Lecture 18: Empirics of the Q Theory

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May 29, 2025

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- Where q_t is the marginal value of another unit of capital (marginal q)
- i.e. $\partial V_t / \partial K_{t+1}$, where V is the value of the firm
- If the following assumptions hold:
  - The production function is CRS
  - The adjustment cost function is CRS
  - Markets are competitive
- Then Average Q is equal to marginal q, where

$$Q_t = \frac{V_t^e}{K_t}$$

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- No other variable should explain investment on top of Q
- i.e. cash flows, liquidity, size of the firm should be irrelevant after controlling for Q

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- In these cases, investment may be determined by current cash flows
  - Firms that generate large cash flows have more internal funds
  - Lower cost of funds as a result
  - And may invest more

Today:

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- How strongly investment reacts to changes in the cost of capital?

Why are these questions important

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- so $\beta_0 = -\frac{1}{\varphi}$, and $\beta_1 = \frac{1}{\varphi}$
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- Implying $\hat{\varphi} = 32.25$

Research Design

- Regression equation

$$\frac{I_{it}}{K_{it}} = \beta_0 + \beta_1 Q_{it} + \epsilon_{it}$$

- Simulateneity problem
  - Higher q calls for higher investment rates
  - Higher investment rates increase future capital stocks
  - Reducing future MPKs
  - Reducing q
- Not clear what direction of causality this regression is exploiting
  - Ideally we need exogenous variation in q

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  - Cooper and Haltiwanger (2006) use $\varphi = 0.049$ using annual data
  - Winberry (2021) use $\varphi = 2.49$ using quarterly data
  - Compare to the $\hat{\varphi} = 32$ in Summers (1981) using annual data

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  - Compare to the $\hat{\varphi} = 32$ in Summers (1981) using annual data
  - caution: this is a parameter that is not trivial to compare across different time dimensions

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- Key question: Is ϵ_{it} orthogonal to Q_{it}?

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  - The sign of the bias is difficult to predict. Depends on the source of omitted variation

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- Is this logic sound enough?

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- Even when the Q theory holds

Moral

Measurement error is really no joke

Fazzari Hubbard Petersen (1988)

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  - Capital adjustment costs are not sorted in the dividend-payment dimension

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- The empirical specification is more general

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- This regression by group has a triple-difference flavor. β_2 is already a dif-dif.

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Table 2. Summary Statistics: Sample of Manufacturing Firms, 1970–84

Statistic	Category of firm		
	Class 1[a]	*Class 2*[b]	*Class 3*[c]
Number of firms	49	39	334
Average retention ratio	0.94	0.83	0.58
Percent of years with positive dividends	33	83	98
Average real sales growth (percent per year)	13.7	8.7	4.6
Average investment-capital ratio	0.26	0.18	0.12
Average cash flow–capital ratio	0.30	0.26	0.21
Average correlations of cash flow with investment (deviations from trend)[d]	0.92	0.82	0.20
Average of firm standard deviations of investment-capital ratios	0.17	0.09	0.06
Average of firm standard deviations of cash flow–capital ratios	0.20	0.09	0.06
Capital stock (millions of 1982 dollars)			
Average capital stock, 1970	100.6	289.7	1,270.0
Median capital stock, 1970	27.1	54.2	401.6
Average capital stock, 1984	320.0	653.4	2,190.6
Median capital stock, 1984	94.9	192.5	480.8

Source: Authors' calculations based on samples selected from the Value Line data base. See Appendix B.
a. Firms with dividend-income ratios of less than 0.1 for at least 10 years.
b. Firms with dividend-income ratios greater than 0.1 but less than 0.2 for at least 10 years.
c. Firms with dividend-income ratios greater than 0.2.
d. Estimated from time series constructed by aggregating the sample data within each category.

Source: Fazzari-Hubbard-Petersen (1988)

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Table 4. Effects of *Q* and Cash Flow on Investment, Various Periods, 1970–84[a]

Independent variable and summary statistic	*Class 1*	*Class 2*	*Class 3*
		1970–75	
Q_{it}	−0.0010	0.0072	0.0014
	(0.0004)	(0.0017)	(0.0004)
$(CF/K)_{it}$	0.670	0.349	0.254
	(0.044)	(0.075)	(0.022)
$\bar{R}^2$	0.55	0.19	0.13
		1970–79	
Q_{it}	0.0002	0.0060	0.0020
	(0.0004)	(0.0011)	(0.0003)
$(CF/K)_{it}$	0.540	0.313	0.185
	(0.036)	(0.054)	(0.013)
$\bar{R}^2$	0.47	0.20	0.14
		1970–84	
Q_{it}	0.0008	0.0046	0.0020
	(0.0004)	(0.0009)	(0.0003)
$(CF/K)_{it}$	0.461	0.363	0.230
	(0.027)	(0.039)	(0.010)
$\bar{R}^2$	0.46	0.28	0.19

Source: Authors' estimates of equation 3 based on a sample of firm data from Value Line data base. See text and Appendix B.

a. The dependent variable is the investment-capital ratio $(I/K)_{it}$, where I is investment in plant and equipment and K is beginning-of-period capital stock. Independent variables are defined as follows: Q is the sum of the value of equity and debt less the value of inventories, divided by the replacement cost of the capital stock adjusted for corporate and personal taxes (see Appendix B); $(CF/K)_{it}$ is the cash flow–capital ratio. The equations were estimated using fixed firm and year effects (not reported). Standard errors appear in parentheses.

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  - Exogenous to future profitability
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  - Changes in tax incentives
  - Effects of HQ shocks on subsidiaries

Temporary Investment Tax Incentives

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- Questions of interest:
  - How effective are these policies as stimulus?
  - What is the response of investment to changes in the cost of capital?
- Large literature: Cummins-Hassett-Hubbard (1994), House-Shapiro (2008), Zwick-Mahon (2017)

Bonus Depreciation

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- Bonus depreciation accelerates this depreciation schedule

Table 1—Regular and Bonus Depreciation Schedules for Five-Year Items

Year:	0	1	2	3	4	5	Total
Normal depreciation							
Deductions (000s)	200	320	192	115	115	58	1,000
Tax benefit (τ = 35 percent)	70	112	67.2	40.3	40.3	20.2	350
Bonus depreciation (50 percent)							
Deductions (000s)	600	160	96	57.5	57.5	29	1,000
Tax benefit (τ = 35 percent)	210	56	33.6	20.2	20.2	10	350

Notes: This table displays year-by-year deductions and tax benefits for a $1 million investment in computers, a five-year item, depreciable according to the Modified Accelerated Cost Recovery System (MACRS). The top schedule applies during normal times. It reflects a half-year convention for the purchase year and a 200 percent declining balance method (2× straight line until straight line is greater). The bottom schedule applies when 50 percent bonus depreciation is available.

Source: Authors' calculations. See IRS publication 946 for the recovery periods and schedules applying to other class lives (https://www.irs.gov/uac/about-publication-946).

Source: Zwick-Mahon (2017)

- Bonus depreciation allows firm to deduct a per dollar bonus of θ at the time of investment and the remaining $1 - \theta$ according to regular schedule
- Table shows bonus depreciation of $\theta = 0.5$

Value of Bonus Depreciation

Frictionless markets view:

- Bonus depreciation only matters due to discounting

$$z^0 = D_0 + \sum_{t=1}^{T} \frac{1}{(1+r)^t} D_t$$

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- Without discounting $z_0 = 1$ (100%), with discounting $z_0 < 1$
- Bonus raises z_0 by bringing deductions forward in time

$$z = \theta + (1 - \theta) z_0$$

Value of Bonus Depreciation

- Frictionless markets view:
  - Value of bonus modest for short-lived investments
  - E.g., with $r = 0.07$, bonus in Table 1 raised z by 2%
  - Value of bonus greater for long-lived investments
- With financial frictions, bonus may have large effect on investment
  - Effect on current cash flow large ($140,000 in Table 1)

Zwick-Mahon (2017)

- Estimate the effect of bonus on investment
- Bonus occurs in recessions
  - Correlated with other determinants of investment
- Use difference-in-difference identification strategy
  - Bonus more valuable for industries with longer lived investments
  - Compare effect of bonus on industries with differing duration of investments

Zwick-Mahon (2017): Policy Variable

- Main policy variable: $z_{N,t}$
  - Where N is a 4-digit NAICS industry
- Compute baseline z_N for pre-period (1993-2000)
  - For each firm-year: weighted average of z across duration categories using a 7% discount rate
  - z_N computed as simple average of these firm-year z
- In bonus years adjust z_N for bonus

$$z_{N,t} = \theta_t + (1 - \theta_t) z_N$$

Zwick-Mahon (2017): Specification

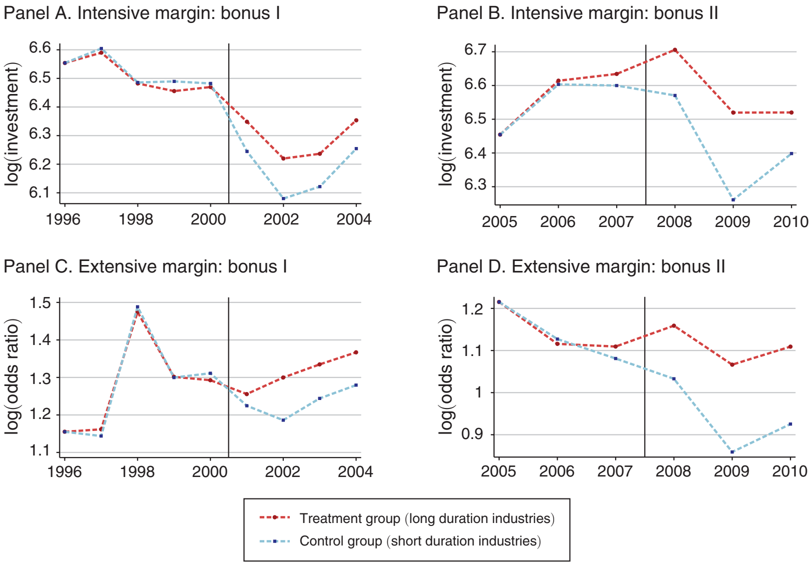
- Baseline difference-in-difference specification:

$$\log(I_{it}) = \alpha_i + \beta z_{N,t} + \gamma X_{it} + \delta_t + \epsilon_{it}$$

  - β is coefficient of interest
  - Industry fixed effects: Allow for average differences in industry investment
  - Time fixed effects: Take out aggregate effects
  - Industry and time fixed effects are what make this a diff-in-diff

Zwick-Mahon (2017): Identification

- Identifying assumption: **Parallel trends**
  - Industries with long- and short-duration investment patterns would have evolved in parallel absent bonus
- Threat to identification:
  - Durable investment industries more resilient in downturns



Source: Zwick-Mahon (2017)

$$f(I_{it}) = \alpha_i + \delta_t + \beta g(z_{N,t}) + \gamma X_{it} + \varepsilon_{it}$$

	LHS Variable is Log(Eligible Investment)					
	All	CF	Pre-2005	Post-2004	Controls	Trends
$z_{N,t}$	3.69***	3.78***	3.07***	3.02***	3.73***	4.69***
	(0.53)	(0.57)	(0.69)	(0.81)	(0.70)	(0.62)
Observations	735341	580422	514035	221306	585914	722262
Clusters (Firms)	128001	100883	109678	63699	107985	124962
R^2	0.71	0.74	0.73	0.80	0.72	0.71
	LHS Variable is Log(Odds Ratio)					
$z_{N,t}$	3.79**	3.87**	3.12	3.59**	3.99*	4.00***
	(1.24)	(1.21)	(2.00)	(1.14)	(1.69)	(1.13)
Observations	803659	641173	556011	247648	643913	803659
Clusters (Industries)	314	314	314	274	277	314
R^2	0.87	0.88	0.88	0.93	0.90	0.90
	LHS Variable is Eligible Investment/Lagged Capital					
$\frac{1-t_c z}{1-t_c}$	-1.60***	-1.53***	-2.00***	-1.42***	-2.27***	-1.50***
	(0.096)	(0.095)	(0.16)	(0.13)	(0.14)	(0.10)
Observations	637243	633598	426214	211029	510653	631295
Clusters (Firms)	103890	103220	87939	57343	90145	103565
R^2	0.43	0.43	0.48	0.54	0.45	0.44

All regressions include firm and year effects. Controls: cash flow in (2); 4-digit Q, quartics in sales, assets, profit margin, age in (5); 2-digit NAICS $\times t^2$ in (6).

Source: Zwick-Mahon (2017)

Zwick-Mahon (2017): Effects Are Large

- Average change in $z_{N,t}$:
  - Early episode: 4.8 cents
  - Later episode: 7.8 cents
- Average change in investment:
  - Early episode: 17.7 log points (3.69 x 0.048 = 0.177)
  - Later episode: 28.8 log points (3.69 x 0.078 = 0.288)

Zwick-Mahon (2017): Effects Are Large

- In simple investment model:
  - Elasticity of investment with respect to net of tax rate, $1 - \tau z$, equals price and interest elasticity

$$\log(I_{it}) = \alpha + \beta \log(1 - \tau z_{N,t}) + \epsilon_{it}$$

- Zwick-Mahon's regressor is $z_{N,t}$ not $\log(1 - \tau z_{N,t})$

- Linear approximation:

$$\log(1 - \tau z_{N,t}) = \log(1 - \tau z_N) - \frac{\tau}{1 - \tau z_N}(z_{N,t} - z_N)$$

- Zwick-Mahon results imply price and interest rate elasticities of investment equal to

$$-3.69 \div \frac{\tau}{1 - \tau z} \approx -7.2$$

TABLE 6—HETEROGENEITY BY EX ANTE CONSTRAINTS

	Sales		Div payer?		Lagged cash	
	Small	Big	No	Yes	Low	High
$z_{N,t}$	6.29	3.22	5.98	3.67	7.21	2.76
	(1.21)	(0.76)	(0.88)	(0.97)	(1.38)	(0.88)
Equality test	$p = 0.030$		$p = 0.079$		$p = 0.000$	
Observations	177,620	255,266	274,809	127,523	176,893	180,933
Clusters (firms)	29,618	29,637	39,195	12,543	45,824	48,936
R^2	0.44	0.76	0.69	0.80	0.81	0.76

Notes: This table estimates regressions from the baseline intensive margin specification presented in Table 3. We split the sample based on pre-policy markers of financial constraints. For the size splits, we divide the sample into deciles based on the mean value of sales, with the mean taken over years 1998 through 2000. Small firms fall into the bottom three deciles and big firms fall into the top three deciles. For the dividend payer split, we divide the sample based on whether the firm paid a dividend in any of the three years from 1998 through 2000. The dividend split only includes C corporations. The lagged cash split is based on lagged residuals from a regression of liquid assets on a ten-piece spline in total assets and fixed effects for four-digit industry, year, and corporate form. The comparison is between the top three and bottom three deciles of these lagged residuals. All regressions include firm and year fixed effects. Standard errors clustered at the firm level are in parentheses.

Source: Zwick-Mahon (2017)

$$\log(I_{it}) = \alpha_i + \delta_t + \varphi T_{it} + \beta z_{N,t} + \eta T_{it} \times z_{N,t} + \gamma X_{it} + \varepsilon_{it}$$

	LHS Variable is Log(Eligible Investment)					
	All	CF	Pre-2005	Post-2004	Controls	Trends
Taxable $\times z_{N,t}$	3.83*** (0.79)	3.08*** (0.93)	1.95* (0.92)	6.43*** (1.46)	4.32*** (0.96)	4.15*** (0.82)
$z_{N,t}$	-0.15 (0.90)	0.60 (1.05)	0.38 (1.06)	-3.03* (1.55)	-0.69 (1.15)	0.88 (0.94)
Medium LCF $\times z_{N,t}$						
High LCF $\times z_{N,t}$						
Observations	735341	580422	514035	221306	585914	722262
Clusters (Firms)	128001	100883	109678	63699	107985	124962
R^2	0.71	0.74	0.74	0.80	0.73	0.72

$T_{it} = 1 \iff$ first dollar of depreciation deduction affects taxes this year

Source: Zwick-Mahon (2017)

Heterogeneity in Effect

- More liquidity constrained firms have larger effects
- Effect only exists for firms with immediate tax benefit

- Concern: Firms with neg. earning may have worse growth prospects
  - Redo analysis including only firms close to zero earning

Micro-Foundation for Adjustment Costs

- Adjustment cost function is a black box
- Crucial aspect of the theory, but we don’t know what it is
- Some possibilities that explain the ZM results
  - Financial frictions
  - Fixed costs of adjustment