Does Finance Flow to High Productivity Firms?

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Sept 2019
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Motivation

- Do financial resources tend to flow towards high productivity firms and away from low productivity firms?
- Suggestive but mixed evidence in the literature.
  - Yes: Maksimovic and Phillips (2001), Foster et al. (2008)
  - No: Zingales (1998), Lee et al. (2016), Whited and Zhao (2019)
  - No exact answer to our question in the literature.
- No direct answer.
  - Hard to measure firm-level productivity

Plan

- Step 1. Measuring firm productivity
  - Study U.S. public traded firms from 1972 to 2015.
  - Use machine learning methods, we develop a reasonable measure of the productivity.
- Step 2. Answering the question. **The answer is ‘no’**.
- Step 3. Understanding why the answer is no.
  - At times of high transitory productivity, due to discounting investors want some extra consumption now. So the firm sends money to the investors while investing in capital. To exploit the transitory opportunity the firm draws down accumulated internal financial resources rather than raising external financing

Some Related Studies

Several distinct literatures are related

- **Productivity**: Olley and Pakes (1996), Petrin and Levinsohn (2003), Ackerberg, Caves and Frazer (2015), Kim Petrin and Song (2016), David and Venkateswaran (2017), Gandhi, Navarro and Rivers (2018)

- **Capital Structure**: Leary and Roberts (2005), DeAngelo, DeAngelo and Whited (2011), Faulkender et al (2012), DeAngelo and Roll (2015), Frank and Shen (2018), Whited and Zhao (2017)

- **Real Asset Sales**: Zingales (1998), Maksimovic and Phillips (2001), Foster, Haltiwanger and Syverson (2008), Hsieh and Klenow (2009), Lee, Shin, Stulz (2018), Eisfeldt and Shi (2018)

Step 1. Measuring Firm Productivity

Measuring Productivity

- How can we tell which firms are more productive?
- Cobb and Douglas (1928 AER),

$$Y_i = e^{\beta_0} K_i^{\beta_1} L_i^{\beta_2} e^{\epsilon_i} \tag{1}$$

  - K and L come from classical economists such as Adam Smith, J.B. Clark, Wicksteed, etc.
  - Cobb and Douglas say β_0 captures forces for which there is no data (land, natural resources, materials, new methods)
- Taking logs,

$$y_i = \beta_0 + \beta_1 k_i + \beta_2 l_i + \epsilon_i \tag{2}$$

- When i is a country, usually get $\beta_1 = \frac{1}{3}$ and $\beta_2 = \frac{2}{3}$
- But what about firms?

Recent Firm Level Studies

- Output is sales revenue net of materials and expensed items such as advertising, r&d, rentals, etc
  - Excluding intermediate inputs, use value-added function
  - Focus on contribution of capital and labor to value-added
- İmrohoroğlu and Tüzel (2014, Management Science)
  - Output: OIBDA + Labor Expense = Sales - (Sales - OIBDP - Labor Expense)
  - Capital: property, plant, and equipment
  - Labor: Labor Expense = number of employees $\times$ average wage
  - find: $Output = 0.226 * Capital + 0.750 * Labor$
- Whited and Zhao (2019)
  - model financial liabilities as factor inputs
  - "...the firms ultimately finance their purchases of factors of production using debt and equity. The proximate factors — capital, materials, labor, and energy — can be thought of as unmodeled intermediate inputs"
  - $Output = A(\alpha D^{\frac{\gamma-1}{\gamma}} + (1-\alpha)E^{\frac{\gamma-1}{\gamma}})^{\frac{\gamma}{\gamma-1}}$

Conventional Methods Using Firm Data

	(1) OLS	(2) OLS First Diff	(3) OLS First Diff	(4) Dynamic Panel	(5) Olley Pakes	(6) ACF
	Year and Industry Fixed Effects					
Capital	0.319		-0.017	-0.271	0.323	0.317
	(0.037)		(0.002)	(0.447)	(0.042)	(0.000)
Labor	0.696		0.014	0.447	0.623	0.706
	(0.040)		(0.003)	(0.004)	(0.014)	(0.000)
ΔCapital		0.015	0.017			
		(0.014)	(0.014)			
ΔLabor		0.479	0.469			
		(0.036)	(0.036)			
[0.5em] Observations	91584	91584	91584	86331	87835	87835

- Griliches and Mairess (1998) concerns are still relevant as shown in columns 1 - 4.

What Inputs To Use for Firms?

- Our issue is firm-level: **What can we learn about firm-level productivity from standard public information?**
- "our theories ... deal with reasonable crude aggregates: output, labor, capital, which turn out to be rather vague concepts when we go down to the micro level ..." (Griliches and Mairesse, 1998)
- Maybe the inputs used, matter for firm-level analysis
- Many variables are actually reported in corporate accounts
  Balance Sheet Income Statement
- Obvious idea: add more entries from the accounts
- But which entries to use?
  - A job for theory, or
  - A job for machine learning

Why Machine Learning Methods?

- There is no generally accepted theory that says what parts of the corporate accounts to use, and what to exclude. So that will not work.
- We could just ‘make it up’ and choose a few ‘reasonable’ variables as inputs. But what if our guesses are mistaken?
- So we use machine learning methods. They provide a systematic approach to the problem that have worked well on somewhat analogous problems.
  - Variable selection, model selection, model heterogeneity

What's wrong with naive OLS using all accounting variables?

- Production technologies exhibit substantial heterogeneity
- It is a difficult task to select inputs when considering such heterogeneity
- $$y_{i,j,t} = \beta_1 X_{it} + \beta_2 D_{jt} + \lambda \mathcal{I}(X_{it}, D_{jt}) + \varepsilon_{it}$$
- $\mathcal{I}(X_{it}, D_{jt})$ is the interaction between covariates and group dummies, capturing the heterogeneity in production.
- The OLS estimates of parameters, jointly denoted by β, are
$$\beta = (X'X)^{-1}X'Y$$
    - Multicollinearity
    - High dimensional
    - No test statistics

ML Method 1: Lasso

$$\widehat{\beta} = \arg\min_{b} \sum_{i=1}^{n} (y_i - \sum_{j=1}^{p} x_{i,j} b_j)^2 + \lambda \sum_{j=1}^{p} |b_j| \gamma_j$$

- A shrinkage technique to select a correctly specified model.
- This version of the Lasso is due to Belloni, Chen, Chernozhukov, and Hansen (2012 Econometrica)
- p is the number of variables, n is the number of observation,
  - Regularization is controlled by the penalty level $\lambda = 2.2 * \sqrt{(2 * n * log(2 * p/(.1/log(n))))}$. It balances overfitting and bias. Coefficient specific penalty loadings are controlled by γ_j
  - Belloni et al (2016 JBES) discuss penalties for panel data
  - The Lasso has recently been added to Stata 16 (which I do not yet have)

ML Method 2: XGBoost

- We use gradient boosting algorithm (XGBoost) to estimate a regression tree model
- A regression tree model can be viewed a generalization of fixed effects.
  - The fixed effects depend on the value of other covariates.
- Address variable selection problem under substantial heterogeneity effects

ML Method 2: XGBoost

- Regression tree model
  - A regression tree is based on an ensemble of trees
  - Partition the characteristics space into several hyper-cubes
  - $$\min_{j,s}\left[\min_{c_1}\sum_{x_i\in R_1(j,s)}(y_i-c_1)^2+\min_{c_2}\sum_{x_i\in R_2(j,s)}(y_i-c_2)^2\right]$$

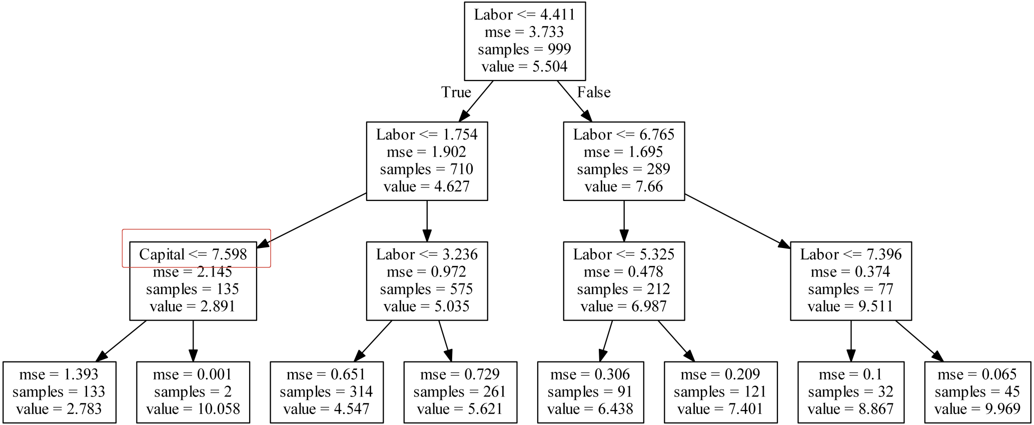
    where

    $$R_1=\{X|X_j\leq s\}\ ;\ R_2=\{X|X_j>s\}$$

    j indexes the splitting variable and s the splitting points.
  - $$\hat{y}(x_i)=\begin{cases}c_1, & \text{if } x_i\in R_1(j,s)\\ c_2, & \text{if } x_i\in R_2(j,s)\end{cases}$$

ML Method 2: XGBoost

- Estimating a simple tree model with a depth of 3
  - 999 COMPUSTAT firms
  - Target variable: sales. Input variables: capital(PPEGT) and labor(Number of Employees)



ML Method 2: XGBoost

- Gradient boosting algorithm
  - Gradient boosting algorithm uses parallel trees. The final prediction is the sum of predictions from each tree.
  - see Chen and Guestrin (2016, 22nd ACM)
- Currently the most successful ‘off the shelf’ learning algorithm
  - https://github.com/dmlc/xgboost
  - https://scikit-learn.org/stable/

ML Method 2: XGBoost

- Selection Criteria
- Measure the 'feature importance' of individual variables
  - Brieman et al (1984) *Classification and Regression Trees*.
  - For one tree it is the improved performance (sum of squared error) due to each variable's split point. Weighted by the number of observations available.
  - Then averaged across all of the decision trees.

Inputs For Machine Learning Algorithms

Key Idea: Use successful ML methods to select the inputs. Then see if the candidate inputs make economic sense.

- Output is defined as sales revenue
- Candidate inputs 1: Variables with a minus in the income statement
- Candidate inputs 2: Variables with a plus in the balance sheet
- Candidate inputs 3: Capital, labor, year, 2-digit sic code industrial dummies
- More than 100, 000 firm/years. 10% from each year set aside for testing (could have stratified further, but did not)

Which Inputs Matter?

	Lasso: Coefficients			XGBoost: Feature Importance		
	All	Manuf	Non-Manuf	All	Manuf	Non-Manuf
COGS	0.708	0.697	0.716	221	234	223
SGA	0.110	0.195	0.069	154	198	115
Total Assets	0.166	0.114	0.178	57	53	54
Depreciation	0.067		0.091	53	10	64
Labor	0.019	0.027	0.008	37	41	54
Interest Expense	-0.016	-0.005	-0.012	15	22	15
Equity Investment	-0.012	-0.006	-0.009	$<$10	$<$10	$<$10
Other Investment		0.002		10	17	10
Intangible Assets		0.006	-0.003	$<$10	13	$<$10

- COGS expenses due to production (materials, wages, etc.)
- SGA expenses (marketing, head office, etc)
- Total assets have an opportunity cost

Production Functions With 3 Factors

	OLS	OLS First Diff	OLS First Diff	Dynamic Panel	OLS	OLS	Olley-Pakes
COGS	0.729	0.732	0.732	0.749	0.991	0.709	0.714
	(0.028)	(0.053)	(0.054)	(0.002)	(0.009)	(0.032)	(0.012)
SGA	0.122	0.161	0.162	0.139		0.115	0.120
	(0.035)	(0.037)	(0.037)	(0.001)		(0.033)	(0.001)
Total Assets	0.196	0.160	0.159	0.122		0.151	0.259
	(0.021)	(0.032)	(0.033)	(0.003)		(0.016)	(0.012)
Depreciation						0.059	
						(0.016)	
Labor						0.022	
						(0.014)	
Add Variable Level		No	Yes				
Observations	91584	91584	91584	86331	91584	91584	91584
R^2	0.978	0.750	0.750	0.978	0.965	0.978	0.970

- Griliches and Mairesse (1998) no longer problematic
- We use Olley-Pakes, but OLS gives the same answers Endogeneity
- 3 factor model is easy to use with standard firm-level data

Productivity and Reasons For Exit

	Last Year:	0	-1	-2
Acquisition or merger	productivity	0.029	0.016	0.014
	observations	2610	2597	2580
Now a private company	productivity	0.024	0.000	0.005
	observations	172	172	171
Leveraged buyout	productivity	-0.024	-0.027	-0.031
	observations	43	43	43
Liquidation	productivity	-0.111	-0.051	-0.042
(chapter 7)	observations	121	120	119
Bankruptcy	productivity	-0.037	-0.022	0.000
(chapter 11)	observations	227	226	223
Reverse acquisition	productivity	-0.076	-0.227	-0.189
(from 1983 onward)	observations	32	32	31
No longer fits original format	productivity	-0.241	-0.175	-0.160
(1978 forward)	observations	2	2	2
Other	productivity	-0.082	-0.055	-0.033
(no longer files with SEC etc.)	observations	539	532	527
Other	productivity	-0.015	-0.001	0.026
(no longer files with SEC etc.)	observations	247	246	245
(but pricing continues)				

Step 1 Summary

- Three factor model is much better than standard KL models
  - Coefficient stability between levels and first differences
  - Strong out-of-sample stability
  - Resolves the Griliches and Mairess (1998) concern
  - ML selected inputs have easy economic interpretations
  - Easy to use with standard firm-level accounting data
- Belloni et al style Lasso and XGBoost produced similar results
- Three factors using OLS or Olley-Pakes is almost as good as using XGBoost directly and simpler to interpret

Step 2. Does Finance Flow to High Productivity Firms?

How Do High and Low Productivity Firms Differ?

Productivity Average	Low		Medium		High
	1	2	3	4	5
Productivity: Three Factors	-0.484	-0.185	-0.069	0.044	0.276
Sales	6.715	6.392	5.674	5.016	4.749
Total Assets	7.150	6.286	5.459	4.730	4.582
Profitability	0.043	0.104	0.114	0.123	0.154
Investment (CAPX)/PPEGT	0.097	0.096	0.096	0.099	0.111
Net Finance/Assets	0.074	0.034	0.028	0.022	0.019
Dividend	0.647	0.610	0.529	0.446	0.427
Market Leverage	0.355	0.342	0.311	0.293	0.246
Tobin Q	3.434	1.973	1.859	1.949	3.414
Financing Constraint 1997-2015					
"Delay Investment"	0.004	-0.023	-0.030	-0.036	-0.023

- The net use of external finance is sharply concentrated in the lowest productivity quintile.

Logged Variables Scaled Variables

Direction of financial resource flow

- Finance does not generally flow to high productivity firm.
- Our story is:
  - At times of high transitory productivity, due to discounting investors want some extra consumption now.
  - To exploit a transitory opportunity, firm needs to acquire extra productive capital quickly
  - For both of these to happen at the same time, firm draws down on accumulated internal financial resources

High and Low Productivity and Variability

Productivity Average	Low		Medium		High
	1	2	3	4	5
Low Productivity Variability Firms					
Average Productivity	0.027	0.041	0.059	0.094	0.278
Sales	8.720	7.380	6.618	5.953	5.263
Total Assets	8.452	6.967	6.155	5.411	4.616
Investment (CAPX)/PPEGT	0.078	0.083	0.084	0.086	0.087
Net Finance	-0.013	-0.005	-0.005	-0.008	-0.014
High Productivity Variability Firms					
Average Productivity	-0.933	-0.287	-0.067	0.122	0.488
Sales	3.530	5.141	4.718	4.528	4.797
Total Assets	5.171	5.679	4.997	4.711	5.151
Investment (CAPX)/PPEGT	0.129	0.119	0.118	0.121	0.135
Net Finance	0.222	0.109	0.092	0.070	0.063

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- Fit productivity into an $AR(1)$ process, $z_{it} = \rho_i z_{i,t-1} + \varepsilon_{it}$
- Difference in net finance is more prominent for high productivity variability firms

Does Productivity Affect Investment?

		Group by within firm volatility of q				Group by Industry	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
L.Tobin q	0.007***	0.045***	0.026***	0.016***	0.006***	0.007***	0.007***
	(0.000)	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Productivity	0.005	0.001	0.007	0.008	0.002	0.012**	-0.006
	(0.005)	(0.006)	(0.008)	(0.008)	(0.008)	(0.005)	(0.009)
Productivity^2	-0.000	-0.015**	-0.017**	-0.003	0.000	0.002	-0.004
	(0.003)	(0.006)	(0.007)	(0.008)	(0.004)	(0.004)	(0.004)
Sample	All Firms	Bin 1	Bin 2	Bin 3	Bin 4	Non-HighT	HighT
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Within-Firm R^2	0.100	0.054	0.071	0.092	0.152	0.074	0.159
Obs	95569	23785	24087	24132	23565	75268	20301

- Complements Andrei, Mann, and Moyen (2018)
- Bin 1 firms have low within firm volatility of Tobin'q. Bin 5 have high volatility
- More productive low tech firms invest more

Do High Productivity Firms Raise More External Finance?

	(1) Net Finance	(2) Net Finance	(3) Net Finance (DivAdj)	(4) Net Finance (Issuance)
Productivity	-0.111***	-0.116***	-0.117***	-0.113***
	(0.002)	(0.004)	(0.004)	(0.004)
Productivity^2	-0.006***	-0.012***	-0.011***	-0.010***
	(0.001)	(0.002)	(0.002)	(0.002)
Financing Constraint		0.121***	0.120***	0.122***
		(0.013)	(0.013)	(0.013)
TFP*Financing Constraint		0.138***	0.135***	0.129***
		(0.026)	(0.027)	(0.027)
Frank Goyal	Y	Y	Y	Y
Industry Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Observations	96401	31909	31909	31909
R^2	0.202	0.274	0.264	0.259

- More productive firm generally make payments to the financial markets
- Financially constrained firm have positive net finance.

Do High Productivity Firms Hold More Cash?

	(1) Cash	(2) Cash	(3) Cash	(4) Cash
Productivity	-0.018***	-0.011***	-0.030***	-0.024***
	(0.002)	(0.003)	(0.003)	(0.003)
Productivity^2	0.030***	0.017***		0.030***
	(0.001)	(0.002)		(0.002)
Financing Constraint		0.091***	0.085***	0.191***
		(0.011)	(0.011)	(0.012)
TFP*Financing Constraint		-0.101***	-0.190***	-0.083***
		(0.022)	(0.021)	(0.025)
Frank Goyal	Y	Y	Y	
Industry Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Observations	96401	31909	31909	31909
R^2	0.265	0.357	0.355	0.215

- High productivity firms keep less cash on hand.

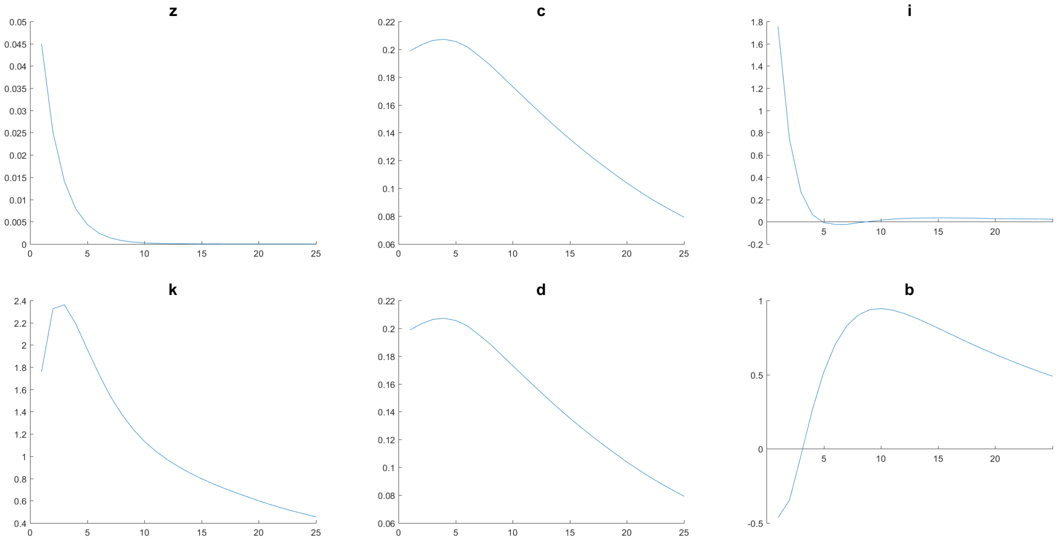
Step 3. Interpreting the Evidence

A Simple Model

- A model with an investor and a firm
- The firm is subject to productivity shocks (z)
- The firm picks investment (i) in capital (k), makes bank account deposits (b), and pays dividends (d) to the investor
- When a positive productivity shock arrives the investor wants to consume (c) more, so the firm must payout funds (d) at the same time that it is buying more capital
- For this to add up, firm reduces bank account holdings (b)

◂ Model Setup

Response to a Productivity Shock



Conclusions

Does Finance Flow to High Productivity Firms?
No. Typically finance flows away from high productivity firms.

1. We derived a new method to measure the productivity of public firms using ordinary corporate accounts. Easy to use.
2. Resolves the Griliches and Mairesse (1998) concerns about the traditional approach. Endogeneity corrections are now minor.
3. Several features of the data make sense using the 3 factors
4. High productivity firms:
    - Commonly invest in more assets and return funds to investors
    - They hold less financial assets

Appendix

COGS Definition from Compustat

- This item represents all costs directly allocated by the company to production, such as material, labor and overhead.

- The total operating costs for non-manufacturing companies are considered as cost of goods sold if a breakdown is not available.

- This item includes the following expenses when broken out separately. However, if a company allocates any of these items to selling, general and administrative expenses, Standard & Poor's will not include them in Cost of Goods Sold.

Agricultural, aircraft, automotive, radio and television manufacturers' amortization of tools and dies Airlines' mutual aid agreements Amortization of deferred costs (i.e., start-up costs) Amortization of tools and dies where the useful life is two years or less Amortization of film and television costs Cooperatives' patronage dividends Direct costs - when a separate selling, general and administrative expenses figure is reported Direct labor Expenses associated with sales-related income from software development Extractive industries' lease and mineral rights charged off and development costs written off Freight-in Heat, light and power Improvements to leased properties Insurance and safety Land developers' investment real estate expense Licenses Maintenance and repairs Operating Expense ? Totals Pension, retirement, profit sharing, provision for bonus and stock options, and other employee benefits, for manufacturing companies. For non-manufacturing companies, this expense goes into Selling, General, and Administrative Expenses Real estate investment trusts' advisory fees Rent and royalty Lease expense Salary expense Supplies Taxes, other than income taxes Terminals and traffic Transportation Warehouse expense Writedowns of oil and gas properties

Firm Level Data
Balance Sheet, USA 1971 - 2015

	Median	EW Mean	VW Mean	Std Dev	25%	75%
Asset						
Cash and Short-Term Investments	0.060	0.117	0.073	0.152	0.022	0.147
+ Receivables - Total	0.170	0.185	0.131	0.130	0.089	0.257
+ Inventories - Total	0.154	0.183	0.113	0.164	0.035	0.287
+ Current Assets/Other/Total	0.020	0.029	0.026	0.036	0.010	0.037
= Current Assets - Total	0.527	0.501	0.318	0.244	0.319	0.693
+ Property Plant and Equipment - Total (Net)	0.267	0.314	0.362	0.220	0.142	0.441
+ Investment and Advances - Equity	0.000	0.012	0.017	0.046	0.000	0.000
+ Investment and Advances/Other	0.000	0.022	0.020	0.074	0.000	0.010
+ Intangible Assets - Total	0.011	0.083	0.112	0.143	0.000	0.104
+ Assets - Other	0.022	0.044	0.049	0.069	0.009	0.050
= Assets - Total	1.000	1.000	1.000	0.000	1.000	1.000
Observations	101140					

Return

Firm Level Data
Balance Sheet, USA 1971 - 2015

	Median	EW Mean	VW Mean	Std Dev	25%	75%
Asset						
Liability and Shareholder Equity						
+ Debt in Current Liabilities - Total	0.025	0.062	0.039	0.129	0.005	0.070
+ Accounts Payable - Trade	0.077	0.098	0.080	0.085	0.046	0.124
+ Income Taxes Payable	0.003	0.010	0.010	0.018	0.000	0.014
+ Current Liabilities/Other/Total	0.077	0.096	0.092	0.106	0.047	0.120
= Current Liabilities - Total	0.230	0.262	0.213	0.220	0.155	0.328
+ Long-Term Debt - Total	0.175	0.208	0.235	0.209	0.053	0.301
+ Liabilities - Other - Total	0.010	0.039	0.073	0.162	0.000	0.042
+ Deferred Taxes and Investment Tax Credit	0.008	0.023	0.039	0.035	0.000	0.034
+ Minority Interest (Balance Sheet)	0.000	0.004	0.004	0.020	0.000	0.000
= Liabilities - Total	0.522	0.539	0.606	0.358	0.378	0.661
+ Preferred/Preference Stock (Capital) - Total	0.000	0.010	0.003	0.081	0.000	0.000
+ Common/Ordinary Equity - Total	0.463	0.446	0.370	0.334	0.323	0.610
= Stockholders Equity - Total	0.469	0.456	0.376	0.315	0.332	0.614
Observations	101140					

Return

Income Statement, USA 1971 - 2015

	Median	EW Mean	VW Mean	Std Dev
+ Sales/Turnover (Net)	1.206	1.350	1.010	0.979
- Cost of Goods Sold	0.801	0.964	0.699	0.877
- Selling General and Administrative Expense	0.228	0.284	0.155	0.264
= Operating Income Before Depreciation	0.125	0.103	0.139	0.188
- Depreciation and Amortization	0.039	0.047	0.043	0.045
= Operating Income After Depreciation	0.082	0.056	0.094	0.195
- Interest and Related Expense - Total	0.019	0.025	0.020	0.067
+ Nonoperating Income (Expense)	0.005	0.010	0.008	0.040
+ Special Items	0.000	-0.012	-0.007	0.142
= Pretax Income	0.063	0.028	0.074	0.302
- Income Taxes - Total	0.021	0.027	0.027	0.041
- Minority Interest (Income Account)	0.000	0.000	0.001	0.005
= Income Before Extraordinary Items	0.041	0.001	0.046	0.288
- Dividends - Preferred/Preference	0.000	0.002	0.000	0.025
+ Common Stock Equivalents - Dollar Savings	0.000	0.000	0.000	0.001
+ Extraordinary Items and Discontinued Operations	0.000	-0.000	-0.000	0.083
Net Income	0.042	0.001	0.046	0.304
Total Observations	101140			
Total Staff Expense	0.339	0.390	0.292	0.325
Observations	10348			

Return

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Productivity Average	Low		Medium		High
	1	2	3	4	5
Productivity: Three Factors	-0.484	-0.185	-0.069	0.044	0.276
Logged Variables					
Sales	6.715	6.392	5.674	5.016	4.749
Capital	6.454	5.652	4.837	4.139	3.978
Labor	5.030	4.620	3.952	3.309	2.943
COGS	6.517	6.032	5.288	4.590	4.043
SGA	5.029	4.558	3.833	3.129	2.622
Total Assets	7.150	6.286	5.459	4.730	4.582
Observations	20448				

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How Do High and Low Productivity Firms Differ?

Productivity Average	Low 1	2	Medium 3	4	High 5
Productivity: Three Factors	-0.484	-0.185	-0.069	0.044	0.276
Scaled Variables					
Investment (CAPX)/PPEGT	0.097	0.096	0.096	0.099	0.111
Investment (Cash Flow)/AT	0.107	0.103	0.096	0.094	0.112
Cash/Assets	0.131	0.094	0.097	0.108	0.136
Net Cash/Assets	-0.207	-0.085	0.001	0.042	0.027
Net Finance/Assets	0.074	0.034	0.028	0.022	0.019
Net Finance (Issuance)/Assets	0.086	0.046	0.039	0.033	0.032
Observations	20448				

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Productivity Variability

Productivity Variability	Low		Medium		High
	1	2	3	4	5
Average σ_i	0.027	0.041	0.059	0.094	0.278
Logged Variables					
Sales	6.790	6.264	5.690	5.259	4.542
Capital	5.862	5.414	4.889	4.548	4.347
Labor	5.076	4.534	3.941	3.499	2.804
COGS	6.421	5.877	5.265	4.783	4.123
SGA	4.908	4.371	3.862	3.336	2.695
Total Assets	6.323	5.949	5.488	5.306	5.142

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Productivity Variability

Productivity Variability	Low		Medium		High
	1	2	3	4	5
Average σ_i	0.027	0.041	0.059	0.094	0.278
Scaled Variables					
Investment (CAPX)/PPEGT	0.084	0.087	0.095	0.108	0.124
Investment (Cash Flow)/AT	0.089	0.090	0.097	0.107	0.130
Cash/Assets	0.074	0.084	0.104	0.129	0.175
Net Cash/Assets	-0.001	-0.010	-0.004	-0.052	-0.155
Net Finance/Assets	-0.009	0.004	0.022	0.048	0.111
Net Finance (Issuance)/Assets	0.008	0.018	0.035	0.057	0.119

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How Do High and Low Productivity Firms Differ?

Productivity Average	Low		Medium		High
	1	2	3	4	5
Productivity: XGBoost	-0.226	-0.043	0.001	0.048	0.220
Total Assets	5.493	5.947	5.823	5.651	5.303
Ratios					
Dividend	0.463	0.573	0.580	0.551	0.488
Tobin q	3.025	1.562	1.703	2.235	4.146
Market to Book	1.216	1.067	1.136	1.255	1.597
Tangibility	0.311	0.319	0.316	0.314	0.329
Profitability	-0.021	0.110	0.136	0.154	0.159
Book Leverage	0.298	0.277	0.264	0.252	0.263
Market Leverage	0.354	0.334	0.308	0.282	0.265
Growth of Assets	10.378	7.704	8.008	8.852	12.937
Observations	20315				
Financing Constraint 1997-2015					
“Delay Investment”	0.000	-0.031	-0.034	-0.031	-0.014
Observations	6666	6471	6482	6619	6578

Does Productivity Affect Investment?

		Group by within firm volatility of q				Group by Industry	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
L.Tobin q	0.007***	0.045***	0.026***	0.016***	0.006***	0.007***	0.007***
	(0.000)	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Productivity	0.007	0.008	0.018*	0.017*	0.001	0.013**	0.001
	(0.006)	(0.008)	(0.010)	(0.010)	(0.009)	(0.006)	(0.010)
$Productivity^2$	0.002	-0.016*	-0.010	0.004	0.002	0.006	-0.001
	(0.004)	(0.009)	(0.011)	(0.010)	(0.005)	(0.004)	(0.007)
Sample	All Firms	Bin 1	Bin 2	Bin 3	Bin 4	Non-HighT	HighT
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Within-Firm R2	0.101	0.054	0.071	0.092	0.152	0.074	0.158
Obs	95009	23482	23994	24041	23492	74784	20225

Do High Productivity Firms Raise More External Finance?

	(1) Net Finance	(2) Net Finance	(3) Net Finance (DivAdj)	(4) Net Finance (Issuance)
Productivity	-0.091***	-0.098***	-0.099***	-0.091***
	(0.003)	(0.005)	(0.005)	(0.005)
Productivity^2	-0.000	-0.009***	-0.009***	-0.005**
	(0.002)	(0.002)	(0.002)	(0.002)
Financing Constraint		0.118***	0.118***	0.120***
		(0.013)	(0.013)	(0.013)
TFP*Financing Constraint		0.109***	0.114***	0.106***
		(0.035)	(0.036)	(0.036)
Controls	Y	Y	Y	Y
Industry Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	95832	31865	31865	31865
R^2	0.189	0.260	0.250	0.246

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Endogeneity

- Three Factors Model

$$y_{it} = \beta^c c_{it} + \beta^s s_{it} + \beta^a a_{it} + \gamma_t + \eta_j + \omega_{it} + \varepsilon_{it}$$

  - y_{it} is sales, c_{it} is COGS, s_{it} is SGA, and a_{it} is total assets, all in logarithm.
  - total assets are predetermined and uncorrelated with productivity shock
  - firm can adjust COGS and SGA after observing productivity shock
  - Apply Olley and Pakes Correction
    - Investment decision f is invertible in ω_{it}
    - Use f^{-1} to approximate ω_{it}
    - Use a two-step approach to estimate the parameters

Endogeneity

- Three Factors Model

$$y_{it} = \beta^c c_{it} + \beta^s s_{it} + \beta^a a_{it} + \gamma_t + \eta_j + \omega_{it} + \varepsilon_{it}$$

- We assume following the timing of input choices
  - $c_{it} = f_C(c_{i,t-1}, s_{i,t-1}, a_{it}, w_{it})$
  - $s_{it} = f_S(c_{i,t-1}, s_{i,t-1}, a_{it}, w_{it})$
  - $i_{it} = f_I(c_{i,t-1}, s_{i,t-1}, a_{it}, w_{it})$
  - $a_{it} = \kappa(i_{i,t-1}, a_{i,t-1})$
- Follow Olley and Pakes, we have the following assumptions:
  - $f_I(c_{i,t-1}, s_{i,t-1}, a_{it}, w_{it})$ is invertible in $\omega_{i,t}$
  - $\omega_{i,t}$ follows an Markov process
  - No cross-sectional variation in input prices

Two-Steps Approach

- Step 1: Estimating β^c and β^s.

- Since we assume that $f_l(c_{i,t-1}, s_{i,t-1}, a_{it}, w_{it})$ is invertible in $\omega_{i,t}$, we denote $w_{it} = f_l^{-1}(c_{i,t-1}, s_{i,t-1}, a_{it}, i_{it})$. We plug $w_{it} = f_l^{-1}$ into the production function to control for the endogenous variable:

$$y_{it} = \beta^c c_{it} + \beta^s s_{it} + \beta^a a_{it} + f_l^{-1}(c_{i,t-1}, s_{i,t-1}, a_{it}, i_{it}) + \gamma_t + \eta_j + \varepsilon_{it}$$

- denote $\varphi_{it}(c_{i,t-1}, s_{i,t-1}, a_{it}, i_{it}) = \beta^a a_{it} + f_l^{-1}(c_{i,t-1}, s_{i,t-1}, a_{it}, i_{it})$, we have

$$y_{it} = \beta^c c_{it} + \beta^s s_{it} + \varphi_{it}(c_{i,t-1}, s_{i,t-1}, a_{it}, i_{it}) + \gamma_t + \eta_j + \varepsilon_{it}$$

- which gives us a partial Linear model in which β^c and β^s can be identified. We use third order polynomial to approximate for $\varphi_{it}(c_{i,t-1}, s_{i,t-1}, a_{it}, i_{it})$. Then we can use a GMM estimator exploiting the conditions that ε_{it} is not correlated with the regressors. The GMM estimators give us unbiasedly estimated $\hat{\beta}^c$, $\hat{\beta}^s$, $\hat{\varphi}_{it}(c_{i,t-1}, s_{i,t-1}, a_{it}, i_{it})$, $\hat{\gamma}_t$, $\hat{\eta}_j$.

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Two-Steps Approach

- Step 2: Estimating β^a and ω_{it}.

- $\omega_{i,t}$ follows an AR(1) process:

$$\omega_{it} = E[\omega_{i,t}|\omega_{i,t-1}] + \mu_{it} = \rho\omega_{i,t-1} + \mu_{it}$$

- $\varphi_{it}(c_{i,t-1}, s_{i,t-1}, a_{it}, i_{it}) = \beta^a a_{it} + f_I^{-1}(c_{i,t-1}, s_{i,t-1}, a_{it}, i_{it}) = \beta^a a_{it} + \omega_{it}$, therefore we have that

$$\begin{aligned}
\varphi_{it} &= \beta^a a_{it} + \omega_{it} \\
&= \beta^a a_{it} + \rho\omega_{i,t-1} + \mu_{it} \\
&= \beta^a a_{it} + \rho\varphi_{i,t-1} - \rho\beta^a a_{i,t-1} + \mu_{it}
\end{aligned}$$

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Endogeneity

- Three Factors Model

$$y_i = \beta_l l_t + \beta_k k_t + \beta_m m_t + \omega_t + \varepsilon_t$$

  - ω_t is correlated with l_t and m_t
  - k_t is state variable
  - $m_t = M_t(\omega_t, k_t)$ and $\omega_t = h_t(m_t, k_t)$
  - Use a two-step approach or Wooldridge (2009) to estimate the parameters

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Firm

The firm's objective function is defined by the expected discounted flow of dividends d_t.

$$E_0 \sum_{t=1}^{\infty} m_t d_t$$

$$F_t(k_t) + (1 + r_t)b_t = i_t + \Phi(i_t, k_t) + b_{t+1} + d_t, \; t \geq 0.$$

The law of motion of capital is given by,

$$i_t = k_{t+1} - (1 - \delta)k_t$$

with $\delta \in (0, 1)$. The convex capital adjustment cost is,

$$\Phi(i_t, k_t) = \frac{a}{2}(\frac{i_t}{k_t})^2 k_t.$$

Revenue from production is given by $F_t(k_t) = e^{z_t} A k_t^{\alpha}$, with $A > 0, \alpha \in (0, 1)$, and

$$z_t = \rho_z z_{t-1} + \varepsilon_t, \; \varepsilon_t \sim N(0, \sigma_z^2) \text{ iid.}$$

◂ Back

Firm

The rate of return on the firm's bank account is

$$r_t = r_f - \omega b_t,$$

where the risk free rate $r_f \in (0, 1)$ is exogenously determined, and $\omega > 0$ is the interest sensitivity to the amount that the firm deposits in the bank b_t. The coefficient ω can be interpreted in following ways.

- A convenient technical assumption that facilitates an interior solution for b_t.
- Free cash flow: firm with a large bank account must be able to show that it has done proper due diligence. This creates an opportunity for empire building inside the firm. This imposes a cost that grows with the size of the account.

◂ Back

Investor

- Investors are not typically well-diversified. This implies that even idiosyncratic shocks to the firm are not fully diversified away. Assume that the only financial product available to the investor is from the firm.

- $$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t)$$

  where E_t is the expectation conditional on date t information, c_t is the date t consumption. we assume that $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$, where $\gamma > 0$.

- Investors determine the pricing kernel

$$p_t = E_t \sum_{j=1}^{\infty} (\beta^j \frac{u_c(c_{t+j})}{u_c(c_t)}) d_{t+j}.$$

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Productivity Variability

Productivity Variability	Low		Medium		High
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Investment (CAPX)/PPEGT	0.084	0.087	0.095	0.108	0.124
Net Finance/Assets	-0.009	0.004	0.022	0.048	0.111

- Fit productivity into an $AR(1)$ process, $z_{it} = \rho_i z_{i,t-1} + \varepsilon_{it}$
- Firms with more volatile productivity invest more and make more active use of financial markets

Logged Variables Scaled Variables