Investing in Misallocation

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Background

- Resource allocation across firms matters for aggregate outcomes
  - Is capital invested in firms where it is creating the highest value?
  - E.g., productivity gaps across countries

"sizeable gaps in marginal products of capital ... in China and India compared with the United States" (Hsieh and Klenow, 2009)

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  - often interpreted as evidence of an inefficient allocation among firms
  - dispersion as a sufficient statistic to measure misallocation
- Helpful to revisit basic investment theory to see ...
  - why cross-sectional dispersion in the marginal product of capital (MPK) could indicate misallocation?

Background: optimal frictionless investment

- Suppose that a firm i solves the following standard investment problem:

$$\max_{I_0} \mathbb{E}_0 \sum_{t=0}^{\infty} \frac{D_{it}}{R^t},$$

where

$$D_{it} = f(Z_{it}, K_{it}) - I_{it}$$
$$K_{it+1} = (1-\delta)K_{it} + I_{it},$$

with $\partial f/\partial Z > 0$, $\partial f/\partial K > 0$, $\partial^2 f/\partial K^2 < 0$, e.g. $f(Z,K) = Z^{\alpha}K^{1-\alpha}$.

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- The optimality condition for investment is given by:

$$R - (1-\delta) = \underbrace{\mathbb{E}_t\left[\frac{\partial f_{it+1}}{\partial K_{it+1}}\right]}_{\text{expected MPK}}.$$

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- The cost of capital (R) is equal to the expected marginal product of capital (MPK) plus the value of undepreciated capital $(1-\delta)$.
- Expected MPK is constant across firms with same R and δ.
  - If a firm has too little (much) capital now relative to expected productivity, it would (dis)invest until its expected MPK satisfies the optimality condition.

Background: distortions

- "Distortions": frictions causing $\mathbb{E}_t\left[\frac{\partial f_{it+1}}{\partial K_{it+1}}\right] >< R-(1-\delta)$
  - adjustment costs: capital may not keep up with productivity or be stuck in unproductive firms
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- Key insight: beneficial if high MPK firms invested more, relative to low MPK firms:

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- Tight connection between “misallocation” and dispersion in MPK
  - These arguments define misallocation in relative terms: further capital allocation to low MPK firms would be “misallocation”

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- Some firms fit the standard investment model quite well while others' (tangible and intangible) capital accumulation may be motivated by the upside potential for productivity in the future, e.g.,
  - building infrastructure to trigger a potential boom in future demand
  - investing for market leadership in the future
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- Akin to *endogenous* growth as common in the macro literature studying the role of innovation and R&D for growth

Extension with endogenous growth

- Suppose that productivity Z_{t+1} does not only depend on Z_t but also K_{t+1}: $Z_{it+1} = g(Z_{it}, K_{it+1}, \epsilon_{it+1})$ with $\partial g_{t+1}/\partial K_{t+1} > 0$ and $\partial g_{t+1}/\partial Z_t > 0$
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$$R - (1-\delta) = \underbrace{\mathbb{E}_t \left[\frac{\partial f_{it+1}}{\partial K_{it+1}} \right]}_{\text{expected MPK}} + \underbrace{\mathbb{E}_t \left[R \eta_{it+1} \frac{\partial g_{it+1}}{\partial K_{it+1}} \right]}_{\text{future productivity benefits}}$$

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- Steady-state η: marginal value of increased productivity resulting from investment

$$\bar{\eta} = \frac{1}{R-1}\frac{\partial f}{\partial Z},$$

- All of the marginal benefit from investing including future productivity benefits is equated across firms, not just the expected MPK
  - Firms with higher endogenous growth opportunities will be optimally "low MPK" today due to capital accumulation
  - But allocating more capital to them is not misallocation, these investments may contribute to future growth of the economy

Outline

- Related literature
- Motivating empirical facts, mostly about growing low MPK firms in Compustat
  - Rapid growth (jumps), MPK, and investment
  - Characteristics of low MPK–high investment firms
- Implications from a simple investment model with endogenous growth
  - Capital helps enhance the upside potential for some firms
  - Estimation targeting cross-sectional general and new moments
  - MPK dispersion and aggregate productivity
- Aggregate implications
  - Competition, creative destruction, and aggregate TFP

Related literature

1. **Misallocation**
    - Heterogeneous distortions (Hsieh and Klenow, 2009; Restuccia and Rogerson, 2008)
    - Adjustment costs and volatility (Asker, Collard-Wexler, and De Loecker, 2014), information frictions (David, Hopenhayn, and Venkateswaran, 2016), multiple channels (David and Venkateswaran, 2019), excess investor demand (Choi, Kargar, Tian, and Wu, 2023), financial constraints (Midrigan and Xu, 2014; Moll, 2014; Whited and Zhao, 2021; Bau and Matray, 2023), risk premia (David, Schmid, and Zeke, 2022)
    - Eliminating the source of dispersion would improve efficiency in the economy
2. **MPK dispersion does not imply inefficiency**
    - Model misspecification (Haltiwanger, Kulick, and Syverson, 2018)
    - Internal capital markets (Kehrig and Vincent, 2020)
3. **Endogenous firm growth**
    - Innovation can enhance firm productivity and growth (Klette and Kortum, 2004; Acemoğlu, Akçiğit, Alp, Bloom, and Kerr, 2018)

Large jumps in sales and MPK

- We focus on expected large upward moves in sales and MPK
- The discrepancy between current MPK and optimal investment is likely highest for firms ...
  - that have the potential to have rare but large growth spurts
  - and, can invest to increase their chances to jump (e.g., Klette and Kortum, 2004; Acemoglu et al., 2018)

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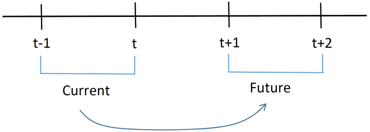

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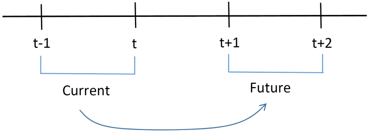

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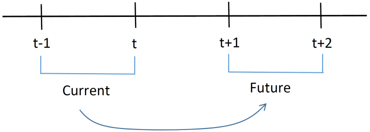
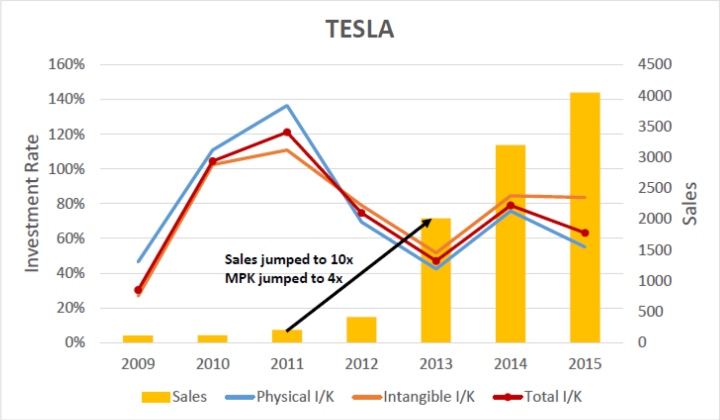


- Adjusted for mergers, overlapping jump periods
- From 1975 to 2021:
  - Unconditional annual jump probability is 1.62%
  - 17% of firms jumped at least once conditional on entering Compustat after 1975 and staying at least 5 years by 2019

Example: Tesla



- Large capital investments while current and next period cash flows are low
- A boom in sales and MPK later
- Tesla arguable invested to increase the chances of a jump

Which firms experience jumps?

- Regressing an indicator for jumps on past firm characteristics: $\mathbb{E}_t[I_{t+1}] = \beta' X_t$

	(1)	(2)	(3)	(4)	(5)
Physical I/K		0.020***	0.020***		
		(11.20)	(12.29)		
Intangible I/K		0.023***	0.031***		
		(7.13)	(9.97)		
Total I/K				0.050***	0.039***
				(15.24)	(11.42)
Log MPK	-0.025***		-0.027***	-0.027***	-0.027***
	(-18.49)		(-21.44)	(-21.15)	(-21.55)
Log age					-0.011***
					(-18.09)
Ind $\times$ Year FE	x	x	x	x	x
R^2	0.043	0.031	0.055	0.053	0.057
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- Total investment captures expected jumps well, we will use that from now on (4)
- We argue that having low MPK is endogenous due to the jump anticipation

Portfolios sorted on I/K and MPK

- Double sorted portfolios by industry-adjusted I/K and MPK
- Off-diagonal firms: which firms grow a lot despite having low current MPK?

	$(I/K_1, MPK_1)$	$(I/K_1, MPK_2)$	$(I/K_2, MPK_1)$	$(I/K_2, MPK_2)$	$(I/K_2, MPK_1)$ Difference	$-$ *All* t $-$stat
N	1428.3	993.8	997.2	1393.9		
Total I/K (median, ind. adj.)	-0.058	-0.048	0.085	0.097		
Log MPK (median, ind. adj.)	-0.40	0.35	-0.36	0.44		
Portfolio share	0.30	0.21	0.21	0.29		
Portfolio share among young firms ($\leq$ 10 years)	0.22	0.14	0.27	0.37		
Age (median)	15.1	16.2	9.20	9.42	-2.96***	-4.65
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- Their share is 27% among younger firms
- They are more likely to experience rapid growth: 4.1% relative to 1.6% annual probability
  - robust to using less (only physical) and more (physical, intangible, inventory, leased) comprehensive capital definitions

Innovative activity by I/K–MPK portfolio

- Any indication that high I/K – low MPK firms are focused on upside potential in their investment policy?

	$(I/K_1, MPK_1)$	$(I/K_1, MPK_2)$	$(I/K_2, MPK_1)$	$(I/K_2, MPK_2)$	$(I/K_2, MPK_1)$ – All Difference	t −stat
Patents/K (mean)	9.24	6.67	**26.5**	17.0	11.9***	5.29
Patent value/K (mean)	24.9	22.8	**90.1**	93.0	32.4**	2.58
Patent Citations/K (mean)	293.9	142.1	**1157.3**	594.5	627.9***	4.04
Top 10% patents/K - 5 yr (mean)	1.17	0.47	**4.40**	2.20	2.40***	3.92
Top 10% patents/K - 10 yr (mean)	1.31	0.48	**4.69**	2.26	2.58***	3.62
Exposure to Life1 stage (median)	0.22	0.19	**0.29**	0.25	0.061***	13.2

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Exposure to Life1 stage (median)	0.22	0.19	**0.29**	0.25	0.061***	13.2

- Higher number and value of patents (Kogan, Papanikolaou, Seru, Stoffman, 2017)

Innovative activity by I/K–MPK portfolio

- Any indication that high I/K – low MPK firms are focused on upside potential in their investment policy?

	$(I/K_1, MPK_1)$	$(I/K_1, MPK_2)$	$(I/K_2, MPK_1)$	$(I/K_2, MPK_2)$	$(I/K_2, MPK_1)$ – All Difference	t –stat
Patents/K (mean)	9.24	6.67	**26.5**	17.0	11.9***	5.29
Patent value/K (mean)	24.9	22.8	**90.1**	93.0	32.4**	2.58
Patent Citations/K (mean)	293.9	142.1	**1157.3**	594.5	627.9***	4.04
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- More exposed to Life1 (product innovation) stage (Hoberg and Maksimovich, 2022)
    - risky since firms need to acquire capacity before knowing the outcome which aligns with the notion of potential jumps

Productivity and returns by portfolio

- Are these simply traditional growth firms low expected returns?

	$(I/K_1, MPK_1)$	$(I/K_1, MPK_2)$	$(I/K_2, MPK_1)$	$(I/K_2, MPK_2)$	$(I/K_2, MPK_1)$	–All
Log TFP (median, ind. adj.)	-0.056	-0.033	0.020	0.074	0.020***	4.09
Log TFP (90th pctile, ind. adj.)	0.36	0.34	0.50	0.59	0.048**	2.33
Log future TFP (5yr later, median, ind. adj.)	-0.021	-0.019	**0.012**	0.010	0.015***	3.09
Log future TFP (5yr later, 90th pctile, ind. adj.)	0.41	0.35	**0.55**	0.50	0.10***	4.53
Excess future stock returns (VW mean, annual, %)	8.46	8.88	9.66	9.86	0.76	0.19
Total q (median)	0.43	0.44	0.86	0.87	0.27***	4.97
SA index (median)	-0.12	-0.26	0.21	0.14	0.21***	11.8
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  - They could potentially invest even more if financial constraints were lifted
- Q differentiates between I/K but not within I/K groups consistent with simple model

Summary of empirical evidence

Low MPK–high investment firms relative to their industry peers ...

- are more likely to experience rapid sales and MPK growth (jumps)
- are more intensively engaged in innovative activity
- are more likely to move up in the TFP distribution and go to its right tail
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We next embed

- the possibility of large positive shocks to productivity, and
- their endogenous probability

into some firms' ("high-type" firms) otherwise standard investment problem and confront the model with the data.

Time series I/K, MPK, jump prob.

Model

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  - Poisson productivity "jump" shocks, $z_{i,t+1} = z_{i,t} + \epsilon_{i,t+1} + J_{i,t+1}$
  - $\mathbb{E}_t[J_{i,t+1}] = \lambda_{i,t}\zeta$ with > 0
  - Conditional jump probability increases with capital, $\lambda_{i,t} = \lambda_0 \left(\frac{k_{i,t}}{k^{ss}}\right)^{\iota}$
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- Constant destruction/exit rate φ, replaced by a new firm

Firm problems

Low-type:

$$V^l(K_{i,t}, Z_{i,t}) = \max_{I_{i,t}} \left(Z_{i,t}^{\alpha} K_{i,t}^{1-\alpha} - I_{i,t} - \frac{1}{2} c \left(\frac{I_{i,t}}{K_{i,t}} - \delta \right)^2 K_{i,t} \right) + \frac{1}{R}(1-\varphi)\mathbb{E}_t \left[V^l(K_{i,t+1}, Z_{i,t+1}) \right]$$

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High-type:

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Data and estimation

- Compustat data, 1975–2021
- Annual frequency
- 3 parameters *calibrated*
  - Depreciation rate, discount factor, production function curvature
- 7 parameters *estimated* targeting 11 moments using SMM
  - Adjustment cost parameter, all parameters of the productivity processes, firm type and switching probabilities

Target moments

	Data	Baseline
Panel A: General moments		
IQR of I/K among young firms	0.252	0.233
IQR of I/K among mature firms	0.094	0.128
Nonnegative investment share	0.988	0.831
IQR of sales growth	0.243	0.211
Panel B: Moments related to jump realizations		
Median sales jump size	2.970	2.832
Median log MPK jump size	0.720	0.784
Median jump age	6.000	6.000
Panel C: Moments for the $(I/K_2, MPK_1)$ **portfolio**		
Portfolio share	0.210	0.201
Jump probability	0.041	0.047
I/K (ind. adj.)	0.085	0.084
Portfolio share among young firms	0.270	0.320

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- Jumps and portfolios measured the same way in the model and data
- Young I/K dispersion helps discipline jump parameters
- Jump age regulates switching probability and the level of jump probability
- High-type moments discipline jump-related parameters as well

Parameter estimates

Panel A: Calibrated parameters	
Capital depreciation rate, δ	0.15
Discount rate, $1/R$	0.91
Production function curvature, α	0.35
Exit probability, φ	0.031
Panel B: Estimated parameters	
Gaussian shock volatility, σ	0.377
	(0.044)
Adjustment cost parameter, c	3.019
	(0.634)
Jump probability level, λ_0	0.025
	(0.011)
Jump probability curvature, ι	0.439
	(0.156)
Jump size, ζ	2.750
	(0.286)
Type switching probability, μ	0.104
	(0.041)
Probability of being born high-type, p	0.947
	(0.237)

- Moments identify the parameters well and support endogenous growth

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- Moments identify the parameters well and support endogenous growth
- Now we can use model "counterfactuals" to inspect the mechanism.

Inspecting the mechanism

Two experiments:

- Do we really need jump shocks? What can a standard model (without firm heterogeneity and jumps) match in the data?
- Could the "jumps" in the data be large realizations of a volatile normal shock?
  - Re-estimate the model with only two parameters: σ and c
  - No-jump model
- Estimation increases σ to match cross-sectional dispersions and there are very low number of observed jumps
- I/K and MPK are perfectly aligned, no off-diagonal firms No jump model

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- What if the true model had jumps, but high-type firms could not take the jump possibility into account when they made investment decisions?
  - i.e., they would not "invest in misallocation" and ignore endogenous growth?
  - Use the parameters from baseline case, but all firms act like low-type firms, some receive "accidental" jump shocks
  - Counterfactual case

Counterfactual model: no "investing in misallocation"

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Panel C: Moments for the $(I/K_2, MPK_1)$ portfolio			
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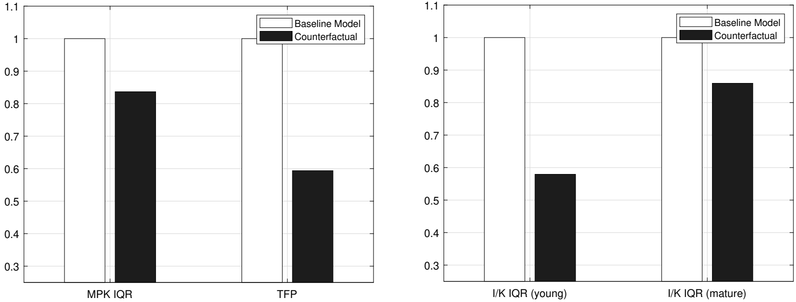
- There are no off-diagonal firms, I/K and MPK perfectly aligned
- Firms accumulate capital only for immediate rewards

Predicting jumps in the model

Dispersion and misallocation

What happens to MPK dispersion if firms ignore the possibility of jumps?



- MPK and investment dispersions go down

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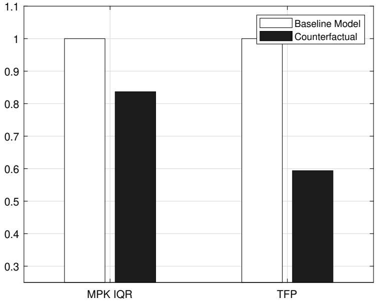

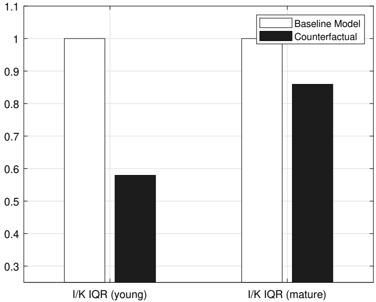

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Dispersion and misallocation

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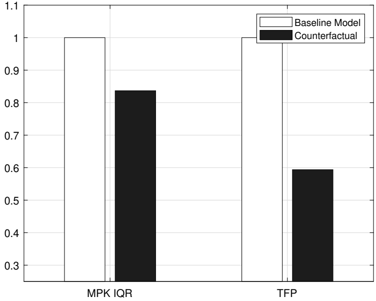

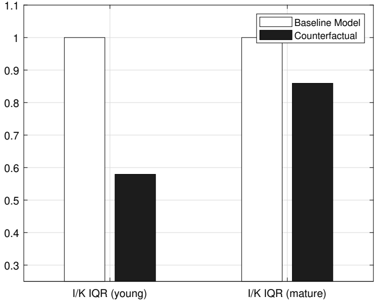

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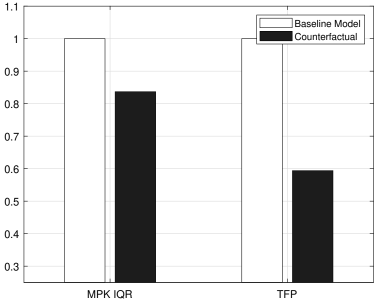

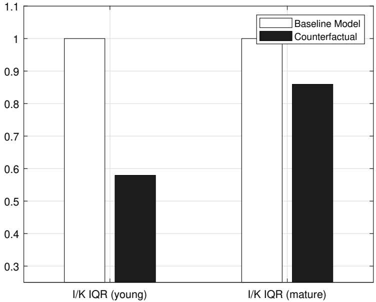

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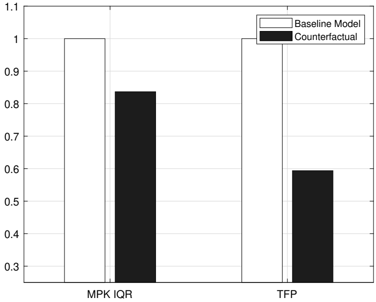

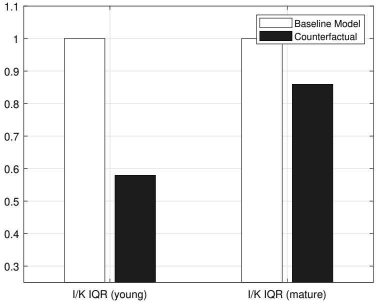

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- Reducing MPK dispersion not a desirable policy goal enhancing aggregate efficiency from the perspective of our model

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- Overall, the evidence suggests that "investing in misallocation" by high type firms has negative effects in the cross-section but positive aggregate net effects

Discussion

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  - But what if the truly constrained firms have low MPK rather than high?
  - Allocation based on MPK alone would lead to wrong conclusions for efficiency
- An empirical challenge to measure what should be equated across firms taking endogenous growth into account, it is not MPK dispersion

Conclusion

- MPK dispersion $\neq$ misallocation
- Part of MPK dispersion driven by endogenous growth can be good for aggregate efficiency
- Simple model with non-Gaussian jumps can *quantitatively* capture important features of data
- Endogenous growth generates “off-diagonal” firms in the investment-MPK matrix

Optimality condition

- The optimality condition is

$$\frac{1}{R}\mathbb{E}_t\left[\frac{\partial f_{it+1}}{\partial K_{it+1}} + 1 - \delta\right] = 1.$$

- Marginal cost of capital is 1. Marginal benefit is next period's MPK plus the undepreciated capital.

Factor exposures: Fama and French (2015) Back

	$(I/K_1, MPK_1)$	$(I/K_1, MPK_2)$	$(I/K_2, MPK_1)$	$(I/K_2, MPK_2)$
MKTRF	0.979***	0.983***	1.018***	1.060***
	(87.23)	(66.57)	(57.56)	(86.94)
SMB	0.005	0.010	0.047*	0.105***
	(0.31)	(0.42)	(1.72)	(5.55)
HML	-0.045**	-0.085***	-0.299***	-0.205***
	(-2.21)	(-3.15)	(-9.28)	(-9.25)
RMW	0.143***	0.201***	-0.396***	0.032
	(6.34)	(6.76)	(-11.15)	(1.32)
CMA	0.298***	0.136***	-0.041	-0.181***
	(9.11)	(3.17)	(-0.80)	(-5.11)
α	-0.114**	-0.061	0.230***	0.079
	(-2.42)	(-0.99)	(3.10)	(1.54)

- Fama-French factors do not price these portfolios well
- $(I/K_2, MPK_1)$'s average return is too high despite significant factor exposures

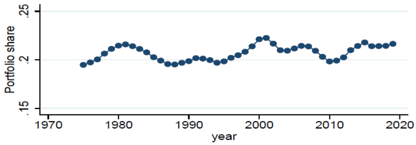
Factor exposures: q^5 factors

Back

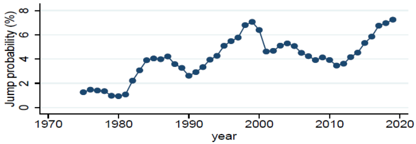
	$(I/K_1, MPK_1)$	$(I/K_1, MPK_2)$	$(I/K_2, MPK_1)$	$(I/K_2, MPK_2)$
r_{Mkt}	0.962***	0.969***	1.039***	1.074***
	(77.53)	(63.68)	(51.13)	(76.62)
r_{Me}	-0.023	-0.035	0.076***	0.079***
	(-1.30)	(-1.61)	(2.65)	(3.98)
$r_{I/A}$	0.201***	0.041	-0.465***	-0.394***
	(7.56)	(1.25)	(-10.67)	(-13.10)
r_{Roe}	0.002	0.198***	-0.381***	-0.005
	(0.10)	(7.20)	(-10.34)	(-0.20)
r_{Eg}	0.042	-0.113***	0.218***	0.045
	(1.33)	(-2.95)	(4.28)	(1.29)
α	-0.079	0.008	0.174*	0.078
	(-1.45)	(0.12)	(1.93)	(1.26)

- Hou, Mo, Xue, Zhang (2021) 5-factor model motivated by the investment model prices portfolios better
  - Current high investment predicts low returns/discounts
  - Current high expected investment (controlling for expected profitability and current investment) predicts high expected returns/discounts
- $(I/K_2, MPK_1)$'s return is exposed to the expected growth factor

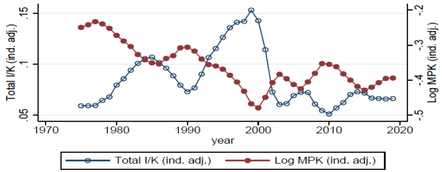
Time series relations Back



(a) Share of Compustat firms placed in $(I/K_2, MPK_1)$ portfolio



(b) Annual jump probability of firms in $(I/K_2, MPK_1)$ portfolio



(c) Median I/K and MPK of firms in $(I/K_2, MPK_1)$ portfolio

- Stable portfolio share and comovement between I/K, MPK, and jump probability

Effect on competitors

Back

	(1) log $\frac{Sale_{t+5}}{Sale_t}$	(2) log $\frac{K_{t+5}}{K_t}$	(3) log $\frac{Profit_{t+5}}{Profit_t}$	(4) log TFP_{t+5}
I/K_{firm}	0.408***	0.627***	0.361***	0.060***
	(10.44)	(14.02)	(7.21)	(4.06)
$I/K_{comp\ \in\ (I/K_1, MPK_1)}$	-0.285	1.312	0.097	0.083
	(-0.33)	(1.44)	(0.09)	(0.46)
$I/K_{comp\ \in\ (I/K_1, MPK_2)}$	0.553*	1.447***	0.230	0.373***
	(1.98)	(5.97)	(0.75)	(3.57)
$I/K_{comp\ \in\ (I/K_2, MPK_1)}$	-0.330**	-0.401***	-0.301**	-0.054***
	(-2.43)	(-3.40)	(-2.21)	(-3.99)
$I/K_{comp\ \in\ (I/K_2, MPK_2)}$	0.408	0.413	0.338	0.086
	(1.65)	(1.58)	(1.22)	(1.24)
Firm FE	x	x	x	x
R^2	0.016	0.092	0.011	0.004
N	134,860	134,860	126,492	90,533

Predicting TFP growth

Back

	(1)	(2)	(3)	(4)	(5)
Panel A: Business sector TFP (5 yr growth)					
$I/K_{(I/K_1, MPK_1)}$	-0.013				
	(-0.07)				
$I/K_{(I/K_1, MPK_2)}$		0.091			
		(0.58)			
$I/K_{(I/K_2, MPK_1)}$			0.091***		0.128***
			(8.95)		(4.28)
$I/K_{(I/K_2, MPK_2)}$				0.092***	-0.047
				(5.08)	(-0.96)
Panel B: Utilization-adjusted TFP (5 yr growth)					
$I/K_{(I/K_1, MPK_1)}$	0.151				
	(0.63)				
$I/K_{(I/K_1, MPK_2)}$		0.263			
		(1.18)			
$I/K_{(I/K_2, MPK_1)}$			0.116***		0.141***
			(7.21)		(3.36)
$I/K_{(I/K_2, MPK_2)}$				0.124***	-0.032
				(5.26)	(-0.54)

Predicting jumps in the model

Back

	Data	Baseline	Counterfactual	Targeting A	Targeting A & B
Total I/K	0.050	0.113	0.017	0.006	0.005
		[0.088; 0.141]	[-0.040; 0.095]	[0.000; 0.038]	[0.000; 0.033]
Log MPK	-0.027	-0.052	-0.003	-0.001	-0.002
		[-0.066; -0.039]	[-0.027; 0.017]	[-0.006; 0.000]	[-0.005; 0.000]

No jump model

Back

	Data	Targeting Panel A	Targeting Panel A & B
Panel A: General moments			
IQR of I/K among young firms	0.252	0.109	0.113
IQR of I/K among mature firms	0.092	0.109	0.113
Nonnegative investment share	0.988	0.592	0.592
IQR of sales growth	0.243	0.246	0.246
Panel B: Moments related to jump realizations			
Median sales jump size	2.970	2.090	2.089
Median log MPK jump size	0.720	0.433	0.432
Median jump age	6.000	9.000	11.000
Jump probability (in %)	1.620	0.005	0.006
Panel C: Moments for the $(I/K_2, MPK_1)$ portfolio			
Portfolio share	0.210	0.000	0.000
Jump probability	0.041	0.000	0.000
I/K (ind. adj.)	0.085	0.000	0.000
Portfolio share among young firms	0.270	0.000	0.000

- Estimation increases σ to match cross-sectional dispersions and there are very low number of observed jumps
- I/K and MPK are perfectly aligned, no off-diagonal firms

Unpacking MPK dispersion Back

	Data	Baseline	Counterfactual	No Jump Targeting A	No Jump Targeting A & B
$(I/K_1, MPK_1)$	-0.40	-0.28	-0.22	-0.33	-0.32
$(I/K_1, MPK_2)$	0.35	0.15	n/a	n/a	n/a
Difference	0.75	0.43	n/a	n/a	n/a
$(I/K_2, MPK_1)$	-0.36	-0.27	n/a	n/a	n/a
$(I/K_2, MPK_2)$	0.44	0.40	0.23	0.31	0.30
Difference	0.80	0.67	n/a	n/a	n/a

- Baseline model generates more than half of the MPK dispersion observed in the data
- Reduction in MPK dispersion in the counterfactual is primarily due to the elimination of the firms in off-diagonal portfolios
- Substantial MPK dispersion in the no-jump model (due to large Gaussian shocks) but cannot capture the off-diagonal firms