

WINNERS AND LOSERS: CREATIVE DESTRUCTION AND THE STOCK MARKET

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INTRODUCTION

- Technological innovation is an important source of economic growth
- Technological progress often leads to displacement
 - ▶ Schumpeter (1942) and creative destruction
- Importantly, benefits and costs are asymmetrically distributed
 - ▶ entrepreneurs versus owners of existing capital
 - ▶ “growth” versus “value” firms

Our focus:

- ① How is uncertainty about technological progress priced by financial markets?
- ② What determines cross-sectional differences in exposures to innovation risk?
- ③ Are the predictions consistent with stylized facts about asset returns?

TWO TYPES OF TECHNOLOGICAL PROGRESS

- Shocks to labor productivity (disembodied)
 - ▶ Berndt (1990) “disembodied technical progress refers to advances in knowledge that make more effective use of all inputs, including capital of each surviving vintage (not just the most recent vintage). . . . The most common example of disembodied technical progress is perhaps the notion of learning curves, in which it has been found that for a wide variety of production processes and products, as cumulative experience and production increase, learning occurs which results in ever decreasing unit costs.”
- Capital-embodied shocks
 - ▶ Solow (1960) “. . . many, if not most, innovations need to be embodied in new kinds of durable equipment before they can be made effective. Improvements in technology affect output only to the extent that they are carried into practice either by net capital formation or by the replacement of old-fashioned equipment by the latest models.”

AN EXAMPLE OF EMBODIED TECHNICAL CHANGE



- Cost in 2010 dollars
 - ▶ **\$ 5,000**; state-of-the-art IBM server, today:
 - ▶ **\$ 5,100,000**; Burroughs 205, in 1960:
 - ▶ **\$ 160,833,333**; computer with same CPU power as IBM server, in 1960 (using NIPA quality-adjusted price index for computers)

EXAMPLE: RAILROADS

- **Railroads displaced water transportation:** *“The early opinion that railroads could not compete with waterways gave ground before practical proofs to the contrary. . . during the last few years of rapid progress in railroad building no new canals were planned, and those which existed near railroads had decreased in their receipts from 33 to 66 percent.”* Balthasar H. Meyer, 1917, *Transportation in the United States before 1860*, Ch. 17 p. 553
- **Automobiles displaced railroads:** *“The triumph of the private passenger car over rail transportation in the United States was meteoric. Passenger miles traveled by automobile were only 25 percent of rail passenger miles in 1922 but were twice as great as rail passenger miles by 1925, four times as great by 1929.”* James J. Flink, 1990, *The Automobile Age*, Ch. 19 p. 360
- In 1900, railroads account for over 50% of market cap of all NYSE firms.
- Between 1927 and 1975 railroads go from 23% to 2% of NYSE market cap.

INNOVATION CAN LOWER THE VALUE OF OLD CAPITAL

“Any expectation that the medallion would function as a shield against the rapid technological advances of the modern world would not have been reasonable. . . In this day and age, even with public utilities, investors must always be wary of new forms of competition arising from technological developments.” (Queens Supreme Court Justice Allan Weiss, Sep 2015)

- Uber, a privately held firm founded in 2009, takes advantage of advances in communication technology to provide taxi services with minimal waiting time. As of December 2014, Uber is valued at \$41 billion.
- Between December 2009 and February 2015, the value of Medallion Financial Corp. (NASDAQ: TAXI), a specialty finance company that originates, acquires, and services loans that finance taxicab medallions has dropped by more than 50% in value relative to the level of the NASDAQ index.
- Uber has been the target of multiple lawsuits by taxi companies.

CROSS-SECTIONAL ASSET PRICING

- Empirical asset pricing literature has established that firms that have the characteristic of “growth” firms,
 - ① have lower average returns than “value” firms, and
 - ② comove with other “growth” firms(Fama and French (1992, 1993, 1995); and many, many others...)
- Fact is robust across different definitions of “growth”, e.g. market-to-book, high investment, high hiring, high P/E, high idiosyncratic volatility, etc
- In response, we have a plethora of reduced form factor models that include a value or investment factor. **But no (full GE) theory!**
- Want to propose an economic mechanism for return comovement and heterogeneity in risk premia.

THIS PAPER

- Technological innovation benefits growth firms at the expense of value firms
- Gains from new technology are asymmetrically distributed
 - ▶ Entrepreneurship requires ideas
 - ▶ Ideas are embodied in people
 - ▶ Cannot contract ex-ante to share gains from new ideas
- Part of the benefits go to Entrepreneurs/Innovators
- Firm owners capture some benefits but bear full cost of creative destruction
- Invest in growth stocks – despite low equilibrium returns – as a hedge

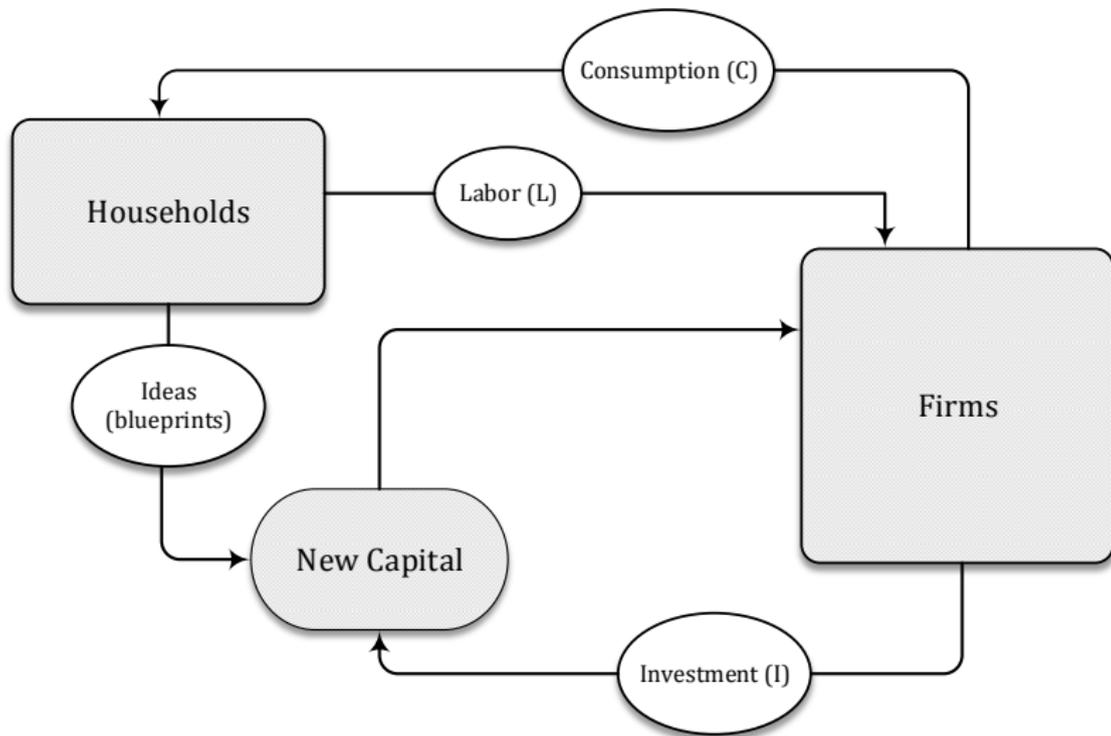
CLOSELY RELATED WORK

- Equilibrium pricing models with production
 - ▶ (Jermann, 1998; Tallarini 2000; Boldrin, Christiano, and Fisher, 2001; Kogan 2001, 2004; Gomes, Kogan and Zhang, 2003; Kaltenbrunner and Lochstoer, 2010; Campanale, Castro and Clementi, 2010; Kung and Schmid, 2011; Gourio 2011); Ai, Croce, and Li (2013) ; Croce (2014)
- Consumption-based asset pricing, limited risk sharing
 - ▶ (Mankiew and Zeldes, 1991; Constantinides and Duffie, 1996; Heaton and Lucas, 1996, 2000; Malloy, Moskowitz, and Vissing-Jorgensen, 2009; Constantinides and Ghosh, 2014)
- Technology shocks and asset prices
 - ▶ (Hobijn and Jovanovic, 2001; Laitner and Stolyarov, 2003; Pastor and Veronesi, 2009; Jovanovic, 2009; Papanikolaou, 2011; Kogan and Papanikolaou, 2013,2014)
- Limited risk sharing and models with production
 - ▶ (Demarzo, Kaniel and Kremer, 2007; Garleanu, Kogan and Panageas, 2012)

OUTLINE

- 1 THE MODEL
- 2 MODEL MECHANISM
- 3 ESTIMATION
- 4 ADDITIONAL IMPLICATIONS
- 5 DIRECT EVIDENCE

THE MODEL



PRODUCTION

- Each production unit j (project) produces output flow

$$y_{j,t} = \left(u_{j,t} e^{\xi_{\tau(j)}} k_{j,t} \right)^{\phi} \left(e^{x_t} L_{j,t} \right)^{1-\phi},$$

- Shock to labor productivity:

$$dx_t = \mu_x dt + \sigma dB_{x,t}$$

Labor and capital are complements, so x raises productivity of **all** capital

- Level of technology frontier ξ at the time of creation

$$d\xi_t = \mu_{\xi} dt + \sigma_{\xi} dB_t^{\xi}$$

Embodied shock ξ only affects productivity of **new** capital

- Idiosyncratic productivity u_{jt} ; new projects start at $u = 1$, evolve according to:

$$du_{jt} = \kappa_u (1 - u_{jt}) dt + \sigma_u u_{jt} dB_{jt}^u$$

PRODUCTION (CONTINUED)

- Each production unit j (project) produces output flow

$$y_{j,t} = \left(u_{j,t} e^{\xi \tau(j)} k_{j,t} \right)^\phi \left(e^{x_t} L_{j,t} \right)^{1-\phi},$$

- Investment is irreversible

- ▶ Scale k_j chosen at the time of creation subject to convex investment costs:

$$k_{j,t} = I_{j,t}^\alpha, \quad \alpha \in (0, 1)$$

- ▶ Installed projects depreciate at rate δ

$$dk_{jt} = -\delta k_{jt} dt$$

- Final good can be used for consumption or investment

$$Y_t \equiv \int_{\mathcal{J}_t} y_{j,t} dj = I_t + C_t$$

HOUSEHOLDS

Households have recursive (EZ) preferences

$$J_t = E_t \left[\int_t^\infty \phi(C_s, J_s; \bar{C}_s) ds \right],$$

where ϕ is the aggregator function:

$$\phi(C, J; \bar{C}) = \frac{\rho}{1-\theta^{-1}} \left(\frac{\left(C^{1-h} \left(C/\bar{C} \right)^h \right)^{1-\theta^{-1}}}{((1-\gamma)J)^{\frac{\gamma-\theta^{-1}}{1-\gamma}}} - (1-\gamma)J \right).$$

and

$$\bar{C}_t \equiv \int_0^1 C_{it} di$$

- degree of preference over relative consumption captured by h
- “risk aversion” γ
- “elasticity of inter-temporal substitution” θ

HOUSEHOLDS

- Unit measure of households work in production, inelastically supplying labor.
 - ▶ Can trade future labor income (from production) without any frictions
 - ▶ Households are born and die at rate δ^h
 - ★ Standard treatment of mortality risk, e.g., annuity markets.
- **Incomplete markets:**
 - ▶ Any household can receive a measure of new ideas, flow probability $\mu_I dt$
 - ▶ Households with ideas sell blueprint to an existing firm, capturing a share η of NPV
 - ▶ Invest the proceeds in financial markets along with the rest of their wealth
 - ▶ Assumption: innovators receive measure of ideas in proportion to their wealth.
- Interpretation:
 - ▶ Entrepreneurs create startups: sell them to existing firms or do an IPO
 - ▶ Researchers create new products and appropriate part of the proceeds
 - ▶ Executives identify investment opportunities and receive a fraction of the surplus

FIRMS

- Each firm f operates a finite portfolio of projects \mathcal{I}_{ft}
 - ▶ New project ideas (blueprints) originate with innovators.
- Firm matched to innovators at rate λ_{ft} – acquires project blueprints
 - ▶ $\lambda_{ft} \in (\lambda_L, \lambda_H)$ evolves as a 2-state Markov chain
- Once a blueprint is acquired, firm implements project by choosing scale k_j (e.g. number of machines) to maximize NPV

$$k_t^* = \arg \max_k \left\{ v_t \equiv P_t e^{\xi_t} k - k^{\frac{1}{\alpha}} \right\}$$

- Static decision: firm does not control future investment opportunities – ‘Q’-theory at the project level.

COMPETITIVE EQUILIBRIUM

- Equilibrium:
 - ▶ Firms and households optimize
 - ▶ Markets clear and all resource constraints are satisfied
- X-sectional distribution of household wealth and firm size irrelevant for prices:
 - ▶ Financial market participants make identical portfolio decisions
 - ★ Existing households differ only in their level of wealth
 - ★ Returns to innovation proportional to wealth preserves homotheticity
 - ▶ Firm investment decisions are independent with past decisions
 - ★ Investment problem becomes static – current size of the firm irrelevant

ECONOMY HAS 'LONG-RUN RISK'

- Aggregate output has a permanent and transitory component

$$Y_t = e^{\chi_t} e^{-\phi \omega_t}.$$

- Aggregate state can be described by a two-dimensional Markov process

$$\chi_t = \frac{1-\phi}{1-\alpha\phi} x_t + \frac{\phi}{1-\alpha\phi} \xi_t \quad (\text{Stochastic trend})$$

$$\omega_t = \xi_t + \alpha \chi_t - \log K_t, \quad (\text{Mean-reverting component})$$

where K is the aggregate quality-adjusted capital stock,

$$K_t \equiv \int_{J_t} e^{\xi_{s(j)}} k_{j,t} dj.$$

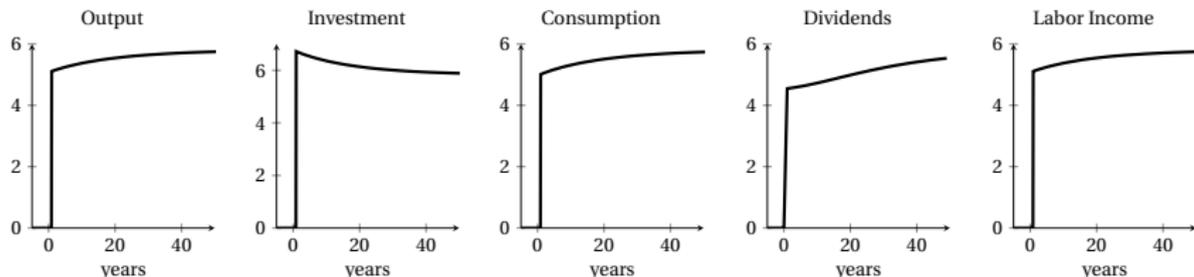
- Mean reverting component captures the current 'growth state' of the economy

OUTLINE

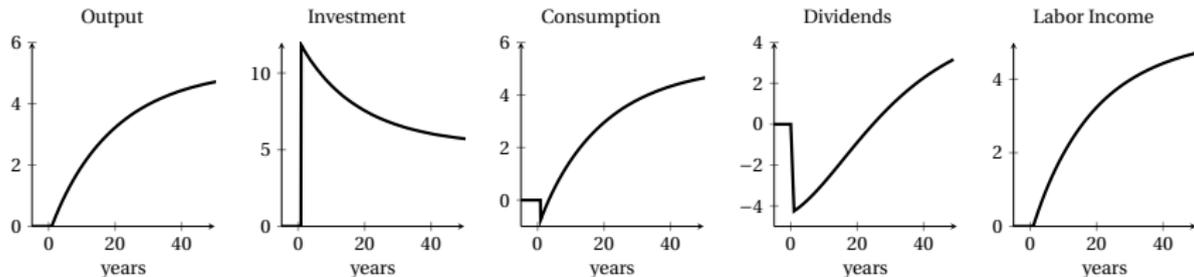
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RESPONSE TO TECHNOLOGY: AGGREGATE QUANTITIES

Response to x : disembodied shock (complementary to existing capital)

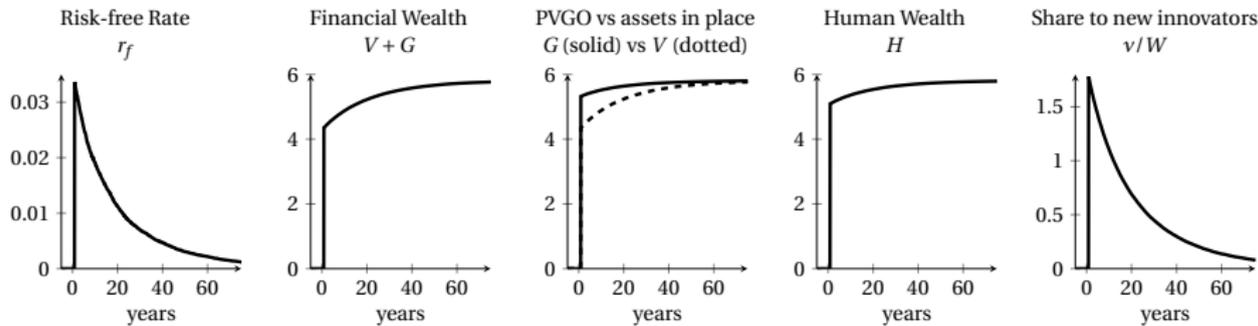


Response to ξ : embodied shock (substitute to existing capital)

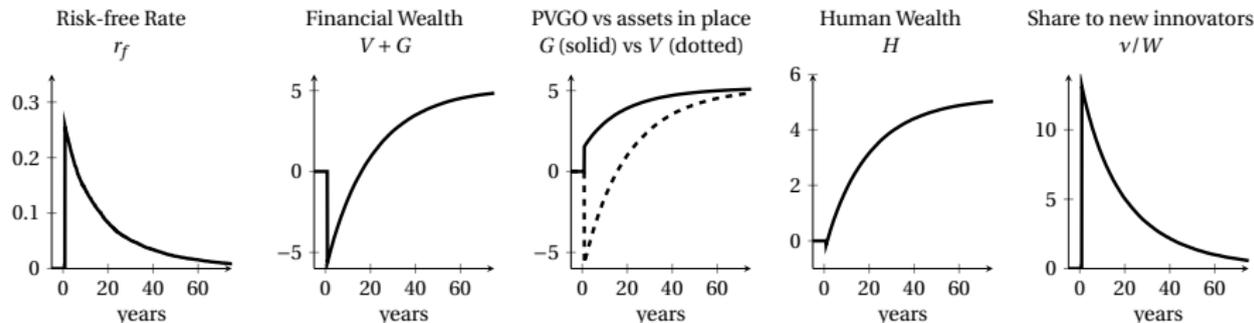


TECHNOLOGICAL SHOCKS AND ASSET PRICES

Response to x : disembodied shock (complementary to existing capital)



Response to ξ : embodied shock (substitute to existing capital)



CONSUMPTION DYNAMICS: INDIVIDUAL HOUSEHOLDS

- Households innovate randomly, consumption (wealth) shares fluctuate

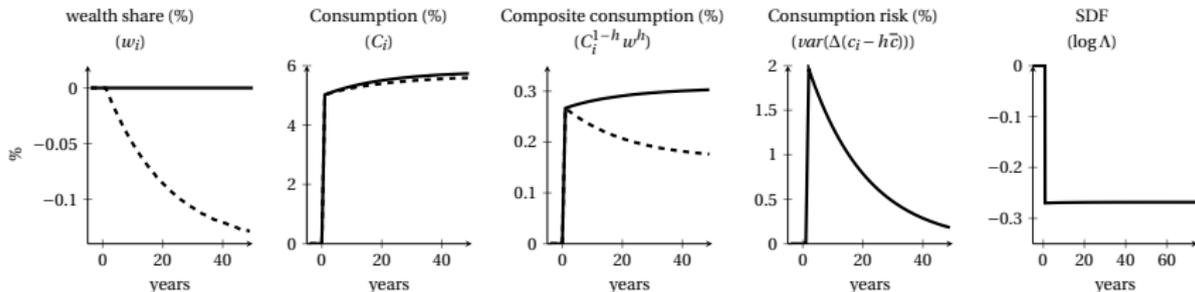
$$C_{n,t} = C_t w_{n,t}$$

$$\frac{dw_{n,t}}{w_{n,t}} = \delta^h dt + \frac{\lambda}{\mu_I} \frac{\eta v_t}{W_t} (dN_{it}^I - \mu_I dt)$$

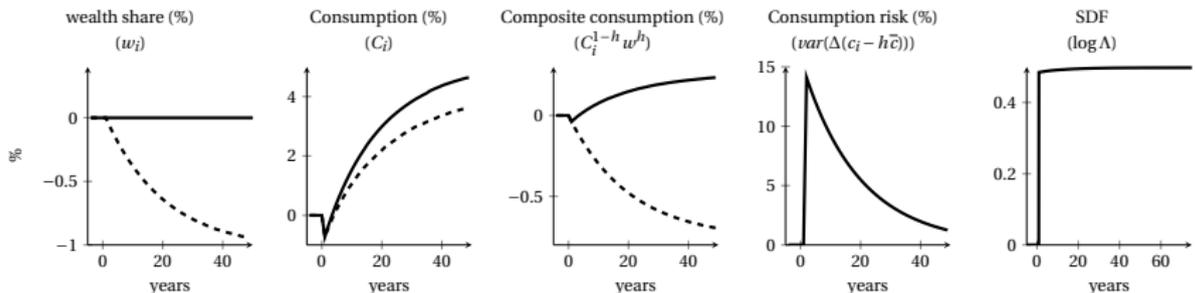
- NPV of new projects v_t relative to total wealth W_t determines dynamics of wealth shares
- Volatility of individual consumption growth endogenous function of current state

TECHNOLOGICAL PROGRESS AND INDIVIDUAL CONSUMPTION

Response to x : disembodied shock

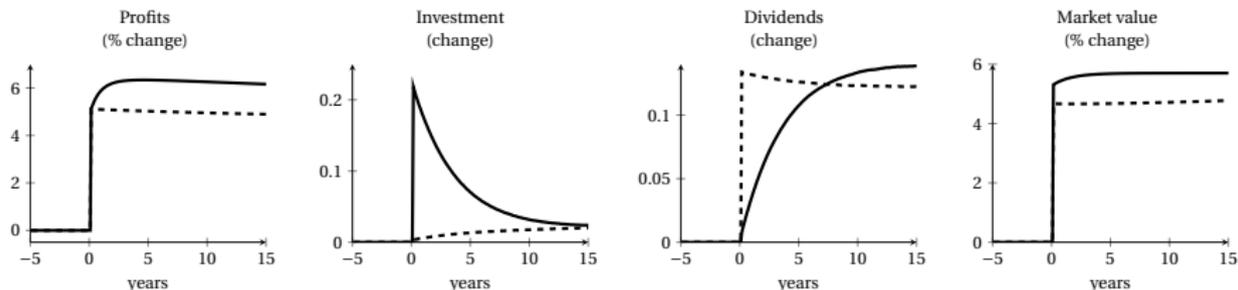


Response to ξ : embodied shock

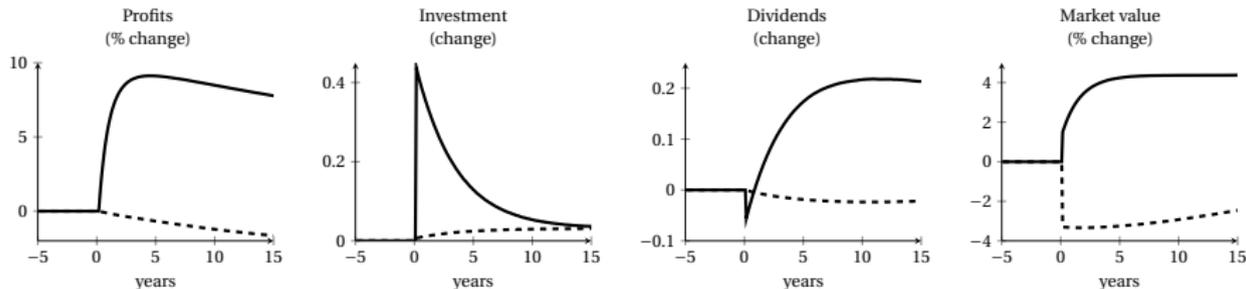


TECHNOLOGY SHOCKS AND FIRMS

Response to x : disembodied shock



Response to ξ : embodied shock



TECHNOLOGY AND THE CROSS-SECTION OF ASSET RETURNS

- A positive (complementary) technology shock x leads to a large positive level effect; returns of growth firms respond more than value firms
- A positive (displacive) technology shock ξ benefits growth firms and harms value firms.
- Households accept low equilibrium returns in holding growth firms to hedge increase in consumption inequality.
- How do value/growth firms in the model map to the data?
 - ▶ Most straightforward: In the model, Tobin's Q (approximately) summarizes firm risk exposures to x and ξ .
 - ▶ More generally, growth firms in the model invest more and have higher P/E ratios. Can add additional wrinkles so that they have higher idiosyncratic volatility, issue equity etc...

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LIMITED MARKET PARTICIPATION

- In this model, labor income increases with both types of technology
 - ▶ No 'vintage' effects in human capital \implies labor income is a hedge against ξ
 - ▶ This feature is clearly unrealistic
- Limit usefulness of labor income as a hedge by introducing limited participation
 - ▶ Households assigned to two types (participant vs non-participant) upon birth
 - ▶ Both types can acquire new ideas
 - ▶ End result is labor income accounts for smaller fraction of total wealth for financial market participants
- Would make sense to model some displacement in human capital – future extensions

ESTIMATING THE MODEL

- A few parameters can be calibrated individually
 - ▶ Probability of death δ^h to get average working life of 40 years.
 - ▶ Probability of innovation $\mu_I = 0.13\%$ to approx. match income share of top 1%.
 - ▶ Leverage of 2.5 – halfway between Bansal-Yaron (3.0) and Rauh-Sufi (2.0)
- Estimate remaining parameters through indirect inference:
 - ▶ Construct a measure of distance D between the model and the data

$$D(\theta) = (\hat{g} - g(\theta)) W^{-1} (\hat{g} - g(\theta))$$

- ▶ Choose parameters θ to minimize $D(\theta)$
- ▶ Construct $g(\theta)$ by simulating model 100 times (fix seed)
- ▶ Choose $W = \text{diag}(\hat{g}\hat{g}')$ to eliminate scale effects
- ▶ Use RBF algorithm in Björkman and Holmström (2000) to find minimum

MODEL FIT

Moment	DATA	Mean	p5	p95
Consumption growth, mean	0.015	0.014	0.004	0.025
Consumption growth, volatility (short-run)	0.036	0.039	0.035	0.043
Consumption growth, volatility (long-run)	0.041	0.053	0.037	0.072
Shareholder consumption share, mean	0.429	0.466	0.433	0.488
Shareholder consumption growth, volatility	0.037	0.039	0.028	0.050
Investment-to-output ratio, mean	0.089	0.080	0.049	0.114
Investment-to-output ratio (log), volatility	0.305	0.274	0.159	0.459
Investment growth, volatility	0.130	0.106	0.090	0.123
Investment and consumption growth, correlation	0.472	0.356	0.196	0.516
Aggregate Innovation, volatility	0.370	0.343	0.217	0.541
Market portfolio, excess returns, mean	0.063	0.061	0.047	0.077
Market portfolio, excess returns, volatility	0.185	0.128	0.117	0.142
Risk-free rate, mean	0.020	0.024	0.019	0.030
Risk-free rate, volatility	0.007	0.007	0.003	0.013
Value factor, mean	0.065	0.069	0.030	0.101
Value factor, volatility	0.243	0.143	0.102	0.229
Value factor, CAPM alpha	0.040	0.058	0.021	0.092
Investment rate, IQR	0.175	0.169	0.130	0.203
Investment rate, persistence	0.223	0.278	0.074	0.447
Tobin Q, IQR	1.139	0.838	0.655	1.073
Tobin Q, persistence	0.889	0.948	0.931	0.962
Tobin Q and investment rate, correlation	0.237	0.167	0.131	0.237
Firm innovation, 90-50 range	0.581	0.610	0.543	0.664
Firm innovation, persistence	0.551	0.585	0.524	0.636
Profitability, IQR	0.902	0.958	0.871	1.176
Profitability, persistence	0.818	0.807	0.784	0.820

PARAMETERS

Parameter	Symbol	Estimate	SE
<i>Preferences</i>			
Risk aversion	γ	56.734	41.163
Elasticity of intertemporal substitution	θ	2.341	2.867
Effective discount rate	ρ	0.044	0.015
Preference weight on relative consumption	h	0.836	0.067
<i>Technology</i>			
Disembodied technology growth, mean	μ_x	0.016	0.011
Disembodied technology growth, volatility	σ_x	0.082	0.010
Embodied technology growth, mean	μ_ξ	0.004	0.018
Embodied technology growth, volatility	σ_ξ	0.110	0.025
Project-specific productivity, volatility	σ_u	0.533	0.065
Project-specific productivity, mean reversion	κ_u	0.210	0.023
<i>Production and Investment</i>			
Cobb-Douglas capital share	ϕ	0.427	0.023
Decreasing returns to investment	α	0.446	0.096
Depreciation rate	δ	0.029	0.011
Transition rate to low-growth state	μ_L	0.364	0.098
Transition rate to high-growth state	μ_H	0.021	0.006
Project mean arrival rate, mean	λ	0.812	0.273
Project mean arrival rate, rel. difference high-low growth states	λ_D	15.674	3.303
<i>Incomplete Markets</i>			
Fraction of project NPV that goes to inventors	η	0.767	0.391
Fraction of households that is a shareholder	ψ	0.148	0.060

MODEL FIT: SUMMARY

- Model at least as successful as existing GE models in generating:
 - ▶ Smooth consumption paths with moderate low-frequency fluctuations
 - ▶ Volatile market returns, high equity premium and low risk-free rate
- Cross-sectional patterns in returns:
 - ▶ Value premium
- Next: Examine additional model implications for **non-targeted** moments

SENSITIVITY TO MODEL ASSUMPTIONS

Parameter	Symbol	BASE	FullPart	Restrict η		
			$\psi = 1$	$\eta = 0$	$\eta \leq 0.3$	$\eta \leq 0.6$
Risk aversion	γ	56.73	104.57	92.80	83.35	72.49
Elasticity of intertemporal substitution	θ	2.34	2.30	2.15	1.96	1.87
Fraction of population that is a shareholder	ψ	0.15	-	0.05	0.06	0.13
Preference weight on relative consumption	h	0.84	0.93	0.92	0.89	0.85
Fraction of project NPV that goes to inventors	η	0.77	0.81	0.00	0.30	0.60
Disembodied technology growth, volatility	σ_x	0.08	0.08	0.08	0.08	0.08
Embodied technology growth, volatility	σ_ξ	0.11	0.12	0.11	0.11	0.11
Moment	DATA	BASE	FullPart	Restrict η		
			$\psi = 1$	$\eta = 0$	$\eta \leq 0.3$	$\eta \leq 0.6$
Shareholder consumption share, mean	0.429	0.464	-	0.320	0.406	0.449
Shareholder consumption growth, volatility	0.037	0.039	-	0.044	0.039	0.039
Investment-to-output ratio (log), volatility	0.305	0.288	0.282	0.325	0.305	0.291
Investment growth, volatility	0.130	0.105	0.101	0.119	0.108	0.107
Investment and consumption growth, correlation	0.472	0.373	0.378	0.401	0.390	0.386
Market portfolio, excess returns, mean	0.063	0.067	0.068	0.053	0.066	0.071
Market portfolio, excess returns, volatility	0.185	0.131	0.138	0.132	0.125	0.129
Value factor, mean	0.065	0.063	0.051	0.034	0.056	0.059
Distance (mean relative deviation)		0.014	0.020	0.024	0.015	0.015
Additional Statistics						
Risk price for x		0.027	0.026	0.021	0.031	0.032
Market exposure to x		1.313	1.347	1.375	1.245	1.293
Value-minus-growth risk exposure to x		-0.184	-0.154	-0.303	-0.237	-0.194
Risk price for ξ		-0.078	-0.065	-0.043	-0.068	-0.079
Market exposure to ξ		-0.653	-0.687	-0.657	-0.468	-0.464
Value-minus-growth risk exposure to ξ		-0.875	-0.885	-0.877	-0.966	-0.862

SENSITIVITY TO MODEL ASSUMPTIONS

Parameter	Symbol	BASE	Restrict h			No ξ	Restrict γ $\gamma \leq 10$
			$h = 0$	$h \leq 0.3$	$h \leq 0.6$		
Risk aversion	γ	56.73	15.74	30.85	34.34	73.37	10.00
Elasticity of intertemporal substitution	θ	2.34	0.82	1.50	1.81	1.73	2.75
Fraction of population that is a shareholder	ψ	0.15	0.05	0.05	0.05	0.16	0.05
Preference weight on relative consumption	h	0.84	0.00	0.30	0.60	0.85	0.99
Fraction of project NPV that goes to inventors	η	0.77	0.86	0.84	0.75	0.27	0.95
Disembodied technology growth, volatility	σ_x	0.08	0.08	0.07	0.08	0.08	0.08
Embodied technology growth, volatility	σ_ξ	0.11	0.12	0.12	0.11	-	0.13

Moment	DATA	BASE	Restrict h			No ξ	Restrict γ $\gamma \leq 10$
			$h = 0$	$h \leq 0.3$	$h \leq 0.6$		
Shareholder consumption share, mean	0.429	0.464	0.408	0.409	0.397	0.443	0.399
Shareholder consumption growth, volatility	0.037	0.039	0.039	0.036	0.039	0.036	0.042
Investment-to-output ratio (log), volatility	0.305	0.288	0.312	0.315	0.304	0.025	0.312
Investment growth, volatility	0.130	0.105	0.112	0.110	0.109	0.048	0.108
Investment and consumption growth, correlation	0.472	0.373	0.275	0.182	0.314	0.998	0.315
Market portfolio, excess returns, mean	0.063	0.067	0.081	0.089	0.078	0.053	0.039
Market portfolio, excess returns, volatility	0.185	0.131	0.139	0.119	0.128	0.116	0.161
Value factor, mean	0.065	0.063	0.014	0.041	0.052	-0.010	0.050
Distance (mean relative deviation)		0.014	0.061	0.050	0.022	0.240	0.028

Additional Statistics							
Risk price for x		0.027	0.053	0.053	0.039	0.041	0.000
Market exposure to x		1.313	1.324	1.265	1.221	1.313	1.263
Value-minus-growth risk exposure to x		-0.184	-0.096	-0.194	-0.252	-0.327	-0.200
Risk price for ξ		-0.078	-0.023	-0.050	-0.057		-0.049
Market exposure to ξ		-0.653	-0.743	-0.610	-0.647		-0.922
Value-minus-growth risk exposure to ξ		-0.875	-0.736	-0.986	-1.104		-1.066

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INEQUALITY PATTERNS CONSISTENT WITH THE DATA

	A. Consumption		B. Wealth		C. Income	
	Model	Data	Model	Data	Model	Data
top 0.1% share (% , all HH)	5.3	0.7	12.1	13.2	5.6	5.6
top 0.5% share	11.2	2.5	26.2	26.2	11.5	10.8
top 1.0% share	16.7	4.2	36.5	32.6	15.6	14.2
99-90 ratio (stockholders)	3.3	1.7	3.3	5.7	3.5	4.2
99-95	2.4	1.5	2.4	3.2	2.5	2.9
95-90	1.4	1.2	1.4	1.8	1.4	1.5
90-50	5.6	1.8	5.6	5.1	5.6	2.5

- Model generates implications for income and wealth inequality **at the top** that are consistent with the data.

CROSS-SECTIONAL RETURN PREDICTABILITY: CAPM FAILS

	Mean	Std	CAPM α	CAPM β	R^2	
Value Spread	0.063	0.152	0.046	0.226	0.038	<i>Model</i>
	0.065	0.243	0.050	0.150	0.018	<i>Data</i>
I/K spread	-0.027	0.092	-0.020	-0.050	0.011	
	-0.056	0.112	-0.067	0.190	0.068	
E/P spread	0.040	0.110	0.025	0.202	0.106	
	0.059	0.141	0.068	-0.120	0.016	

- Model generates not only the value premium, but also the value **factor**, as well as the failure of the CAPM.

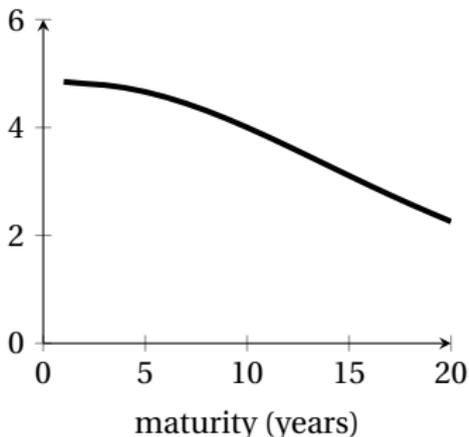
UPWARD-SLOPING REAL YIELD CURVE

Maturity	1y	2y	3y	4y	5y	6y	7y	8y	9y	10y
Yield, average (%)	2.0	2.0	2.1	2.2	2.2	2.3	2.4	2.4	2.5	2.6
Yield, volatility (%)	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9
Excess return, mean (%)		0.1	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.4
Excess return, volatility (%)		0.3	0.6	0.9	1.2	1.5	1.8	1.8	2.3	2.5

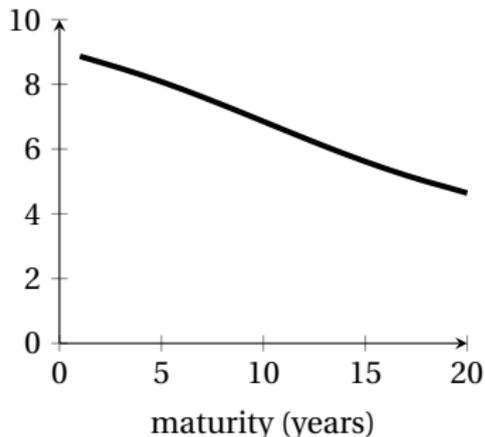
- Model generates an upward sloping term structure of real interest rates.

DOWNWARD-SLOPING TERM STRUCTURE OF PAYOUT CLAIMS

A. Risk premia (%)



B. Volatility (%)



- Moments of aggregate payout strips; these are analogs of dividend strips in the model, although payout and dividends are not the same.

OUTLINE

- 1 THE MODEL
- 2 MODEL MECHANISM
- 3 ESTIMATION
- 4 ADDITIONAL IMPLICATIONS
- 5 DIRECT EVIDENCE**

TESTABLE PREDICTIONS

- **Main mechanism:** Technological progress has a heterogenous effect on households and firms.
- Testable predictions?
 - ▶ Technological improvements benefit growth firms at the expense of value firms
 - ▶ Technological progress is followed by an increase in inequality
- To test either prediction, we need an estimate of v_t , i.e. the economic value created by new technologies at time t
- We do so using data on patents and stock returns, following the methodology of Kogan, Papanikolaou, Seru and Stoffman (QJE, 2017)

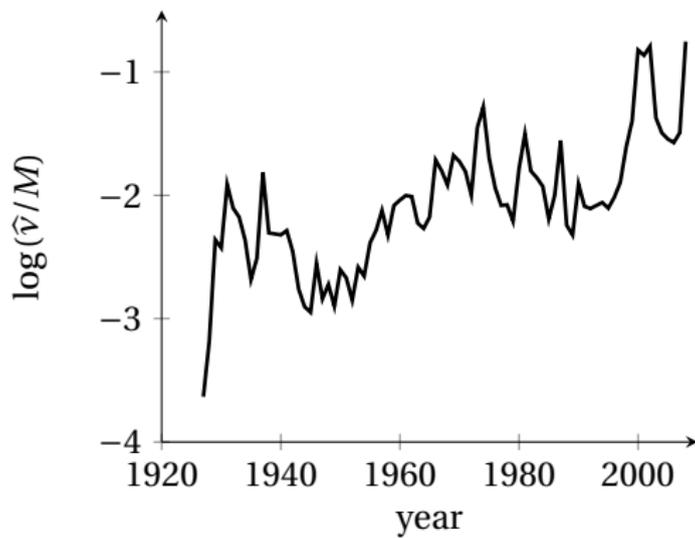
MAPPING THE MODEL TO THE DATA

- In model, what drives firm profitability and inequality is value of new projects v_t scaled by value of assets in place V or shareholder wealth W , respectively.
- Neither are observable. Scale by sum of market capitalization M of all firms

$$\hat{\omega}_t = \frac{\hat{v}_t}{\hat{M}_t}$$

- ▶ In the model, v/V , v/W and v/M all monotonically related

INNOVATION SERIES



MEASURING VALUE OF NEW TECHNOLOGIES – DATA VS MODEL

Value of new inventions ($\hat{\omega}$)	Correlation			
	($t \rightarrow t+1$)	($t \rightarrow t+2$)	($t \rightarrow t+3$)	
A. Consumption growth, aggregate	0.04	0.00	0.00	Model Data
	-0.02	-0.08	-0.14	
	(0.16)	(0.16)	(0.15)	
B. Consumption growth, shareholders	-0.13	-0.18	-0.18	
	-0.22	-0.13	-0.13	
	(0.11)	(0.11)	(0.13)	
C. Investment growth	0.61	0.66	0.68	
	0.30	0.27	0.30	
	(0.12)	(0.10)	(0.12)	
D. Market portfolio	-0.34	-0.33	-0.32	
	-0.50	-0.30	-0.09	
	(0.11)	(0.13)	(0.13)	
E. Value factor	-0.34	-0.45	-0.49	
	-0.34	-0.44	-0.52	
	(0.09)	(0.09)	(0.12)	

TECHNOLOGY AND FIRM PROFITABILITY

- How does technological innovation impact firm profitability?
- KPSS document large dispersion in innovation outcomes across industries
 - ▶ What is the impact of large innovation waves in an industry on firm profits
- Estimate

$$s_{ft+T} - s_{ft} = (a_0 + a_1 q_{ft}) \hat{\omega}_{I \setminus ft} + Controls + \varepsilon_{t+T}$$

- ▶ q_{ft} dummy variable if firm Q above industry median
 - ▶ $\hat{\omega}_{I \setminus ft}$ industry innovation (excluding firm)
 - ▶ Controls: firm's own innovation, lag profits, size, time, and industry FE
- Focus on the estimated coefficients
 - ▶ a_0 effect on low- Q firms
 - ▶ a_1 differential effect on high- Q firms

TECHNOLOGY AND FIRM PROFITABILITY

$\Delta\pi_{f,t \rightarrow t+h}$	Horizon						
	(1)	(2)	(3)	(4)	(5)	(6)	
$\hat{\omega}_{I\Delta t}$	-0.026 -0.037*** (0.004)	-0.043 -0.036*** (0.005)	-0.054 -0.043*** (0.007)	-0.061 -0.040*** (0.008)	-0.065 -0.043*** (0.009)	-0.068 -0.050*** (0.010)	Model Data
$\hat{\omega}_{I\Delta t} \times G_{ft}$	0.010 0.024*** (0.004)	0.030 0.024*** (0.006)	0.046 0.030*** (0.008)	0.055 0.032*** (0.008)	0.062 0.031** (0.009)	0.069 0.038*** (0.010)	
Observations	68,818	63,618	59,278	55,321	51,551	48,053	
R^2	0.118	0.137	0.150	0.149	0.157	0.165	

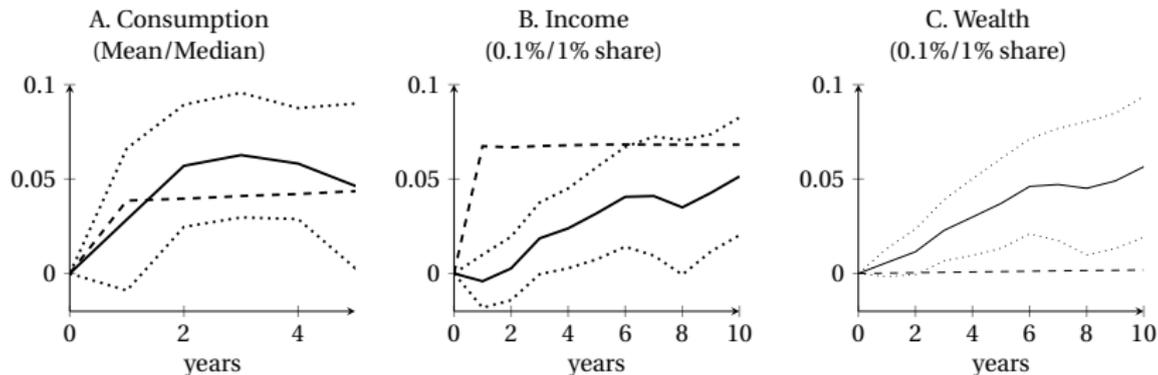
- Profitability of value falls much more than growth firms following innovation by competing firms

TECHNOLOGICAL PROGRESS AND INEQUALITY

- Part of model's mechanism operates through inequality
 - ▶ In consumption: compare growth of average per capita growth consumption with the growth of median consumption in the CEX.
 - ★ Logic: median is insensitive to growth of the “top 0.1%” while the average is
 - ▶ Wealth and income: examine inequality at the extreme right tail, share of top 0.1% to top 1%
- Estimate:

$$Ineq_T - Ineq_t = b_1 (\hat{\omega}_T - \hat{\omega}_t) + b_2 Ineq_t + b_3 \hat{\omega}_t + u_t$$

TECHNOLOGY AND INEQUALITY: DATA VS MODEL



- Model (dotted) vs data (solid)

CONCLUSION

- Technological innovation has heterogeneous impact on households and firms
- Limited sharing of gains from innovation is key
 - ▶ Model insights also applicable to entrepreneurs, scientists, innovators, ...
 - ▶ Shareholders not the sole claimant of firm 'intangibles'
- Growth firms provide insurance – hence have low equilibrium returns
- Open questions and future work:
 - ▶ Displacement of human capital