6 months.
- Last at least 6 months

Model Design: Vertical position measure

- Bottom layer produce final consumption goods. All others are direct/indirect suppliers to bottom firms.
- Measure: the smallest number of supplier-customer links between itself and firms at the bottom layer
- Monthly base
- Step: Assign position 0 to all firms in the Consumer Discretionary (GICS code 25) and Consumer Staples sectors (GICS code 30), estimate vertical positions of the remaining firms in the sample.



Empirical Results: Layer returns and TMB

- Sort firms at the beginning of month t using vertical positions computed at the end of month t-2.

Vertical position and stock returns

	Value-weighted returns		Equal-weighted returns	
	Mean	SD	Mean	SD
Layer 5	1.78	6.54	1.78	7.30
Layer 4	1.41	6.23	1.11	7.11
Layer 3	0.99	5.64	0.95	6.27
Layer 2	0.87	4.93	0.92	6.31
Layer 1	0.73	4.47	0.86	6.36
Layer 0	0.73	3.97	0.70	6.56
TMB (5-0)	1.05**	5.36	1.08**	4.54
	(2.07)		(2.51)	

Empirical Results: Exposure to productivity shocks

Vertical position and exposures to aggregate productivity shocks

	TMB	Layer 0	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
A. $R^e_{i,t} = const + \beta_1 \Delta Prod_t + error$							
$Prod$ = *BLS labor productivity:*							
β_{prod}	1.664	1.214	1.306	1.645	2.534	2.072	2.878
	(1.61)	(1.36)	(1.29)	(1.30)	(1.70)	(1.28)	(2.65)
$Prod$ = *Solow residual:*							
β_{prod}	1.332	1.245	1.193	1.409	1.491	1.414	2.578
	(1.87)	(2.37)	(2.14)	(2.32)	(2.80)	(2.08)	(3.54)
B. $R^e_{i,t} = const + \beta_1 \Delta Prod_t + \beta_2 \Delta Prod_t^2 + error$							
$Prod$ = *BLS labor productivity:*							
β_{prod}	3.254	1.530	2.006	2.882	4.308	4.175	4.784
	(2.76)	(1.14)	(1.42)	(1.73)	(2.29)	(2.22)	(4.77)
$Prod$ = *Solow residual:*							
β_{prod}	1.937	0.599	0.583	0.909	1.171	0.942	2.536
	(2.32)	(1.07)	(0.86)	(1.02)	(1.17)	(0.95)	(2.45)

$$\boxed{\beta_{prod} = E\left[\frac{\partial R^e_i}{\partial \Delta Prod}\right]}$$

Firms in the top layers are more exposed to the aggregate productivity shock.

DSGE Model

Production sector: N+1 layer (0: bottom layer)

Each layer is captured by a single representative firm (under perfect competition, homogeneity).

- Layer j - Firm j:

hires labor $n_{j,t}$ with capital $k_{j,t}$ and productivity shock $Z_{j,t}$

production： $Y_{j,t} = Z_{j,t} k_{j,t}^{\alpha} n_{j,t}^{1-\alpha}, \quad j \in \{0, 1, .., N\}$

capital: $k_{j,t+1} = (1 - \delta + i_{j,t}) k_{j,t}$

dividend: $d_{j,t} = P_{j,t} Y_{j,t} - W_t n_{j,t} - P_{j+1,t} \Phi(i_{j,t}) k_{j,t}$

DSGE Model

Firm chooses optimal investment and optimal hiring to maximize its market value:

$$\boxed{V_{j,t} = \max_{\{n_{j,s}\, k_{j,s+1}\}} \quad E_t \sum_{s=t}^{\infty} M_{t,s} d_{j,s}}$$

The household chooses the layer-specific labor supply and consumption to maximize its lifetime utility

$$\boxed{\max_{C_s, \{n_{j,s},\ \omega_{j,s+1}\}_{j\in\{1..N\}}} U_t, \quad s.t. \quad P_{0,t} C_t + \sum_{j=0}^{N} \omega_{j,t+1} V_{j,t}^{X} = W_t \sum_{j=0}^{N} n_{j,t} + \sum_{j=0}^{N} \omega_{j,t} V_{j,t}}$$

$$U_t = \left[(1-\beta) C_t^{\frac{1-\gamma}{\theta}} + \beta (E_t U_{t+1}^{1-\gamma})^{\frac{1}{\theta}} \right]^{\frac{\theta}{1-\gamma}}$$

DSGE Model

Wage and output prices are set to clear all markets:

Labor market clearing:	$\sum_{j=0}^{N} n_{j,t} = 1,$
Differentiated capital goods market clearing:	$\Phi(i_{j-1,t})k_{j-1,t} = Y_{j,t}, \quad \forall j \in \{1, \ldots, N\},$
Consumption goods market clearing:	$C_t = Y_{0,t},$
Firm ownership market clearing:	$\omega_{j,t} = 1, \quad \forall j \in \{0, \ldots, N\}$

DSGE Model

With a few simplifying assumptions, the equilibrium policies and prices are given by

$$n_{j,t} = \overline{n}_j,$$

$$k_{j,t} = \left(\prod_{\ell=j+1}^{N} Z_{\ell,t}^{\alpha^{\ell-j-1}} \right) \overline{k}_j,$$

$$I_{j,t} = \left(\prod_{\ell=j+1}^{N} Z_{\ell,t}^{\alpha^{\ell-j-1}} \right) \overline{I}_j,$$

$$P_{j,t} = D_t \cdot S_{j,t}^{-1} \cdot \overline{P}_j,$$

where $D_t = \prod_{\ell=0}^{N} Z_{\ell,t}^{\alpha^{\ell}},$ $S_{j,t} = \prod_{\ell=j}^{N} Z_{\ell,t}^{\alpha^{\ell-j}},$

DSGE Model - the mechanism

Properties:

1. Log-valuation of assets-in-place of firms increases/decreases with productivity shocks of layers below/above it.
2. With perfect correlation between the productivity of different layers, the cumulative vertical creative destruction is monotonically increasing in j.
3. The difference between top and bottom productivity beta rises with chain length. The market price of risk for productivity is positive and increases with the chain length.
4. The expected returns are increasing with the vertical position.

Quantitative Results - Inspecting the mechanism

Theorem1

Model-implied productivity elasticities by vertical position

Layer j	$dlog(Q_j)/d\varepsilon_z$	$dlog(P_{j+1})/d\varepsilon_z$	$dlog(\Phi'(i_j))/d\varepsilon_z$	$d(i_j)/d\varepsilon_z \times 10$
4	0.058	0.016	0.042	0.128
3	0.052	0.014	0.039	0.126
2	0.045	0.012	0.034	0.122
1	0.036	0.009	0.028	0.107
0	0.025	0.005	0.021	0.081

Theorem2

Exposures of firms to layer-specific technology shocks

Layer index (j)	$\beta_{j,5}$	$\beta_{j,4}$	$\beta_{j,3}$	$\beta_{j,2}$	$\beta_{j,1}$	$\beta_{j,0}$	$\sum_{k=0}^{5}\beta_{j,k}$
5	0.0485	0.0339	0.0420	0.0937	0.2562	1.7000	2.1743
4	−0.1242	0.1001	0.0788	0.1091	0.2599	1.7000	2.1237
3	−0.0172	−0.1102	0.1089	0.1217	0.2595	1.7000	2.0627
2	−0.0023	−0.0155	−0.1002	0.1420	0.2565	1.7000	1.9805
1	−0.0003	−0.0018	−0.0121	−0.0798	0.2474	1.7000	1.8533
0	−0.0000	−0.0003	−0.0014	−0.0069	−0.0298	1.7000	1.6616

Quantitative Results - Testing the Mechanism

Examine the impact of market power on the TMB spread and on the returns of bottom-layer firms

TMB spread and competition: Augmented model versus data

	High competition			Low competition		
	Model	Data		Model	Data	
A. Excess returns by vertical position						
Layer 5	16.14	15.21	[10.10, 20.32]	16.26	11.10	[3.48, 18.72]
Layer 4	12.85	10.18	[5.64, 14.72]	16.13	14.10	[8.37, 19.83]
Layer 3	10.31	8.29	[4.36, 12.22]	14.86	6.44	[1.64, 11.25]
Layer 2	7.96	5.28	[1.90, 8.66]	13.03	8.65	[3.54, 13.76]
Layer 1	5.86	4.67	[1.28, 8.07]	10.80	6.18	[1.40, 10.95]
Layer 0	3.98	5.25	[2.01, 8.48]	8.37	6.47	[2.08, 10.86]
B. Spreads						
Spread (5-0)	12.15	9.97	[5.30, 14.64]	7.90	4.63	[−2.08, 11.34]

Empirical Results - Testing the Mechanism

Examine the TMB spread in firms whose assets-in-place represent a larger fraction of their value.

TMB spreads in subsamples

	Value-weighted		Equal-weighted		Value-weighted		Equal-weighted	
	A. Book-to-market split				*B. Depreciation split*			
	Low	High	Low	High	Low	High	Low	High
TMB	8.18	11.87	3.07	16.05***	14.01*	6.02	10.68**	9.08**
t-stat	(1.23)	(1.59)	(0.68)	(3.08)	(1.92)	(1.27)	(2.2)	(2.07)
	C. Organization capital split				*D. Inventory split*			
	Low	High	Low	High	Low	High	Low	High
TMB	9.30**	−0.54	14.99***	2.44	8.76	12.01**	5.47	13.33**
t-stat	(2.34)	(−0.04)	(4.15)	(0.27)	(1.28)	(1.99)	(1.17)	(2.52)

Robustness

- Use input-output tables from the U.S. Bureau of Economic Analysis (BEA) to compute an inter-industry TMB spread from 1973 to 2017.
- Use the Compustat Segment database to construct a sample from 1985 to 2017, accounting for the strength of each supplier-customer relationship.
- Use different rebalancing or methodologies to compute vertical positions.

Alternative explanations for the TMB spread

- Network centrality
- Financial and operating leverage
- Profitability and asset growth
- Familiarity hypothesis

Book /market	ROA	Debt /asset	Cash /asset	Operating leverage	Asset growth	Bid-ask spread	Forecast dispersion	Institutional ownership	Network centrality
0.512	0.094	0.194	0.137	0.645	0.061	0.200	0.123	0.578	0.088
0.505	0.094	0.173	0.135	0.646	0.046	0.189	0.132	0.570	0.084
0.471	0.094	0.182	0.149	0.589	0.048	0.181	0.132	0.608	0.232
0.504	0.094	0.147	0.176	0.693	0.034	0.194	0.135	0.640	2.108
0.473	0.098	0.117	0.187	0.781	0.024	0.177	0.134	0.653	4.589
0.528	0.119	0.219	0.087	1.114	0.016	0.191	0.126	0.642	0.737
−0.015	−0.025***	−0.024	0.050***	−0.469***	0.044***	0.010	−0.004	−0.064***	−0.648***
(−0.45)	(−5.00)	(−1.60)	(2.83)	(−17.64)	(7.06)	(0.70)	(−0.83)	(−3.09)	(−16.54)

Conclusion

- Firms at higher vertical position have higher stock returns; and greater exposure to aggregate productivity.
- We provide a risk-based explanation (vertical creative destruction) of these new findings using a quantitative general equilibrium model.
- We document several novel facts that connect firms' position and competition environment to their risk. Vertical creative destruction can explain these facts quantitatively.