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Essays in entrepreneurship: overcoming financing constraints

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ESSAYS IN ENTREPRENEURSHIP: OVERCOMING FINANCING CONSTRAINTS

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A DISSERTATION
PRESENTED TO THE FACULTY
OF PRINCETON UNIVERSITY
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Abstract

This collection of essays investigates how institutions like venture capital and public policy may facilitate starting and developing businesses.

In Chapter 1, I study the impact of venture capitalists' effort on their portfolio companies compared to no involvement. I examine two new empirical measures, one is the management score, the other is the organizational-capital-to-asset ratio. The main finding is that after controlling for observables, venture-funded firms have a higher management score. Moreover, they have higher sales and employment growth, but use less organizational capital. This chapter demonstrates that venture capitalists' effort improves firms' productivity by increasing management efficiency.

In Chapter 2, I propose a new general equilibrium model that explains observations of Chapter 1 and additional observations. Venture capitalists can help increase firms' productivity, yet they face increasing entry costs to enter. I characterize steady state effort choice, entry threshold, and mass of venture capitalists, and show how they are affected by change in upfront investment, interest rate, and entry costs. The key contribution is that public policy to stimulate startups by subsidizing upfront investments or reducing interest cost have limited success if not accompanied by an increasing supply of experts who can improve business ideas.

In Chapter 3, I conduct a policy exercise about how much the introduction of a Norwegian-sized lottery sector to the United States would affect startups. The key results are that public cash transfer programs (like lottery) do not increase much the number of new startups, but increase the size of startups, and only modestly increase aggregate productivity and output. The most important factor for entrepreneurs to start new businesses is their ability.

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Contents

Abstract 3

Acknowledgements 4

List of Tables 10

List of Figures 12

1 Venture Capitalists' Effort: Empirical Evidence 14

1.1 Introduction 14

1.2 Literature Review 17

1.3 Data 18

1.4 Empirical Results 20

1.4.1 Management Quality 20

1.4.2 Organizational Capital 24

1.4.3 Heterogeneity in Venture Capitalist Involvement 28

1.5 Conclusion 31

2 Venture Capitalists' Effort: General Equilibrium Study 33

2.1 Introduction 33

2.2 Literature Review 35

2.3 Stylized Facts 36

2.3.1 Characteristics of Venture-Funded Firms 37

2.3.2 Comparison of Venture-Funded and Non-Venture-Funded Firms 40

2.3.3 Supply of Venture Capitalists' Effort 42
2.3.4 Summary 44
2.4 Partial Equilibrium 44
2.4.1 Model Environment 45
2.4.2 Optimal Contracts and Financing Decision 46
2.4.3 Empirical Implications 50
2.5 General Equilibrium 53
2.5.1 Model Environment 53
2.5.2 Decision Problems 55
2.5.3 Stationary Competitive Equilibrium 57
2.6 Comparative Statics 60
2.6.1 A Decrease in the Upfront Investment 60
2.6.2 A Decrease in Interest Rates 64
2.6.3 A Decrease in Venture Capitalists' Entry Cost 65
2.7 Conclusion 68

3 Lottery Experiment on Entrepreneurs' Financing Constraint 70
3.1 Introduction 70
3.2 Literature Review 72
3.3 The Model 73
3.3.1 Endowment 74
3.3.2 Preference 74
3.3.3 Technology and Production 74
3.3.4 Borrowing Sector 75
3.3.5 Lottery Sector 75
3.3.6 Government 76
3.3.7 Household Problem 76
3.3.8 Stationary Competitive Equilibrium 78

3.4 Calibration 80
3.5 Benchmark Economy 82
3.6 Lottery Experiments 85
3.6.1 Steady State Results 85
3.6.2 Simulation 88
3.6.3 Different Lottery Prize Structures 90
3.7 Results Discussion 90
3.7.1 Connecting Model with Literature 92
3.7.2 Policy Implications 93
3.8 Conclusion 93

A Appendices for Chapter 1 **94**
A.1 Merging Compustat and VentureXpert 94
A.2 Merging WMS and VentureXpert 95

B Appendices for Chapter 2 **96**
B.1 Merging NETS and VentureXpert 96
B.1.1 Limitation of NETS 98
B.2 Proofs 98
B.2.1 Proof for Proposition 2.4.1 98
B.2.2 Feasibility Region 99
B.3 Numerical Example 101
B.3.1 Computation Algorithm 101

C Appendices for Chapter 3 **103**
C.1 Computation Algorithm 103
C.1.1 Benchmark Economy Steady State 103
C.1.2 Lottery Economy Steady State 104
C.1.3 Simulation 105

C.2 Markov processes for η and θ 105
C.3 Gambling in Norway 106

References **108**

List of Tables

1.1 Descriptive Statistics of Firms in VentureXpert 19

1.2 Descriptive Statistics of Firms in the World Management Survey . . . 20

1.3 Comparison of Firm Characteristics 21

1.4 Regression of Management Scores by Venture Status 22

1.5 Comparison of Venture-Funded Firms in VentureXpert and WMS . . 23

1.6 Regression of Organizational Capital by VC Status 27

1.7 Regression of R&D, Sales and Employment Growth by VC Status . . 28

1.8 Regression of O/K Ratio by VC Quality 31

2.1 Regression of Long Term Employment on Venture Status 41

3.1 A Priori Parameters 80

3.2 Lottery Sector Parameters 81

3.3 Benchmark Model Moments and Data 83

3.4 Benchmark model: entrepreneurial activities by ability θ 84

3.5 Steady State Moments 86

3.6 Lottery economy: entrepreneurial activities by ability θ 86

3.7 Lottery economy: leverage across prizes 87

3.8 Regression: entrepreneur decision, consumption, and investment . . . 89

3.9 Alternative Lottery Structure 90

3.10 Entrepreneur decision, consumption, and investment - Small Prize . . 91

3.11 Entrepreneur decision, consumption, and investment - Large Prize . . 91

B.1 Composition of Merged Names in NETS and VentureXpert 97

B.2 Main Parameters 101

B.3 Steady State Values 102

List of Figures

1.1 Management Scores Comparison 21

1.2 Organizational Capital: 1970-2014 26

1.3 Management Scores Comparison by Investor Quality 30

2.1 Percentage of Venture-Funded Firms in the Economy 38

2.2 Age Distribution of Venture-Funded Firms 39

2.3 Employment Quintile of Venture-Funded Firms 39

2.4 Employment After Venture Funding 40

2.5 Employment Growth After Venture Funding 42

2.6 Number of Active Investors by Year 43

2.7 Feasibility Region for VC and Bank Financing 50

2.8 Optimal Effort Choice h by Total Factor Productivity z 51

2.9 Optimal Effort Choice h by Founder's Effort Cost c 52

2.10 Effects of decrease in I - effort levels and entrepreneur's surplus. . . . 62

2.11 Effects of decrease in I - venture-funded region 63

2.12 Effects of decrease in r - effort levels and entrepreneur's surplus. . . . 65

2.13 Effects of decrease in κ_v - optimal effort and entrepreneur's surplus . 67

2.14 Effects of decrease in κ_v - venture-funded region 67

3.1 Lottery Prize Distribution - Fagereng, Holm, and Natvik (2016) . . . 82

3.2 Benchmark model: distribution of abilities θ 83

3.3 Benchmark model: investment by asset and ability 84
3.4 Benchmark model: density and CDF of assets by occupation 85
3.5 Lottery economy: savings and consumption policy by winning status 87
3.6 Lottery economy: entrepreneur's investment policy by winning status 88

Chapter 1

Venture Capitalists' Effort: Empirical Evidence

1.1 Introduction

This chapter uses two empirical measures to quantify the impact of venture capitalists' effort compared to the case of no involvement. The first publicly funded venture capital, ARD, was established to play an active role in managing its investments. During the investment period, venture capitalists constantly travel to portfolio companies, participate in board meetings, give advice to founders, and make business decisions. A few venture-backed startups have since become technological giants, such as Apple and Google, suggesting the long-term impact venture capitalists might have on their investments. Thus, it is important to understand the role of venture capitalists and their impact.

Hellmann and Puri (2002) is among the early papers that develop professionalization measures to measure the outcome of venture capitalists' management. Their measures focus on specific business decisions made by venture capitalists, such as hiring policies and stock option plans. The results show that venture capitalists play

a role beyond mere information collection, and has important influence down the organization. Despite the importance of their contribution, it is difficult to use these measures for two reasons. First, the data is hand-collected, and therefore is difficult to merge with widely-used firm datasets, such as Compustat or VentureXpert. And second, the measures are very specific, and may be contingent on the state of the firm. We need a measure that is applicable to all firms.

On the other hand, most papers use very broad measures. For example, Puri and Zarutskie (2012) uses failure rates, employment and sales growth to compare venture- versus non-venture-funded firms. The advantage is that we can easily get these measurements from all firms. However, it is ambiguous whether decreased failure rates is a result of venture capitalists' management decisions, or just due to more financing. Therefore, we need a measure that is more directly related to venture capitalists' actions.

I reference the management and organizational capital literature to obtain two empirical measures that are direct consequences of venture capitalists' effort. First, I use the management score developed by Bloom and Reenen (2007) to examine the management quality of venture-funded firms. Their data is collected via nation-wide interview-based surveys that focus on management practices, and most firms have reached medium size. The management score will then inform the impact of venture capitalists after firms' exits from venture funding. Second, venture capitalists' effort to set employee incentives and hire key talents will be reflected in the organizational capital. Lev and Radhakrishnan (2005) first developed this measure to capture exactly resources allocated to building up the systems and processes of the business, and thus will be ideal for my purpose. Since organizational capital is mostly captured by the capitalized value of past SG&A expenditures, it is a readily available source.

My main assumption is that venture capitalists' monitoring does have an effect on firm performance. Literature has long been concerned with proving and disentangling

the effect of monitoring from screening. The most recent findings indicate a positive effect of monitoring, which I will be relying on for my analysis. Like most papers, I will be comparing venture-funded versus non-venture-funded firms. Although firm-level unobserved characteristics may lead to selection bias issues, the impact on my two measures is minimal. Most firms have little organizational capital when they receive venture funding, and the key managerial talent is usually just the founder. Most of the organizational capital stock and managerial practices are developed after the involvement of venture capitalists. Therefore, it is unlikely that my results will contain significant selection bias.

The key contribution of this chapter is that both measures show a positive effect of venture capitalists' monitoring. Venture capitalists improve business quality of firms and reduce fixed cost. First, venture-funded firms have higher management scores compared to non-venture-funded firms, conditional on observables. Moreover, among the four components of management scores (operations, monitoring, target, and incentives), venture-funded firms have significantly higher incentive scores. This is in line with the findings of Hellmann and Puri (2002) that venture capitalists help set up human resource policies and employee incentive plans. Second, venture-funded firms have lower organizational capital-to-asset ratios. Venture-funded firms operate with a lower expense paid out to maintain business operations, conditional on firm size and other observables. Additionally, I find that firms funded by more experienced venture capitalists have a lower organizational capital-to-asset ratio. This shows that there is heterogeneity in venture capitalists' involvement.

Results in this chapter not only show the usefulness of the organizational capital and management quality measures, but also motivate the theory in Chapter 2. Traditional financial intermediation theory tend to focus on reducing informational friction by financial intermediaries. However, venture capitalists' play a much more active role beyond screening and collecting information. Their managerial expertise

improves firm performance and therefore affects the production function by increasing business productivity and output.

1.2 Literature Review

This chapter contributes to the literature that studies the effect of venture capitalists' involvement in their portfolio companies. Most papers try to distinguish the effect of monitoring from screening by comparing venture-funded versus non-venture-funded firms. After controlling for observable characteristics, venture-funded firms have higher sales and employment growth (Puri and Zarutskie (2012)), higher R&D investments (Greenwood, Han, and Sanchez (2018)), more patents (Akcigit, Dinlersoz, Greenwood, and Penciakova (2019)), and overall higher total factor productivity (Chemmanur, Krishnan, and Nandy (2011)). Some papers use structural modeling. Kortum and Lerner (2000) estimates a patent production function and find that venture capitalist involvement is associated with higher patent rates. Sørensen (2007) develops a two-sided matching model and shows that venture capitalists' monitoring does influence the success of IPO. More recently, Bernstein, Giroud, and Townsend (2016) exploits an exogenous source of variation in venture capitalist involvement: the introduction of new airline routes that reduces the travel time to portfolio companies. They confirm the importance of venture capitalist involvement in increasing both innovation and the probability of successful exits. My study differs from the above papers in that I examine two outcome measures that are more specifically related to venture capitalist' business decisions.

I also try to answer the question of what exactly is monitoring. Early papers (Gompers (1995), Lerner (1995)) define monitoring as an information collection action to reduce adverse selection and moral hazard. However, if monitoring is just passive oversight of firms' operations, then venture capitalists should provide more of

a homogeneous service, and control rights will not be that important. Instead, quite a few papers (Kaplan, Sensoy, and Mberg (2009), Ewens and Malenko (2020)) find that venture capitalists acquire an increasing board presence at their portfolio companies. Moreover, Hsu (2004) shows that entrepreneurs are willing to accept a discount of about 15% on the valuation of their businesses in order to be affiliated with more reputable venture capitalists. My findings support the thesis that venture capitalists' monitoring is active, especially in the management aspect, and has a positive effect on business operations. I extend the analysis of Bottazzi, Rin, and Hellmann (2008) and Hellmann and Puri (2000) by using a wider sample of firms.

Lastly, this chapter contributes to the management literature that focuses on the impact of resources allocated to firm operations and management practices. Most studies (Bloom and Reenen (2007), Bloom, Lemos, Sadun, Scur, and Van Reenen (2014), Bloom, Sadun, and Van Reenen (2015)) show that management practices have positive effects on firms' productivity. I use the same data from these studies (the World Management Survey) to further distinguish the differences in management practices between venture and non-venture-funded firms.

1.3 Data

I use three datasets: VentureXpert, World Management Survey, and Compustat. And I restrict the analysis to US firms. To compare management quality between venture- versus non-venture-funded firms, I use the World Management Survey. Then, I use Compustat fundamentals data to construct the organizational capital-to-asset ratio measure and compare venture- versus non-venture-funded firms.

In order to identify venture-funded firms in both the World Management Survey and Compustat, I first use probabilistic names matching to merge VentureXpert with Compustat, and then merge World Management Survey with Compustat using Com-

pustat IDs as the common identifier. Details of the merging procedure can be found in Appendix A. 10% of the observations in the World Management Survey are from venture-funded firms, and 20% in Compustat.

The VentureXpert data provided by Thomson Financial contains round-level investment information. In each round, it records the round number, funding amount, and the names of all its investors. It provides firm-level identifiers such as name, founding year, industry, and current stage. The sample has 84,542 firms funded by venture capitalists between 1980 and 2015.

Table 1.1 presents descriptive statistics of firms funded by venture capital. 58% of firms first receive funding at early stage. On average, a firm is funded by 6 investors, goes through 3 rounds, and receives $25 million of funding.

Table 1.1: Descriptive Statistics of Firms in VentureXpert

	OBS	MEAN	STD.DEV	MIN	MAX
Total Fund Amount($Mil)	84542	24.55	195.90	0	37605
Number of Rounds	84542	2.52	2.43	1	32
Number of Investors	84542	5.85	8.93	1	164
Early Stage	84542	.58	.49	0	1

The World Management Survey data, pioneered by Bloom and Van Reenen in 2003, combines survey data [1] from 2004 to 2014 on 1515 randomly chosen US manufacturing firms' management practice, both public and private. Bloom, Lemos, Sadun, Scur, and Van Reenen (2014) describes that the survey covers 4 aspects: operations, monitor, target, and people. The authors recruit 62 MBA-type students to interview plant managers at middle level and employ a double-blind survey technique. Interviewers score managers' responses from 1 (worst practice) to 5 (best practice) across 18 management practice questions.

[1] The WMS website (http://worldmanagementsurvey.org) has details on datasets, methods, and papers.

Table 1.2: Descriptive Statistics of Firms in the World Management Survey

	OBS	MEAN	STD.DEV	MIN	MAX
Management	1355	3.31	.66	1	5
Operations	1355	3.30	1.08	1	5
Monitor	1355	3.54	.80	1	5
Target	1355	3.22	.79	1	5
People	1355	3.20	.70	1	5
Age (Years)	1355	52	43	0	130
Employee	1355	1266	3092	14	60000

Table 1.2 describes firms in the World Management Survey. The average firm is medium-sized, employs about 1200 people, and has been operating for about 50 years. Management is the average of Operations, Monitor, Target, and People scores, and thus represents overall management quality. Operations measures whether firms adopt lean production process or use automation in their daily operations. Monitor checks whether firms track and review key performance indicators, and follow up with changes. Target captures short- and long-term goal setting. And People measures whether firms attract and keep talent by employee incentives, bonus and promotion policies.

1.4 Empirical Results

1.4.1 Management Quality

Comparison

I first compare scores of management and the four metrics for venture- and non-venture-funded firms. Figure 1.1 illustrates that venture-funded firms on average have higher scores for every metric, and score higher overall. A closer look at other firms'

characteristics shows that venture-funded firms are slightly younger but employs more people, and their managers tend to be younger. This is in line with other paper's findings that venture-funded firms tend to be younger but reach a larger size.

Figure 1.1: Management Scores Comparison

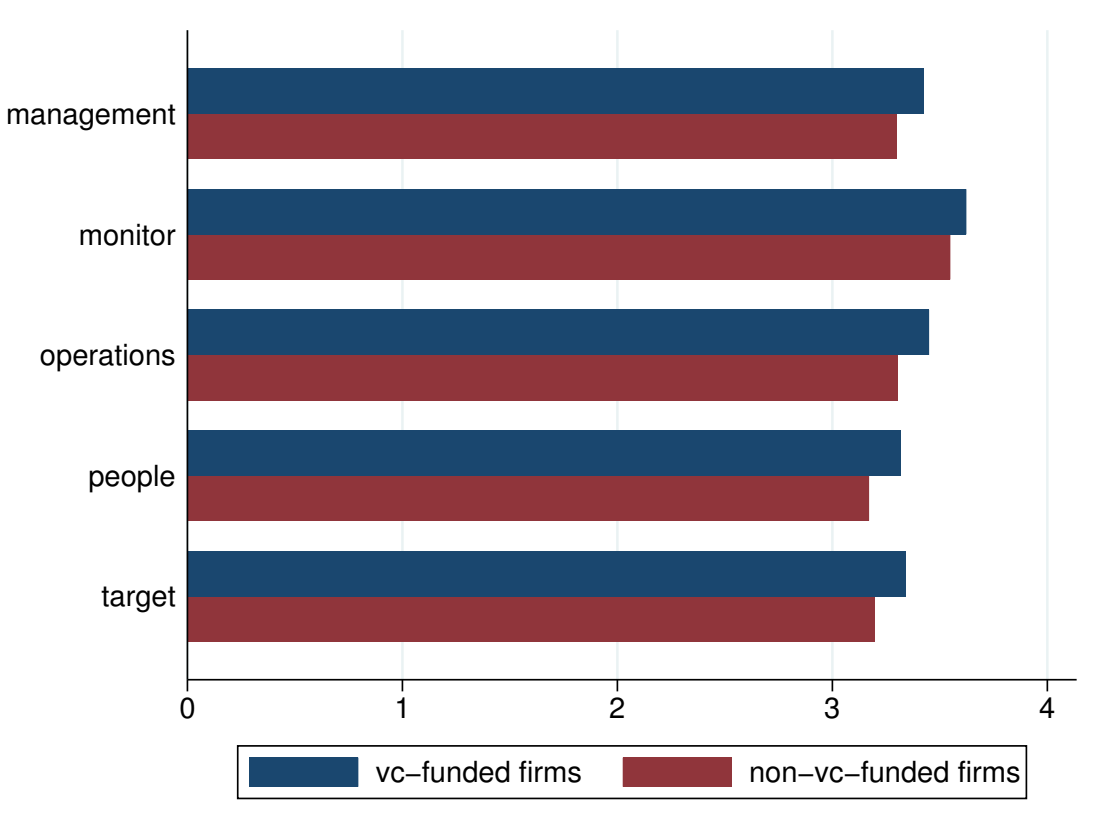


Table 1.3: Comparison of Firm Characteristics

	VC	Non-VC
Age (Years)	34	54
Employee	1664	1219
Manager's Seniority (Years)	3	3
Manager's Tenure (Years)	10	13

I then run a regression of the management score and its four components' scores on the venture-funded status and control for observables.

$$Y_{it} = c_0 + \beta \mathbb{1}_{VC,i} + \gamma \text{Controls}_{it} + \epsilon_{it} \tag{1.1}$$

Following Bloom, Lemos, Sadun, Scur, and Van Reenen (2014), I include firm controls such as firm age and size. However, I did not include noise controls (the duration of the interview, an interviewee dummy, and an interview reliability score), as the sample size is too small (their sample size is 15038). Similar to their findings, the regressions in Table 1.3 show that venture-funded firms have significantly better management practices, at least at the 95% confidence level. Moreover, venture-funded firms perform especially better in the Target and People metric. This corroborates the findings in other papers that venture capitalists are involved in hiring policies and help set up business strategies. With venture capitalists' involvement, firms on average score 4.3% higher in overall management scores.

Table 1.4: Regression of Management Scores by Venture Status

	Management	Operations	Monitor	Target	People
VC(=1,if backed by VC)	0.143*	0.171	0.117	0.150*	0.149**
	(0.058)	(0.090)	(0.069)	(0.072)	(0.058)
Constant	3.274***	3.274***	3.492***	3.172***	3.178***
	(0.028)	(0.047)	(0.034)	(0.034)	(0.032)
Observations	1357	1355	1357	1357	1357
R-Squared	0.013	0.016	0.009	0.011	0.007
Firm Controls	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Limitations

There are two limitations to my analysis. First, the average age of firms surveyed in the World Management Survey is high. Typically, venture capitalists exit after the firm is around 5 to 10 years old. Firms could have adopted better management practices after venture capitalists leave. My results rely on the assumption that most of the management practices are set in firms' formative years, and change very little as firms grow large.

The second limitation is that venture-funded firms in the World Management Survey are slightly different from a typical firm in VentureXpert. By survey design, only manufacturing firms are interviewed in the World Management Survey. On the other hand, venture capitalists tend to fund more firms in the informational technology sector. This partly explains why only 80 venture-funded firms are identified in the World Management Survey. Table 1.5 shows additional difference between an average venture-funded firm in the World Management Survey and that in VentureXpert in terms of total amount of funding received during the funding period, number of rounds, and so on.

Table 1.5: Comparison of Venture-Funded Firms in VentureXpert and WMS

	VentureXpert	WMS
Total Fund Amount($Mil)	24.51	73.90
Number of Rounds	2.52	2.89
Number of Investors	5.84	7.25
Early Stage	0.58	0.35

1.4.2 Organizational Capital

Measuring Organizational Capital

I use organizational capital as an outcome measure of venture capitalists' effort in building up their portfolio businesses. The definition of organizational capital, according to Lev and Radhakrishnan (2005), is "an agglomeration of technologies – business practices, processes and designs, and incentive and compensation systems – that together enable some firms to consistently and efficiently extract from a given level of physical and human resources a higher value of product than other firms find possible to attain." Venture capitalists' day-to-day activities, such as hiring marketing professionals, setting up employee stock incentives, will thus be reflected in the stock of organizational capital.

Following Lev and Radhakrishnan (2005) and Eisfeldt and Papanikolaou (2013), I use SG&A expenses as a proxy for organizational capital. The U.S. GAAP definition of SG&A expenses states that it contains salaries paid to administrative, marketing, and human resource departments, costs of advertising and sales commissions, and executive compensations. Most of the items in SG&A expenses are influenced by venture capitalists in Hellmann and Puri (2002), either by venture capitalists' hiring actions, or by their compensation policies. For a given level of sales, the less the SG&A expenses, the more efficient the business is.

I construct the stock of organizational capital O using the perpetual inventory method, which is common in the intangible capital literature. I recursively construct the stock of organizational capital by cumulating the deflated value of SG&A expenses,

$$O_{it} = (1 - \delta_O)O_{it-1} + \frac{SGA_{i,t}}{cpi_t} \tag{1.2}$$

where cpi_t denotes the seasonally adjusted consumer price index. Following Peters and Taylor (2017), I measure SG&A as Compustat variable *xsga* minus *xrd*. This is because Compustat almost always include R&D expenses to *xsga*, so I exclude R&D as it is less influenced by venture capitalists. I choose the initial stock of organizational capital according to

$$O_0 = \frac{SGA_1}{g + \delta_O} \tag{1.3}$$

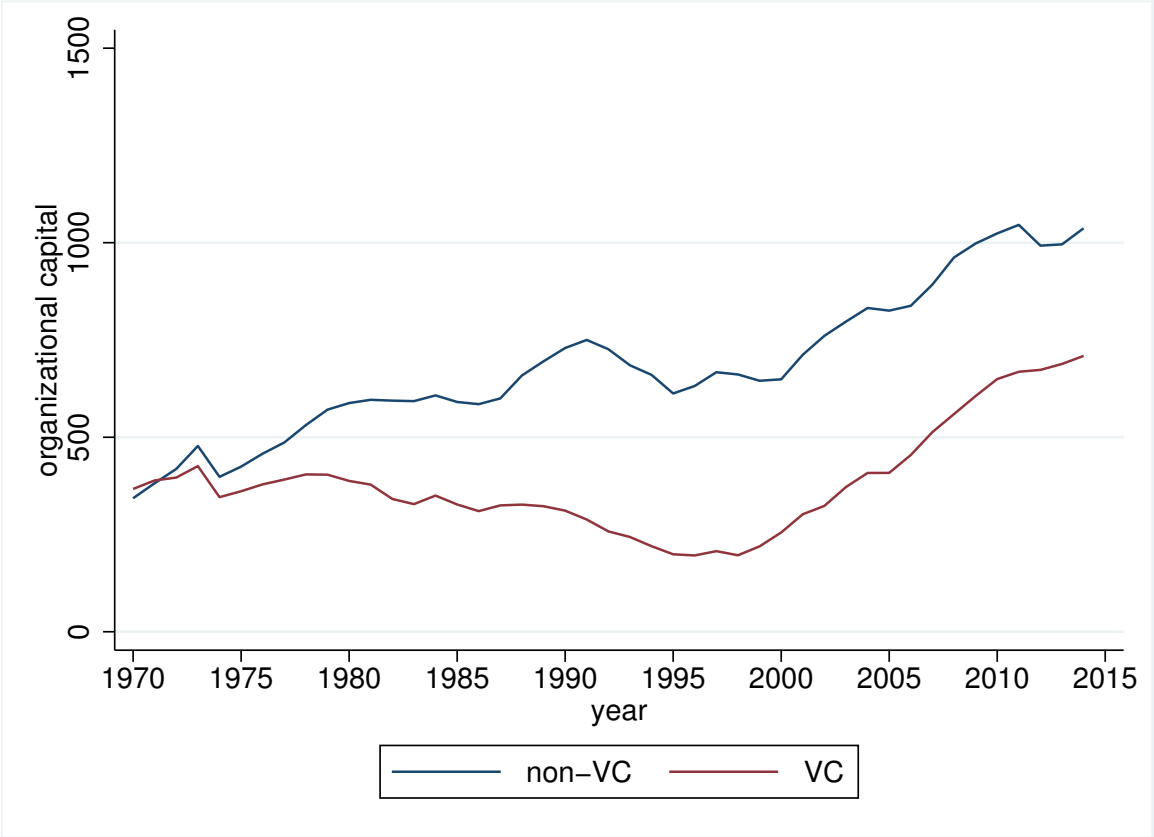
I use a depreciation rate of 15%, following the BEA in its estimation of R&D capital in 2006. g is chosen to match the average real growth rate of firm-level SG&A expenditures, which in my sample equals 11%. I treat missing values of SG&A as zero. My results are robust to a choice of depreciation rate δ_O between 10% and 50%, and to dropping the first 5 years of data for every firm, which minimizes the error in the measurement of initial stock O_0. Finally, I scale organizational capital O by the firm's book assets K to obtain the organizational capital-to-assets O/K ratio.

My sample includes all nonfinancial firms in Compustat with fiscal year ending in December, that have nonmissing SIC codes and nonzero values of organizational capital. I group firms into 17 industries based on Fama and French (1997) classification. My sample includes a total of 16913 firms from 1970 to 2015. And 4176 firms are identified from VentureXpert as funded by venture before their IPO; this is about 25% of the sample.

Comparison

Figure 1.2 illustrates the average organizational capital stock over the years for venture-funded and non-venture-funded firms. Venture-funded firms have consistently lower organizational capital.

Figure 1.2: Organizational Capital: 1970-2014



To rule out the possibility that venture-funded firms concentrate in only a few industries, I run a regression of O/K ratio on venture-funding status, controlling for firm age and size, and industry and year fixed effects.

For firm i in industry s and time t,

$$\frac{O}{K}_{ist} = c_0 + \beta \mathbb{1}_{VC,i} + \gamma_1 \text{YearsIPO}_{ist} + \gamma_2 ln\text{employment}_{ist} + \alpha_s + \chi_t + \epsilon_{ist} \qquad (1.4)$$

Table 1.6 presents the second main finding of this chapter: venture-funded firms have lower organizational capital-to-asset ratios. The coefficient on the venture status indicator is consistently negative as I add more control variables, and is significant at the 99% confidence level. On average, firms being funded by venture capital will have an O/K ratio that is 1/3 less than a typical firm (the mean of O/K ratio across

all firms is 6.16). This suggests that firms funded by venture capitalists operate with a leaner organization, paying less fixed cost to administrative, sales, and marketing needs, while maintaining the same level of employment.

Other coefficients of the regression are intuitive as well. First, as firms operate longer periods of time, they accumulate more organizational capital. Moreover, SG&A is a fixed cost, so the O/K ratio decreases as number of employees increases.

Table 1.6: Regression of Organizational Capital by VC Status

	O/K	O/K	O/K
VC(=1, if backed by VC)	-1.62***	-1.97**	-2.05***
	(0.45)	(0.69)	(0.38)
Years since IPO		0.087**	0.099*
		(0.027)	(0.038)
ln(employment)	-1.69***	-1.79***	-1.88**
	(0.080)	(0.084)	(0.53)
constant	2.59***	1.72***	1.66**
	(0.23)	(0.36)	(0.42)
Observations	144601	144601	144601
R-squared	0.003	0.003	0.004
Industry Fixed Effect	No	No	Yes
Year Fixed Effect	No	No	Yes

Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

I then run a robustness check to make sure venture-funded firms have at least similar levels of business activities as non-venture-funded firms.

$$Y_{ist} = c_0 + \beta \mathbb{1}_{VC,i} + \gamma_1 \text{YearsIPO}_{ist} + \gamma_2 ln\text{employment}_{ist} + \alpha_s + \chi_t + \epsilon_{ist} \qquad (1.5)$$

Business activities, Y_{ist}, are measured using R&D-to-Sales ratio, employment growth, and sales growth. This is to ensure that venture-funded firms are not having smaller organizations because they sell less products, do less R&D, or expand less. On the contrary, Table 1.7 shows that venture-funded firms have a higher R&D ratio, grow 3% faster in sales and 2% faster in employment. Therefore, I interpret the evidence as venture-funded firms are operationally more efficient; they achieve higher levels of sales and employment with a lower fixed cost.

Table 1.7: Regression of R&D, Sales and Employment Growth by VC Status

	Sales Growth	Employment Growth	R&D / Sales
VC(=1, if backed by VC)	0.031***	0.024***	0.040***
	(0.0030)	(0.0022)	(0.0089)
Years since IPO	-0.0033***	-0.0022***	-0.0016***
	(0.00015)	(0.00011)	(0.00017)
ln(employment)	0.0067***	0.0072***	-0.019***
	(0.00066)	(0.00068)	(0.0017)
constant	0.12***	0.052***	0.085***
	(0.0020)	(0.0015)	(0.0030)
Observations	144601	144601	144601
R-Squared	0.081	0.054	0.303
Industry Fixed Effect	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes

Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

1.4.3 Heterogeneity in Venture Capitalist Involvement

Hsu (2004) finds that entrepreneurs are willing to give more equity to more experienced venture capitalists, and attributes the reason to certification effect. On

the other hand, Akcigit, Dinlersoz, Greenwood, and Penciakova (2019) finds that the impact of high quality venture capitalists goes beyond better screening. Firms funded by high quality venture capitalists have higher employment levels and patent stock 10 years after receiving funding. To examine whether there is heterogeneity in venture capitalists' involvement in firms' operations, I compare the management scores and organizational capital-to-asset ratios of firms funded by high quality ventures versus those funded by low quality ventures.

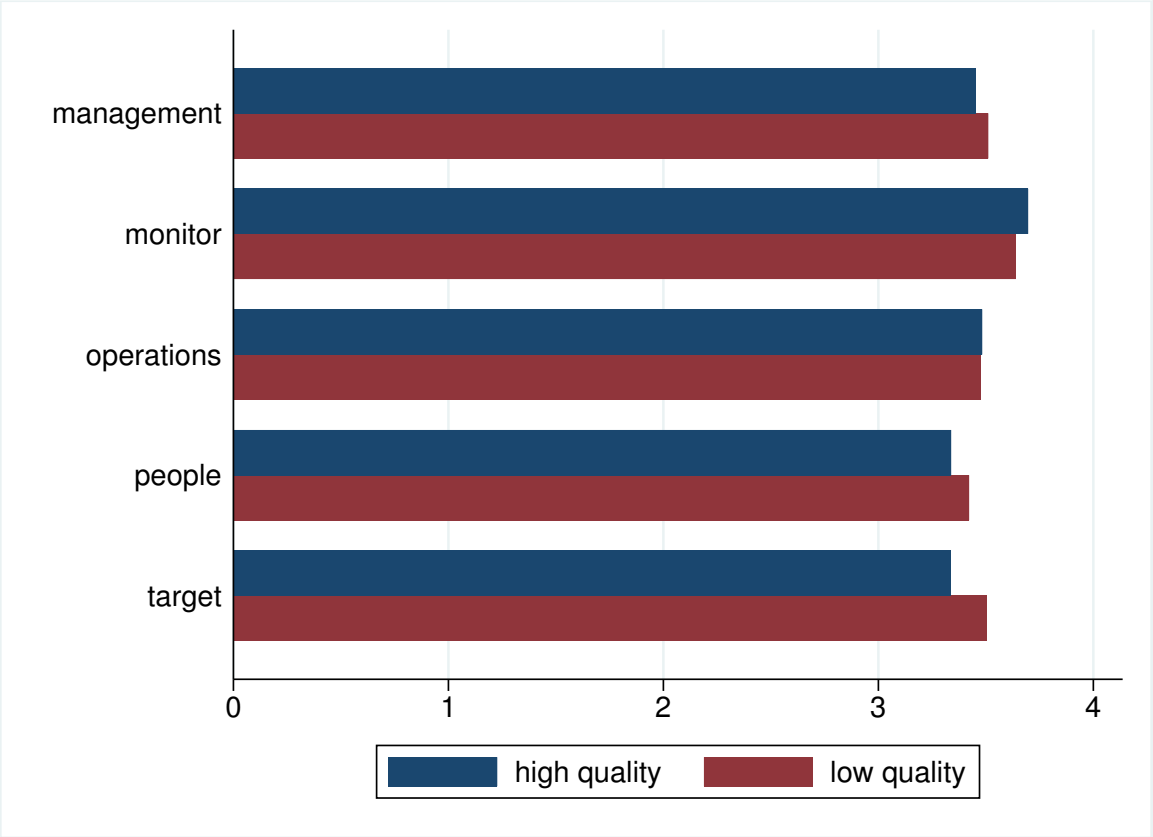
Measuring Venture Capitalist Experience

Among all the experience measures used in the literature, such as number of investment rounds, venture fund age, and cumulative number of investment amount, I follow Sørensen (2007) and use the number of investment rounds. Investors that have participated in more rounds have dealt with more businesses and survived for long time. Similar to Akcigit, Dinlersoz, Greenwood, and Penciakova (2019), I define a venture capitalist as "high quality" if the number of rounds it is involved in the entire sample period is in the 90th percentile of the distribution over the total number of rounds by venture capitalists, and "low quality" otherwise. A firm is considered to be funded by high-quality venture capitalists if 50 percent or more of a firm's investors are of high quality. The average venture capitalist has participated in 13 rounds, and a high quality investor has invested in 30 rounds.

Comparison

Management scores between firms funded by high and low quality investors are very similar (Figure 1.3). Data does not show a significant difference in the overall and component management scores between the two quality groups. One reason could be data limitation, as I am only able to identify 131 observations (about 10% of the total sample size) in the World Management Survey as funded by venture capitalists.

Figure 1.3: Management Scores Comparison by Investor Quality



On the other hand, I find that firms funded by high quality venture capitalists have a significantly lower organizational capital-to-asset ratio. The magnitude is -2.51, which is about 1/3 of the O/K values of an average Compustat firm. This suggests that after controlling for funding amount and other observables, more experienced venture capitalists make firms more operationally efficient.

Table 1.8: Regression of O/K Ratio by VC Quality

	O/K	O/K
High quality dummy	-2.59**	-2.51*
	(0.99)	(0.87)
Years since IPO	0.15**	0.16**
	(0.05)	(0.04)
ln(funding amount)	0.10	0.10
	(0.21)	(0.05)
ln(employment)	-1.90*	-2.13**
	(0.62)	(0.69)
Observations	28240	28240
R-Squared	0.004	0.005
Industry and Year Fixed Effect	No	Yes

Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

1.5 Conclusion

Venture capitalists play an active role in their portfolio companies, and their impact extend far beyond startups' initial public offering. Previous literature uses several hand-collected surveys to help us understand what business decisions venture capitalists make and their impact for a subset of startups. Thanks to the recent development in the measurement of intangible capital and management quality, now we are able to use the management scores in World Management Survey and organizational capital to measure the impact of venture capitalists on all venture-funded firms. This chapter presents three important findings: (1) venture-funded firms have better management practices, especially in setting business strategies and hiring policies. (2) Venture-funded firms operate with lower organizational capital, paying a

lower fixed cost while achieving higher sales and employment. (3) Firms funded by more experienced venture capitalists have a much lower organizational capital. Overall, these results send a consistent message that venture capitalists make firms more operationally efficient.

Results in this chapter have important implications for theory. Traditional financial intermediation theory assumes that financial intermediaries reduces adverse selection or moral hazard. Financial intermediaries might make entrepreneurs more productive, but not adding value to productivity themselves. However, both management scores and organizational capital measures suggest otherwise. Venture capitalists' involvement in setting employee incentives and marketing strategies does have a positive effect on firms' productivity. Moreover, such impact is long term. Firms funded by venture capitalists have higher employment even 10 years after their IPO. Therefore, we need a new production function for financing with venture capitalists.

Chapter 2

Venture Capitalists' Effort: General Equilibrium Study

2.1 Introduction

Venture capitalists play a prominent role in the US economy, tracing back to as early as the 19th Century. The earliest venture capitalists invested in the whaling industry, which at that time had high returns on capital but was both risky and complex in organizational structure. Nowadays, venture capitalists' influence has already extended to quite a few industries. Venture capitalists play an active role in innovative startups in information technology, medical sciences, communications, and so on. They first screen and evaluate potential startups for their future value. Then, they sign a contract with founders that stipulates the amount of funding and allocation of shares. After funding has been injected, venture capitalists go through several rounds to further evaluate startups, provide managerial expertise to improve business operations, and provide further funding, or withdraw investments, depending on the status of startups. Startups that eventually succeed will go through an exit

event of either an IPO or a merger and acquisition, and venture capitalists will cash out their shares at that time.

Given the amount of uncertainty and information asymmetry in the early stage of startups, how to write efficient contracts (initially and subsequently) is often the focus of venture capitalist literature. Contracts that allocates funds to "good" projects and incentivizes entrepreneur's effort will have a positive effect on aggregate total factor productivity (TFP), as resources are allocated more efficiently (Greenwood, Han, and Sanchez (2018)). What is often neglected, however, is that venture capitalists' managerial expertise also enhances startups' TFP, by making business operations more efficient. This is largely due to the lack of data. Venture capitalists are very discreet about their operations. Moreover, their actions are often state-contingent. Thus, it is difficult to assemble a dataset that records what actions have been taken on startups and their outcomes.

This chapter leverages the result in Chapter 1. The World Management Survey, a rare dataset that gathers management performance of both venture and non-venture-funded firms, shows that venture-funded firms have a higher management score, specifically in setting business targets and hiring policies. This allows me to motivate a production function in which venture capitalists' effort enhances firms' TFP and study its macroeconomic impact.

The key contribution of this chapter is that it is the first general equilibrium model about venture capitalists' human capital and its supply. The key assumption is that venture capitalists allocate their effort to firms with heterogeneous productivities under a supply constraint, and their effort enhances firms' TFP.

The results of the model align with empirical observations. It correctly predicts the selection of high-productivity startups, and higher employment levels of venture-funded firms in the long run. Moreover, the comparative statics are also in line with empirical findings in literature. For example, a drop in initial investment increases

the number of marginal projects funded, induces more venture capitalists to enter, and increases aggregate labor productivity. Therefore, this model can be used as a benchmark theoretical model about venture capitalists' effort allocation.

The limitation of this study is that it is unable to quantify the increase in aggregate TFP brought by venture capitalists. In order to do that, a micro-level dataset on venture capitalists' time use is needed. Moreover, moments on the annual number of employees in the venture capital industry are also essential to determine the entry dynamics. It is thus left for future study.

2.2 Literature Review

This chapter is related to three strands of literature. First is the theory for determining the contract between venture capitalists and entrepreneurs. Earlier papers focus on the allocation of control rights. The contract mainly resolves the conflicts of future actions on the firm (Berglöf (1994)), or hold-up problem (Hellmann (1998)). Papers later on start to understand information frictions between venture capitalists and entrepreneurs. Bergemann and Hege (1998) discusses how to determine contracts when venture capitalists learn about project's type over time. This chapter is closest to the strand of literature that focuses on double moral hazard (Casamatta (2003), Repullo and Suarez (2004)). Similar to other papers' setup, my model features unobservable effort by both venture capitalists and entrepreneurs. The difference is that venture capitalists' effort increases the productivity of the project, yet there is a supply limit. As a result, the optimal contract between venture capitalists and entrepreneurs is determined by the optimal allocation of effort among projects with different productivities.

This chapter also touches upon the difference between banks and venture capitalists. In Ueda (2004), venture capitalists have a better screening technology, so

that they can fund entrepreneurs with little collateral or projects that require large upfront investments. In Winton and Yerramilli (2008), venture capitalists are better at assessing uncertainty in firms' business strategies, and thus are suited for funding riskier projects with skewed payoffs. In this chapter, venture capitalists play a role that goes beyond passive assessment. Instead, they possess managerial expertise that can even enhance entrepreneur's own effort to build up business organizations. Their effort will positively affect output even in the long run.

This chapter is also the first general equilibrium model that endogenizes the supply of venture capitalists' effort by modeling the entry dynamics of both entrepreneurs and venture capitalists. My model abstracts from search frictions, discussed in Silveira and Wright (2016), in order to focus on how the supply of venture capitalists' effort affects macroeconomic quantities. Opp (2019) focuses on the cyclicality of venture capitalists' investments and how it affects growth. My model mainly focuses on steady state comparisons. Greenwood, Han, and Sanchez (2018) incorporates dynamic contracts into an endogenous growth framework with both asymmetric information and moral hazard problems, whereas my model chooses to focus on moral hazard. Akcigit, Dinlersoz, Greenwood, and Penciakova (2019) also talks about the complementality between venture capitalists and entrepreneurs, but does not consider the variable intensity of venture capitalists' effort.

2.3 Stylized Facts

This section provides a picture of venture-funded firms in the macro-economy, capturing key facts that the general equilibrium model predicts. I seek to understand the characteristics of venture-funded firms upon selection, and how venture-funded firms compare to those non-venture-funded ones. Despite data limitations, I try to provide some evidence of the supply of venture capitalists' effort.

I combine two datasets for the analysis. The dataset that allows me to track all firms over time is the National Establishment Time Series (NETS) based on Dun & Bradstreet microdata[1]. It provides detailed annual establishment-level information on identifiers, industry, employment, sales, and so on.[2] Firms that receive venture funding are identified using the VentureXpert dataset, which contains round-level information on the funded firm, funding amount, and the identity of venture capitalists. Firms in VentureXpert are matched with NETS using name and other identifier matching techniques, and details can be found in Appendix B.

2.3.1 Characteristics of Venture-Funded Firms

The number of firms funded by venture capitalists is very small and concentrated in a few industries. Figure 2.1 shows the percentage of venture-funded firms (or establishments) found in NETS. Less than 0.01% of the firms are newly funded by venture capitalists every year. The total number of firms funded by venture capitalists at some point in time also does not exceed 0.05%. In VentureXpert, 65% of the firms are in the information technology sector. Among the rest, medical and life science firms comprise another 23%.

Firms funded by venture capitalists are also very young. In Figure 2.2, most firms are at Age 0 when they first receive venture funding, where Age 0 is the year that an establishment is first observed in NETS. Some firms are funded even earlier before they get recorded in NETS as an employer.

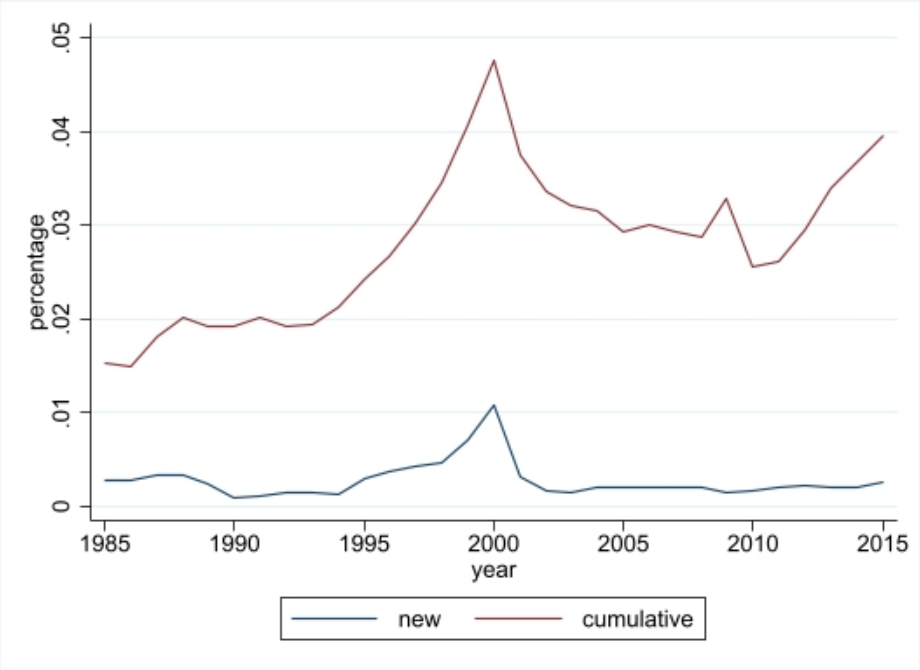
At the first year of their funding, venture-funded firms are much larger in employment compared to their peers. Figure 2.3 shows that almost 50% of the venture-

[1]D&B has strong profit incentives to compile accurate data, as they use and sell the data for marketing and credit scoring. They collect data from state secretaries, Yellow Pages, court records, credit inquiries, and direct telephone contact.

[2]Although the US Census Bureau's Longitudinal Business Database (LBD) is a better source of data, it is not accessible during the pandemic period. A comparison between LBD and NETS is discussed in Appendix B.

funded firms are in the highest quintile when they were selected.[3] This suggests that venture capitalists are highly selective in their investments, preferring to work with firms that exhibit high employment in their early years.

Figure 2.1: Percentage of Venture-Funded Firms in the Economy



[3]There is too much missing data to compute employment growth quintile for venture-funded firms.

Figure 2.2: Age Distribution of Venture-Funded Firms

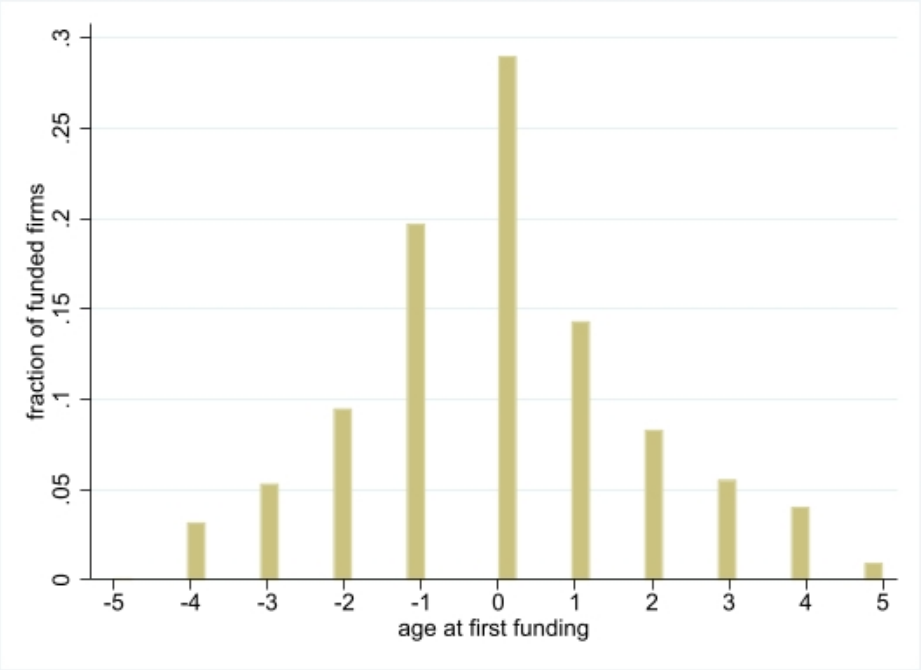
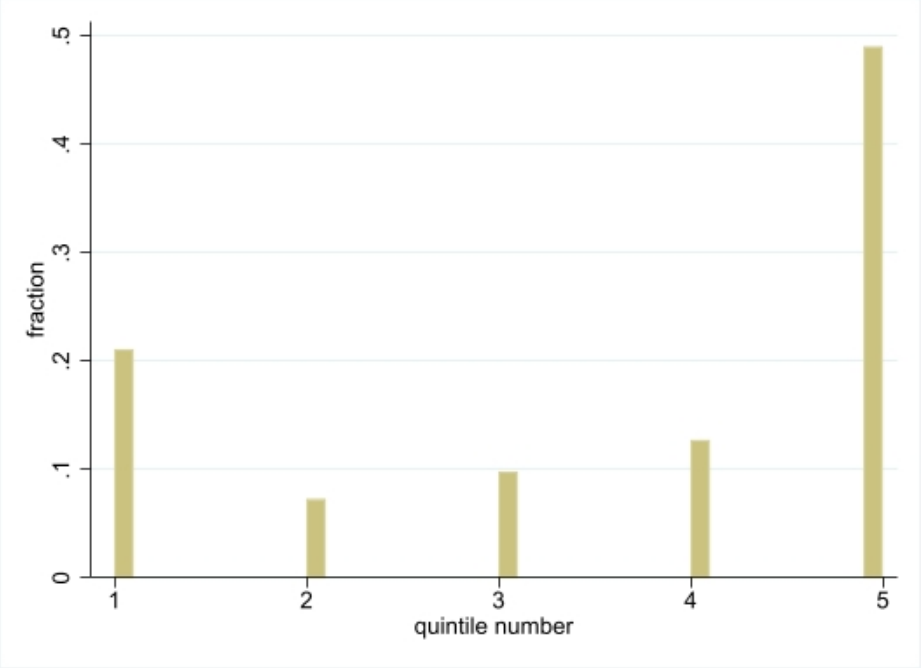


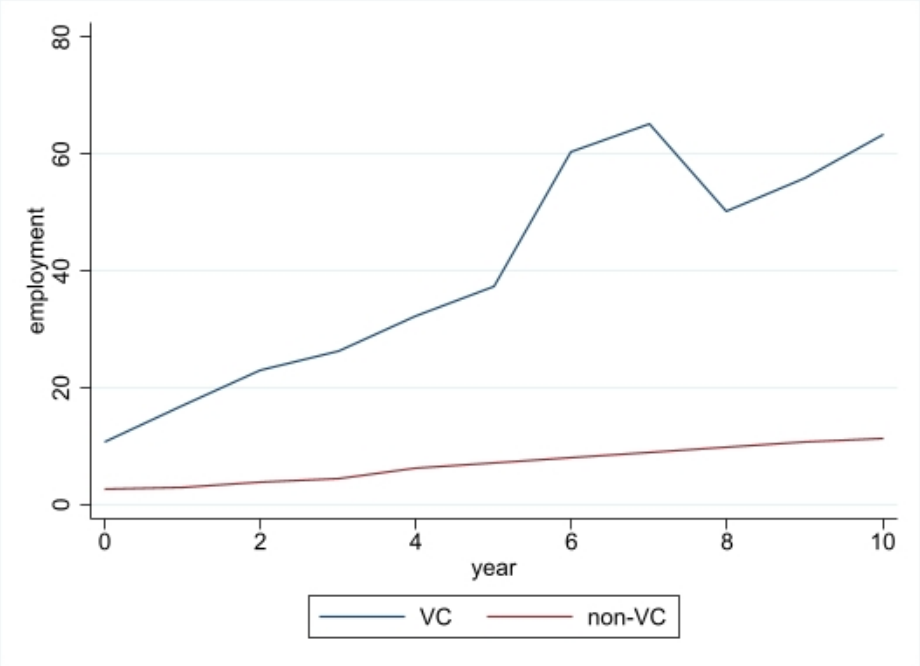
Figure 2.3: Employment Quintile of Venture-Funded Firms



2.3.2 Comparison of Venture-Funded and Non-Venture-Funded Firms

Now I examine the effects of venture capitalist involvement post-funding. Figure 2.4 plots the evolution of average employment after the first venture funding year for both venture- and non-venture-funded firms, where year 0 is the first year that a firm receives venture funding. The two groups both exhibit an upward trend in employment. However, venture-funded firms grow to a much larger size following first funding. At the end of year 5, a venture-funded firm is almost 4 times larger than a non-venture-funded firm on average.

Figure 2.4: Employment After Venture Funding



To control for observables, I run the regression of post-funding employment on venture-funded status, controlling for the initial size of the firm, state, and industry. Table 2.1 shows the results for employment at 3, 5, and 10 year horizon. Firms funded by venture capitalists on average will be 70.5% larger after 3 years of funding, 87.8%

larger after 5 years, and almost twice the size after 10 years. This suggests that venture capitalist involvement in firms is likely to have a strong effect[4].

I also plot the evolution of employment growth for venture- and non-venture-funded firms. 30% of observations is missing employment growth, so there is significant noise. Figure 2.5 shows that venture-funded firms have higher employment growth after funding.[5]

Table 2.1: Regression of Long Term Employment on Venture Status

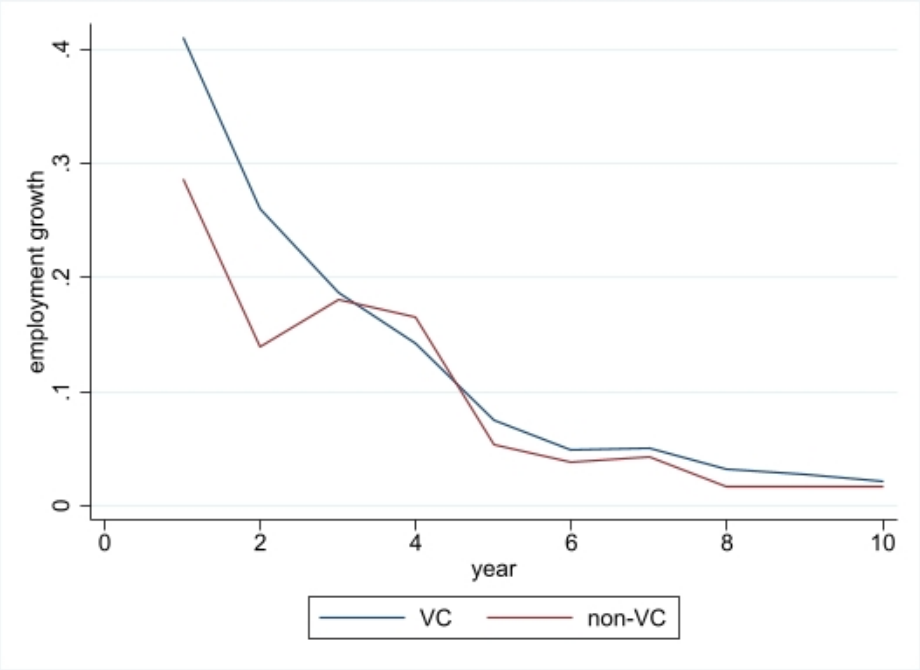
	Emp(3yr,ln)	Emp(5yr,ln)	Emp(10yr,ln)
VC(Dummy)	0.705***	0.878***	1.054***
	(0.025)	(0.033)	(0.035)
Employment at first year (ln)	0.773***	0.713***	0.676***
	(0.008)	(0.008)	(0.008)
Constant	0.295***	0.387***	0.462***
	(0.006)	(0.006)	(0.008)
State F.E.	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
N	24,213,551	16,486,433	7,474,253
R^2	0.619	0.554	0.515

Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[4]In Chapter 1, I document that the channel of such positive effect is through the improvement of managerial productivity.

[5]Akcigit, Dinlersoz, Greenwood, and Penciakova (2019) documents significantly higher employment growth of venture-funded firms using Census data, which has better data quality especially for younger-aged establishments.

Figure 2.5: Employment Growth After Venture Funding



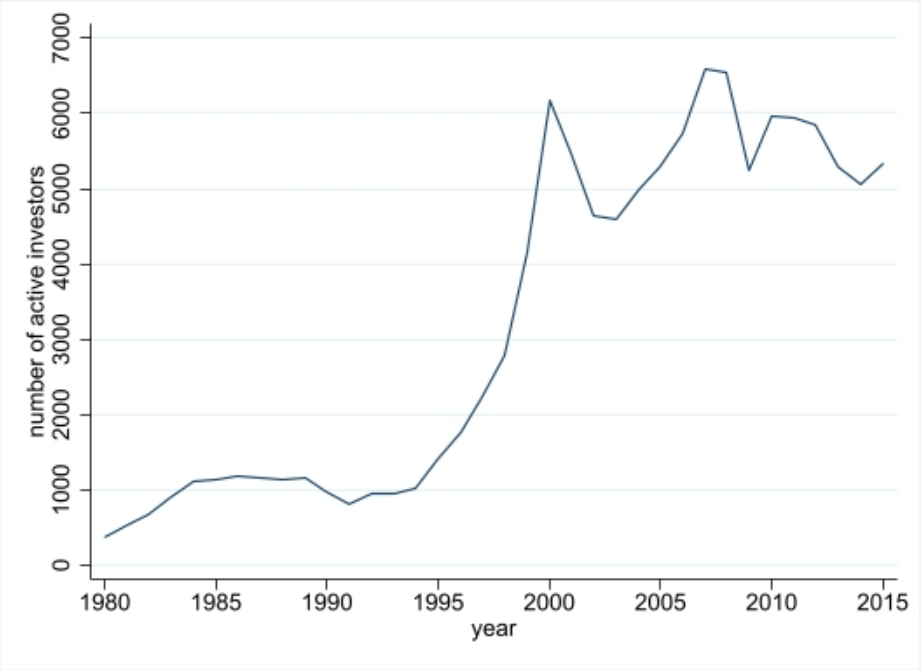
2.3.3 Supply of Venture Capitalists' Effort

Since venture capitalists' involvement heavily influence firms' performance, it is important to understand the total supply of venture capitalists' effort every year, and how venture capitalists allocate their time to different firms. Ideally, we would like to have a dataset that tracks the number of investment staff at each venture capital firm every year[6]. We would also like to have a time use dataset that records the number of hours spent on each firm. Such a dataset, however, is difficult to obtain. Therefore, to understand the supply of venture capitalists' effort, I will use venture capital firm (which can include multiple funds and fund managers) as the unit of measure and examine its number over the years.

Figure 2.6 shows the number of active investors from 1980 to 2015. An active investor is a venture capital firm that has made at least one investment in that year. The number of active investors is relatively constant at about 1000 before the Internet

[6]The Preqin Private Equity dataset has a section with the number of investment staff at each fund, However, it is only the most up-to-date staff number count and does not vary by year.

Figure 2.6: Number of Active Investors by Year



boom, and hovers around 5500 after the boom. There are two possible reasons that equilibrium supply of investors varies little in the short term. On the demand side, it is possible that the number of good firms is limited, until a large technological shock happens. On the supply side, venture capital funds may face capacity constraints if fund manager's human capital is not easily scalable and it takes time to train a new, qualified fund manager.

Some anecdotal evidence leans towards a supply capacity constraint interpretation. In Bernstein, Giroud, and Townsend (2016), the authors note that, "investors are time constrained and notoriously reluctant to provide data on their operations". Moreover, their paper shows that the introduction of new airline routes that reduce venture capitalists' travel times to their existing portfolio companies increases onsite involvement. This suggests that venture capitalists might be facing a capacity constraint for the amount of time available to engage with portfolio companies. Once that constraint is loosened, venture capitalists are able to put in more effort.

In terms of work hours, Gompers, Gornall, Kaplan, and Strebulaev (2020) provides a glimpse into the amount of time allocated to different types of firms and different activities. In terms of time use, venture capitalists work on average 55 hours a week. The majority of hours is split between sourcing deals (15 hours) and assisting portfolio companies (18 hours). Among the 900 venture capital firms being surveyed, the average number of hours spent on information technology and healthcare companies is similar, at about 20 hours. Thus, I deduce that venture capitalists face a capacity constraint, and the optimal amount of effort allocated to companies is less likely to depend on industry type.

2.3.4 Summary

Below are the key observations that my general equilibrium model seeks to capture.

1. Venture capitalists selectively invest in young firms with high employment.
2. Venture capitalists' involvement increases firms' employment even in the long run.
3. Following a positive technological shock, the equilibrium supply of venture capitalists increases.

2.4 Partial Equilibrium

I first illustrate fundamental forces that influence venture capitalists' effort provision and financing decision using a two period model in partial equilibrium. The key element of the model is the production function that describes how venture capitalists' effort increases total factor productivity.

2.4.1 Model Environment

Consider an economy with two dates ($t = 0, 1$), a large set of penniless risk-neutral entrepreneurs, a group of risk-neutral venture capitalists, and a risk-neutral bank. Entrepreneurs have innovative projects that require an upfront investment I, which can come from the bank or venture capitalists. Both venture capitalists and the bank can raise funds at risk free interest rate r.

Entrepreneurs are heterogeneous with observable types (z, c) distributed as $\Phi(z, c)$. The production function is given by,

$$y = z^{\chi} F^{\theta} l^{\beta}, \qquad F = [\gamma h^{\frac{\sigma-1}{\sigma}} + f^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}, \chi + \theta + \beta = 1 \tag{2.1}$$

where z represents total factor productivity (excluding management), F represents management productivity, and l is labor, which is supplied at wage w. Management can come from either entrepreneurs, using f units of effort at cost c, or from venture capitalists, using h units of effort. The importance of venture capitalists' effort is γ, and the degree of substitutability between venture capitalists' effort and entrepreneurs' effort is σ. I assume here that $\sigma > 1$, i.e. h and f are gross substitutes.[7] The probability of success for all projects is constant at ϵ.

Each entrepreneur is matched with a particular venture capitalist, and venture capitalist can work with many entrepreneurs. There is no search friction. Upon the match, venture capitalists observe (z, c) and provide h units of effort. The total supply of effort is H. The contract between venture capitalists and entrepreneurs is determined by Nash Bargaining. It specifies a payment p to venture capitalists if the project is successful, with venture capitalists' bargaining power being α. Effort levels are not observable and therefore not contractible.

[7] Literature notes substantial management turnover at venture-funded firms (Hellmann and Puri (2002),Kaplan, Sensoy, and Strömberg (2009)). Either venture capitalists or new CEOs will be able to replace founders to continue business operations.

The sequence of events is as follows:

- At $t = 1$, entrepreneurs draw (z, c) and decide whether or not to undertake the project, and where to seek financing. If entrepreneur goes to the bank, he receives investment I, and then puts effort f to work on the project on his own. If entrepreneur goes to the venture capitalist, the two of them first sign a contract specifying p, and I is invested. Then, entrepreneur and venture capitalist each chooses his effort level.

- At $t = 2$, project outcome is realized. Successful project produces output according to 2.1, whereas unsuccessful project has zero remaining value. Entrepreneurs repay the bank and venture capitalists.

2.4.2 Optimal Contracts and Financing Decision

Given wage w, labor choice l of an ex post successful project is given by the following profit maximization problem,

$$\Pi \equiv \max_{l} \{z^{\chi} F^{\theta} l^{\beta} - wl\} \tag{2.2}$$

The first order condition with respect to l gives,

$$l = \left(\frac{\beta}{w}\right)^{\frac{1}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} \tag{2.3}$$

so that profit is

$$\Pi = (1-\beta)\left(\frac{\beta}{w}\right)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} \tag{2.4}$$

Bank Finance

Faced by a zero-profit constraint, the bank will charge an interest rate i so that it receives an expected repayment of I. When the project fails, entrepreneurs default

on the principal and interest and repay zero. Thus, the interest rate i satisfies,

$$1 + i = \frac{1 + r}{\epsilon} \tag{2.5}$$

Given bank's interest rate i, bank-financed entrepreneurs solve the following problem to maximize the present value of profit at $t = 0$,

$$\max_f \frac{\epsilon}{1+r}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - cf - I, \qquad F = f \tag{2.6}$$

Solving for the first order condition with respect to f, entrepreneurs' effort choice is

$$f = z\Big(\frac{\epsilon\theta}{c(1+r)}\Big)^{\frac{\theta+\chi}{\chi}} \Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}} \tag{2.7}$$

Present value of the project is thus,

$$E \equiv \max\Big\{z\chi\Big(\frac{\theta}{c}\Big)^{\frac{\theta}{\chi}}\Big(\frac{\epsilon}{1+r}\Big)^{1+\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}} - I, 0\Big\} \tag{2.8}$$

since entrepreneurs always have the outside option of not starting the project after the draw of (z, c). Entry threshold for a bank-financed entrepreneur is therefore,

$$z_s = \frac{I}{\chi}\Big(\frac{\theta}{c}\Big)^{-\frac{\theta}{\chi}}\Big(\frac{\epsilon}{1+r}\Big)^{-1-\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{-\frac{\beta}{\chi}} \tag{2.9}$$

Venture Capital Finance

The contract between venture capitalists and entrepreneurs is determined by the following Nash Bargaining problem,

$$\max_p [\frac{\epsilon}{1+r}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - \epsilon p - E]^{1-\alpha}[\epsilon p - I]^{\alpha}, \quad F = [\gamma h^{\frac{\sigma-1}{\sigma}} + f^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}} \tag{2.10}$$

where E, is the outside option for the entrepreneur, that he can choose to finance with the bank or not start the project. Venture capitalists' outside option is I, in that they can invest the funds in another project.

Solving for the first order condition for p, the surplus for entrepreneur and venture capitalists respectively, is,

$$S_v \equiv \epsilon p - I = \alpha(\frac{\epsilon}{1+r}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - I - E) \tag{2.11}$$

$$S_e = (1-\alpha)(\frac{\epsilon}{1+r}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - I - E) \tag{2.12}$$

After the contract is signed and I is invested, entrepreneurs and venture capitalists choose their effort level to maximize their expected surplus, given the contract and their rational expectation of the effort of the other. The incentive-compatible effort level for the entrepreneur is,

$$\max_f (1-\alpha)(\frac{\epsilon}{1+r}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - I - E) - cf, \qquad F = [\gamma h^{\frac{\sigma-1}{\sigma}} + f^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}} \tag{2.13}$$

Similarly, venture capitalists' incentive-compatible effort maximizes his surplus, taking into account entrepreneur's effort, and the capacity constraint at H.

$$\max_h \alpha(\frac{\epsilon}{1+r}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - I - E) \tag{2.14}$$

$$\int_{z \geq z_v, c \geq c_v} h(z,c) d\Phi(z,c) = H \tag{2.15}$$

where z_v, c_v denote the threshold values for financing with venture capitalists. Let v denote the shadow cost of venture capitalists' effort, solving for the first order conditions with respect to f and h, optimal levels of effort are,

$$f = \Big(\frac{v}{c}\frac{1-\alpha}{\alpha\gamma}\Big)^{\sigma} h \tag{2.16}$$

$$h = z\Big(\frac{\alpha\epsilon\theta}{v(1+r)}\Big)^{\frac{\theta+\chi}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}}\gamma^{\frac{\theta\sigma}{\chi(\sigma-1)}}\Big[1+\gamma^{-\sigma}\Big(\frac{v}{c}\frac{1-\alpha}{\alpha}\Big)^{\sigma-1}\Big]^{\frac{\theta}{\chi(\sigma-1)}-1} \tag{2.17}$$

Lastly, the participation constraint for entrepreneurs, is

$$\frac{\epsilon}{1+r}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}}z^{\frac{\chi}{1-\beta}}F^{\frac{\theta}{1-\beta}} - I \geq E \tag{2.18}$$

So that total surplus should be larger than zero.

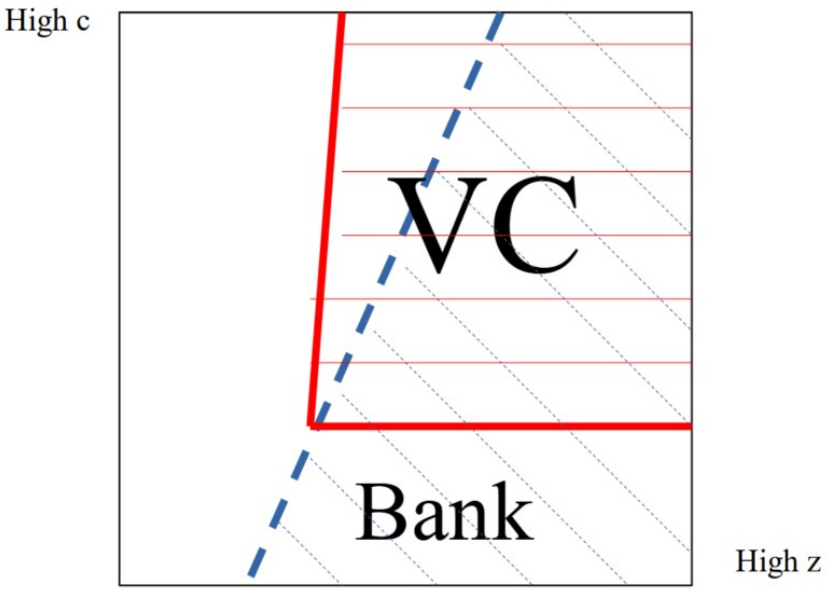
Proposition 2.4.1 *Venture capitalists' level of effort, h, is increasing in z and c, and increasing in H (decreasing in v).*

From the production function, entrepreneur's total factor productivity, z, and management productivity are complements. The better entrepreneur's idea (higher z), the higher the marginal product of venture capitalists' effort h, and therefore a higher level of h will be required to equalize the shadow cost v. Secondly, venture capitalists' effort is a substitute for entrepreneur's effort ($\sigma > 1$). A less efficient entrepreneur (higher c) will cause effort to be shifted toward venture capitalists. Lastly, a smaller supply of venture capitalists' effort H makes it more costly to seek venture capitalists' effort. Thus, a higher marginal product of h is needed to equalize the higher shadow cost v, hence lowering effort level h.

Figure 2.7 depicts the feasibility region for bank and venture capitalist financing respectively. More details can be found in Appendix B. The area in the blue dashed region is the range of projects that will be profitable for entrepreneurs if funded by banks. For an entrepreneur with a higher cost of effort c, his project has a lower management productivity, and therefore requires a higher z to produce enough output to repay the upfront investment. The area in the red solid region is the range of projects that are profitable for venture capitalist funding. It consists of two parts. First, projects that are feasible under bank financing are now more profitable when financed by venture capitalists. Second, some projects that are not feasible under

bank financing are now profitable with venture capitalists. This corresponds to the red-shaded area in between the red solid line and the blue dashed line. This is because venture capitalists' effort is more efficient (lower shadow cost v) than some entrepreneurs' effort cost c. Working with venture capitalists yields a higher management productivity than working as a solo entrepreneur, and the output is higher.

Figure 2.7: Feasibility Region for VC and Bank Financing



2.4.3 Empirical Implications

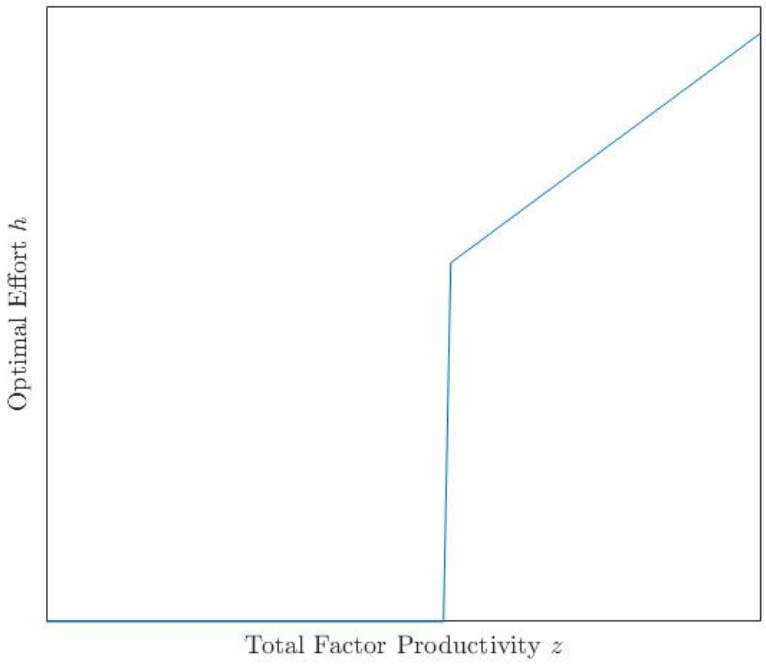
Results from the partial equilibrium model have the following empirical implications.

A. Highly innovative startups get funded by venture capitalists.

Figure 2.8 shows the model predictions on effort choice varying by total factor productivity, for a given founder's effort cost. Only projects with high enough productivity are funded by venture capitalists, and more productive projects receive more effort. It is commonly observed that venture capitalists concentrate their funding in highly

innovative startups, mostly from the information technology and biotechnology sectors. Moreover, startups that turn out to be exceptionally successful, such as Square, Uber, and Snapchat, often have board members from quite a few venture capital funds. Anecdotes from professionals suggest that venture capitalists tend to devote more time to larger startups.

Figure 2.8: Optimal Effort Choice h by Total Factor Productivity z

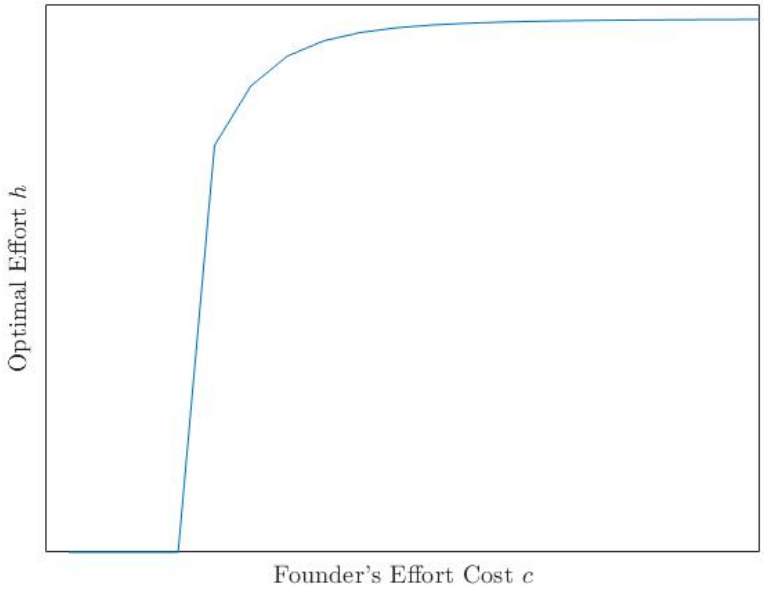


B. Early stage startups receive more help from venture capitalists.

In this model, venture capitalists' effort choice also depends on the relative effort cost of founders. In Figure 2.9, only startups that are more inefficient in management are funded by venture capitalists. Established firms with a complete set of business operations and management structures therefore will not need venture capitalists for financing. On the other hand, early stage startups receive a lot more resources and attention from venture capitalists. Anecdotes often note that early stage startups get hands-on assistance from venture capitalists to set up human resource policies, em-

ployee incentives, and other management strategies. Hochberg (2016) documents the recent rise in the accelerator program, in which venture capitalists provide mentorship specifically for startups that are just founded.

Figure 2.9: Optimal Effort Choice h by Founder's Effort Cost c



C. More startups can be funded when there are more venture capitalists.

The effort cost v for venture capitalists is the shadow cost on the supply constraint. Higher H reduces v and thus increases h. Gompers, Gornall, Kaplan, and Strebulaev (2020) notes that venture capitalists work about 55 hours a week. There is therefore a capacity constraint on the supply of venture capitalists' effort. When there are more venture capitalists, it will be less costly to spend time on startups. Thus, more startups will be funded and receives more effort on average. Kortum and Lerner (2000) analyzes a policy change in 1979 that increases venture capitalist activity, and finds an increase in the number of startups funded and overall higher patent rates.

2.5 General Equilibrium

I embed the partial equilibrium model into a general equilibrium model with free entry of both entrepreneurs and venture capitalists. I characterize the competitive equilibrium and show how venture capitalists' selection and effort choice are affected by entrepreneur types. Then, I analyze the effects of an exogenous decrease in the upfront investment, an exogenous decrease in the interest rate, and an exogenous decrease in the entry cost respectively, and show that the predictions of the model align with empirical observations.

2.5.1 Model Environment

There is a small open economy that takes risk free rate r as given. It has infinite horizon starting at $t = 0$, a representative consumer, a set of penniless risk-neutral entrepreneurs, and a financial sector consisting of risk-neutral bankers and venture capitalists. Entrepreneurs have investment projects that require financing from either bankers or venture capitalists. The projects produce final goods for consumption. The financial sector takes savings from the consumer to fund these projects. The consumer supplies L units of labor.[8]

Entrepreneurs

In the beginning of period t, entrepreneurs each receive a draw of an idea with productivity $z \in [\underline{z}, \bar{z}]$ and managerial effort cost $c \in [\underline{c}, \bar{c}]$. z and c are distributed according to $\Phi(z, c)$. Project requires an upfront investment of I. The production function is,

$$y = z^{\chi} F^{\theta} l^{\beta}, \qquad F = [\gamma h^{\frac{\sigma-1}{\sigma}} + f^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}, \chi + \theta + \beta = 1 \tag{2.19}$$

[8] I abstract from modeling the consumer, who has a lifetime utility function $\sum_{t=0}^{\infty} \beta^t c_t^{1-\rho}/(1-\rho)$.

If project is successful, entrepreneur sells the project and gets the present value of the profits in $t+1$. Success probability of the project at the end of period t is ϵ. Subsequent survival rate of the project every period is s_e.[9]

Bankers

Bankers collect deposits at risk free rate $1+r$. Discount rate, δ, is thus

$$\delta = \frac{1}{1+r} \tag{2.20}$$

The interest rate, i, charged by bankers is such that bankers make zero profit, i.e.

$$1+i = \frac{1}{\delta\epsilon} \tag{2.21}$$

So an entrepreneur who borrows I in period t will repay $I/\delta\epsilon$ in $t+1$.

Venture Capitalists

Each entrepreneur is matched with a particular venture capitalist, and venture capitalist can work with many entrepreneurs. There is no search friction. Upon the match, venture capitalists observe (z, c), and provide h units of expertise to improve the managerial productivity of the project. The aggregate supply of venture capitalists' effort is H. The continuation rate of venture capitalists is s_v.[10]

The contract between venture capitalists and entrepreneurs specifies a payment p to venture capitalists in period $t+1$ when project is successful, with venture capitalists' bargaining power being α. Neither h or f is observable and cannot be contracted upon.

[9] It is commonly observed that success probability during the development period of a project is lower than the survival rate after the project has been successfully developed.

[10] At the end of each period, $1-s_v$ venture capitalists will retire. They stop helping startups and become a pure saver.

Entry

There is free entry with an entry cost c_e and c_v for entrepreneurs and venture capitalists respectively. Entry cost is an increasing function of the number of new entrants, i.e.

$$c_e = \kappa_e m_e^{\eta_e} \tag{2.22}$$

$$c_v = \kappa_v m_v^{\eta_v} \tag{2.23}$$

where κ_e, κ_v are positive constants and m_e, m_v are steady state mass of new entrants for entrepreneurs and venture capitalists respectively.

Timeline of Events

In the beginning of time t, entrepreneurs draw (z, c) and decide whether or not to undertake the project, and where to seek financing. If entrepreneur goes to the bank, he receives investment I, and then puts effort f to work on the project on his own. If entrepreneur goes to the venture capitalist, the two of them first sign a contract specifying p, and I is invested. Then, entrepreneur and venture capitalist each chooses his effort level.

At time $t+1$, project outcome is realized. Successful project produces output according to 2.1, whereas unsuccessful project has zero remaining value. Entrepreneurs repay the bank and venture capitalists.

2.5.2 Decision Problems

Given wage w, labor choice l of an ex post successful project is given by the following profit maximization problem,

$$\Pi \equiv \max_l \{z^\chi F^\theta l^\beta - wl\} = (1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} \tag{2.24}$$

For an entrepreneur who enters at period t, the present value of profits from a successful project is

$$\delta \sum_{t=0}^{\infty} (\delta s_e)^t \Pi = \frac{\delta}{1-\delta s_e}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} \tag{2.25}$$

Bank Finance

Bank-financed entrepreneurs solve the following maximization problem at t,

$$\max_f \frac{\delta\epsilon}{1-\delta s_e}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - cf - I, \qquad F = f \tag{2.26}$$

Solving for the first order condition for f, we have

$$f = z\Big(\frac{\delta\epsilon\theta}{c(1-\delta s_e)}\Big)^{\frac{\theta+\chi}{\chi}} \Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}} \tag{2.27}$$

The present value of profits from a bank-financed project and entry threshold is,

$$E \equiv \max\Big\{z\chi\Big(\frac{\theta}{c}\Big)^{\frac{\theta}{\chi}}\Big(\frac{\delta\epsilon}{1-\delta s_e}\Big)^{1+\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}} - I, 0\Big\} \tag{2.28}$$

$$z_s \geq \frac{I}{\chi}\Big(\frac{\theta}{c}\Big)^{-\frac{\theta}{\chi}}\Big(\frac{\delta\epsilon}{1-\delta s_e}\Big)^{-1-\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{-\frac{\beta}{\chi}} \tag{2.29}$$

Venture Capital Finance

The contract between venture capitalists and entrepreneurs is determined by the following Nash Bargaining problem,

$$\max_p [\frac{\delta\epsilon}{1-\delta s_e}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - \epsilon p - E]^{1-\alpha}[\epsilon p - I]^{\alpha} \tag{2.30}$$

Solving first order condition for p, the surplus for entrepreneur and venture capitalists respectively, is,

$$S_v \equiv \epsilon p - I = \alpha(\frac{\delta\epsilon}{1-\delta s_e}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - I - E) \tag{2.31}$$

$$S_e = (1-\alpha)(\frac{\delta\epsilon}{1-\delta s_e}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - I - E) \tag{2.32}$$

Entrepreneur and venture capitalists maximize surplus respectively given the expectation of the other's effort level. Optimal levels of effort are,

$$f = \Big(\frac{v}{c}\frac{1-\alpha}{\alpha\gamma}\Big)^{\sigma} h \tag{2.33}$$

$$h = z\Big(\frac{\alpha\delta\epsilon\theta}{v(1-\delta s_e)}\Big)^{\frac{\theta+\chi}{\chi}} \Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}} \gamma^{\frac{\theta\sigma}{\chi(\sigma-1)}} \Big[1+\gamma^{-\sigma}\Big(\frac{v}{c}\frac{1-\alpha}{\alpha}\Big)^{\sigma-1}\Big]^{\frac{\theta}{\chi(\sigma-1)}-1} \tag{2.34}$$

Entrepreneur's participation constraint is such that total surplus should be larger than zero,

$$\frac{\delta\epsilon}{1-\delta s_e}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - I \geq E \tag{2.35}$$

Similar to the partial equilibrium model, there is a threshold level $z \geq z_v, c \geq c_v$ above which entrepreneurs will seek venture capitalist financing.

2.5.3 Stationary Competitive Equilibrium

Distribution of Entrepreneurs and Venture Capitalists

To analyze the law of motion for the mass of entrepreneurs, let M_t denote the mass of entrepreneurs at period t.

$$M_t = s_e M_{t-1} + \epsilon m_{e,t} \tag{2.36}$$

That is, the mass of entrepreneurs at t consists of surviving entrepreneurs from last period and successful entrants in this period. In steady state, the mass of new entrants is,

$$m_e = \frac{1 - s_e}{\epsilon} M \tag{2.37}$$

In steady state, the entry condition for entrepreneurs is,

$$\int_{z \geq z_s} E(z, c) d\Phi(z, c) + \int_{z \geq z_v s, c \geq c_v} S_e(z, c) d\Phi(z, c) = c_e = \kappa_e m_e^{\eta_e} \tag{2.38}$$

That is, the expected value of projects (either with bank or with venture capitalists) equals the entry cost.

The law of motion for the supply of venture capitalist effort is,

$$H_t = s_v H_{t-1} + m_{v,t} \tag{2.39}$$

In steady state

$$m_v = (1 - s_v) H \tag{2.40}$$

Entry condition is,

$$\int_{z \geq z_v, c \geq c_v} S_v(z, c) d\Phi(z, c) = c_v = \kappa_v m_v^{\eta_v} \tag{2.41}$$

Aggregate Quantities

In aggregate, the demand for labor from successful entrepreneurs add up to the total supply of labor L from the representative consumer. Among the successful entrepreneurs, those with $z \geq z_v, c \geq c_v$ seek venture capitalists financing, while the rest are funded by the bank.

$$M\Big(\int_{z \geq z_s} l(z, c) \mathbb{1}_{\text{Bank}}(z, c) d\Phi(z, c) + \int_{z \geq z_v, c \geq c_v} l(z, c) d\Phi(z, c) \Big) = L \tag{2.42}$$

The demand for venture capitalist effort from new entrants who seek their financing equals the total supply H.

$$m_e \int_{z \geq z_v, c \geq c_v} h(z,c) d\Phi(z,c) = H \tag{2.43}$$

Lastly, the demand for funding from new entrants equals the supply of savings S from the representative consumer.

$$m_e I \Big(\int_{z \geq z_s} \mathbb{1}_{\text{Bank}}(z,c) d\Phi(z,c) + \int_{z \geq z_v, c \geq c_v} d\Phi(z,c) \Big) = S \tag{2.44}$$

Definition

An equilibrium consists of prices $\{r, w, v\}$, entry and financing choices of entrepreneurs, effort choice of venture capitalists and entrepreneurs, payment to venture capitalists, labor choice of successful projects, and the distribution over the state space $\mathbb{S}$ given by $\Phi(s), s = (z,c), s \in \mathbb{S}$, such that

1. Given wage w, successful projects' labor choice satisfies 2.3.

2. Given r, w, v, entrepreneurs' decision to enter satisfies 2.29, and the decision to finance with venture capitalists satisfies 2.35. Entrepreneurs' effort choice with bank financing satisfies 2.27, and 2.33 when with venture capitalists.

3. Given r, w, v, venture capitalists' effort choice satisfies 2.34.

4. Entrepreneur's surplus when financing with venture capitalists, satisfies 2.31, and venture capitalists' surplus satisfies 2.32.

5. Mass of entrepreneurs evolves according to 2.36.

6. Mass of venture capitalists evolves according to 2.39.

7. Labor, venture capitalist effort, and savings markets clear in 2.42, 2.43, and 2.44.

2.6 Comparative Statics

2.6.1 A Decrease in the Upfront Investment

To analyze the effects of an exogenous decrease in the upfront investment I, I first examine entrepreneur's value under bank financing and his surplus under venture capitalist financing. Notice that,

$$\frac{\partial z_s}{\partial I} = \frac{1}{\chi}\Big(\frac{\theta}{c}\Big)^{-\frac{\theta}{\chi}}\Big(\frac{\delta\epsilon}{1-\delta s_e}\Big)^{-1-\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{-\frac{\beta}{\chi}} > 0 \tag{2.45}$$

so entrepreneurs with lower productivity z will now find it more profitable to enter with a decrease in I. Moreover, using equation 2.31 and 2.28, entrepreneur's surplus is,

$$S_e = \max\Big\{\frac{\alpha\delta\epsilon}{1-\delta s_e}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - z\alpha\chi\Big(\frac{\theta}{c}\Big)^{\frac{\theta}{\chi}}\Big(\frac{\delta\epsilon}{1-\delta s_e}\Big)^{1+\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}}, \\ \frac{\alpha\delta\epsilon}{1-\delta s_e}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - I\Big\} \tag{2.46}$$

where the first part of the surplus is independent of I. That is, entrepreneurs who get funded by venture capitalists because it is more profitable than bank financing will not experience a direct impact from a decrease in the upfront cost I. On the other hand, entrepreneurs who get funded by venture capitalists but would otherwise not undertake their projects will experience an immediate increase in their surplus following a drop in the cost of starting projects.

Thus, the direct impact of a drop in upfront investment is that more entrepreneurs on the margin will enter to start projects, using either bank or venture capitalist financing.

To analyze the general equilibrium effect of a drop in I, first notice that the total mass of entrepreneurs, M, increases due to the increased entry of marginal

entrepreneurs. This causes equilibrium labor wage, w, to increase. Moreover, the increase in new entrants, m_e, also makes the supply constraint for venture capitalists' effort tighter, raising the shadow cost v. As a result, the amount of effort, h, that each venture-funded project receives, decreases, for projects already receiving venture capitalist financing.

To understand the impact on the supply of venture capitalists' effort H, I look at the surplus for venture capitalists,

$$S_v = \max\Big\{\frac{(1-\alpha)\delta\epsilon}{1-\delta s_e}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - z(1-\alpha)\chi\Big(\frac{\theta}{c}\Big)^{\frac{\theta}{\chi}}\Big(\frac{\delta\epsilon}{1-\delta s_e}\Big)^{1+\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}}, \\ \frac{(1-\alpha)\delta\epsilon}{1-\delta s_e}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}} z^{\frac{\chi}{1-\beta}} F^{\frac{\theta}{1-\beta}} - I\Big\} \quad (2.47)$$

where the first part is independent of I and increasing in h. That is, surplus collected from entrepreneurs who also would have qualified for bank financing becomes less, since less effort is spent per project with an increase in new entrants. On the other hand, surplus collected from entrepreneurs who would have not entered before now becomes larger, benefiting from a decrease in I. The overall effect on H depends on the relative magnitude of the two surpluses. There will be more venture capitalists in equilibrium, provided that the increase in surplus from marginal entrepreneurs outweighs the decrease in surplus from other entrepreneurs.

Lastly, the effect on labor productivity is,

$$\frac{Y}{L} = \frac{M\int_{z\geq z_s} y(z,c)\mathbb{1}_{\text{Bank}}(z,c)d\Phi(z,c) + M\int_{z\geq z_v, c\geq c_v} y(z,c)d\Phi(z,c)}{M\int_{z\geq z_s} l(z,c)\mathbb{1}_{\text{Bank}}(z,c)d\Phi(z,c) + M\int_{z\geq z_v, c\geq c_v} l(z,c)d\Phi(z,c)} = \frac{w}{\beta} \quad (2.48)$$

since for every operating business, the first order condition with respect to l gives,

$$w = \beta z^{\chi} F^{\theta} l^{\beta-1} = \frac{y}{l} \quad (2.49)$$

Thus labor productivity is proportional to w and hence increases.

I summarize the results as follows.

Proposition 2.6.1 *A decrease in the upfront cost of investment I leads to*

1. *a reduction in the entry threshold z_s, z_v.*

2. *a decrease in effort received from venture capitalists h.*

3. *an increase in the total mass of entrepreneurs M.*

4. *an increase in labor productivity $\frac{Y}{L}$.*

Figure 2.10 illustrates the effects of a decrease in the upfront investment I using a numerical example. Details can be found in Appendix B. Equilibrium values before the change are indicated with blue solid lines while those after the change are represented by red solid lines. For a given founder's cost c, projects with lower z get funded and receive more surplus than before. However, projects already funded before the change now receive less effort and surplus.

Figure 2.10: Effects of decrease in I - effort levels and entrepreneur's surplus.

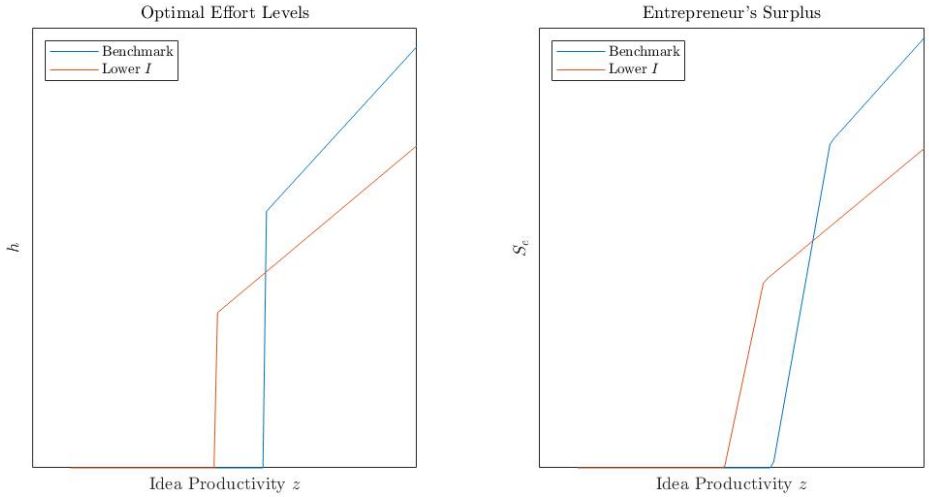
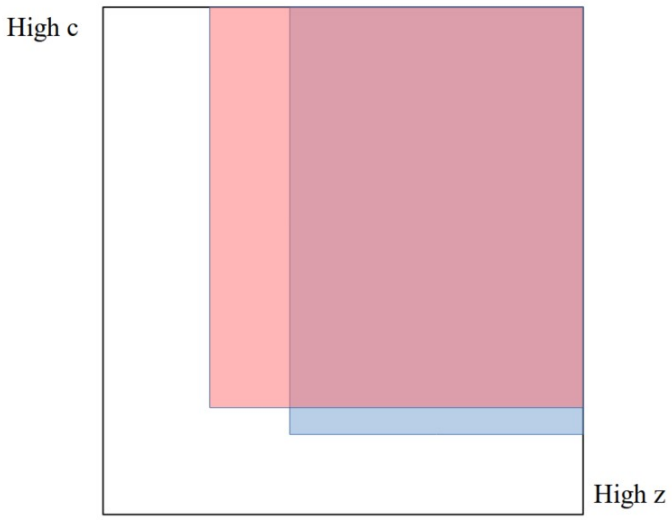


Figure 2.11 shows the venture-funded region before and after the decrease in I. The region funded before the change is indicated with blue-shaded area, while the

region funded after is the red-shaded area. Entrepreneurs with lower z benefit from the decrease in the upfront investment. On the other hand, entrepreneurs with lower c now opt out of venture capitalists' service, as the cost of venture capitalists' effort becomes higher due to an increase in demand for their effort.

Figure 2.11: Effects of decrease in I - venture-funded region



In Ewens, Nanda, and Rhodes-Kropf (2018), the authors analyze changes in investment approach by venture capitalists following the advent of Amazon's Web Services (AWS) in early 2006. Cloud computing lowers the initial cost of starting businesses for firms in online services. Using a difference-in-difference approach, the authors find that startups affected by cloud computing require a lower initial funding size (I). Moreover, venture capitalists have made more investments, while providing less governance (h) to their portfolio companies. The authors further note that marginal ventures with lower expected payoffs comprise of most of the new investments made by venture capitalists. Their observations align with the model predictions on the effects of a decrease in I.

2.6.2 A Decrease in Interest Rates

A decrease in interest rate, r, increases the discount rate δ. The direct effect of an increase in δ is,

$$\frac{\partial E}{\partial \delta} > 0, \qquad \frac{\partial S_e}{\partial \delta} > 0, \qquad \frac{\partial S_v}{\partial \delta} > 0, \qquad \frac{\partial h}{\partial \delta} > 0 \tag{2.50}$$

That is, higher present value of projects leads to higher expected payoff when financing with the bank, higher surplus for both entrepreneurs and venture capitalists, and motivates venture capitalists to provide more effort.

In equilibrium, higher surplus induces more entrepreneurs and venture capitalists to enter, raising the total mass M and H. This in turn leads to higher demand for labor and venture capitalist effort, raising equilibrium prices v and w. Higher v, w reduces effort h and expected payoff and surplus S_e, S_v, E. Thus, the overall effect on effort levels h is less clear. Labor productivity increases as wage increases.

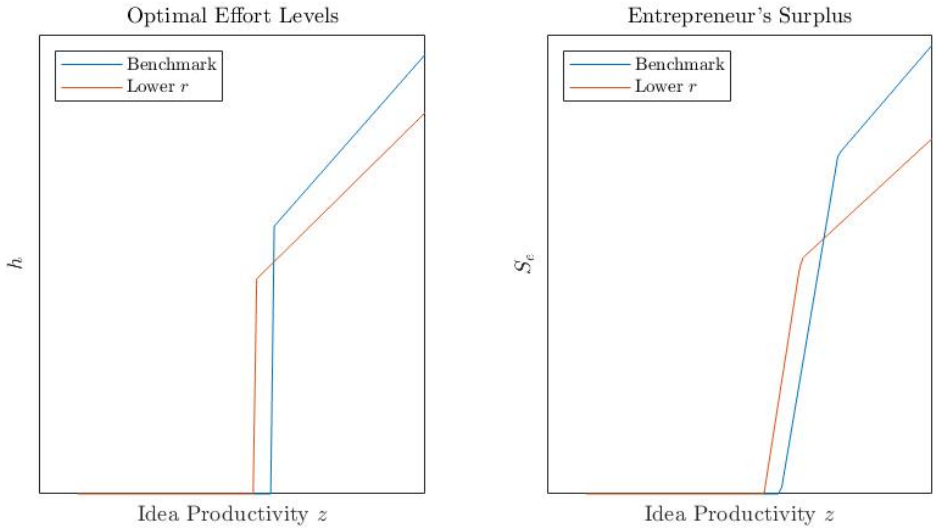
Proposition 2.6.2 *A decrease in interest rate r leads to*

1. *a reduction in the entry threshold z_s, z_v.*
2. *an increase in the total mass of entrepreneurs M.*
3. *an increase in the total supply of venture capitalists effort H.*
4. *an increase in the labor productivity, $\frac{Y}{L}$.*

Figure 2.12 shows the optimal effort level and entrepreneur's surplus before and after the decrease in interest rate r. Given the parameters, the negative impact on h from an increased w, v significantly outweighs the positive impact from a decrease in r. As a result, while the newly funded projects get attended by venture capitalists compared to not funded at all, the projects that would have been funded before the decrease in r now receives less attention. As entrepreneur's surplus is an increasing

function of h, the effect on entrepreneur's surplus on the right panel exhibits the same pattern as the left panel.

Figure 2.12: Effects of decrease in r - effort levels and entrepreneur's surplus.



A recent Economist article[11] notes that the fall in interest rates has prompted more investors to enter into venture capital financing, investing more funds into riskier businesses. This is in line with model predictions, that lower interest rates encourages the entry of marginal entrepreneurs and also venture capitalists.

2.6.3 A Decrease in Venture Capitalists' Entry Cost

When regulatory changes lower venture capitalists' entry cost, κ_v, the immediate effect is to raise the amount of venture capitalists' effort, H. From the entry condition, we have,

$$H = \frac{1}{1-s_v}\left(\frac{\int_{z\geq z_v, c\geq c_v} S_v(z,c)d\Phi(z,c)}{\kappa_v}\right)^{\frac{1}{\eta_v}} \tag{2.51}$$

[11] https://www.economist.com/finance-and-economics/2021/11/23/the-bright-new-age-of-venture-capital/21806438

so that $\frac{\partial H}{\partial \kappa_v} < 0$. Moreover, from the market clearing condition,

$$m_e \int_{z \geq z_v, c \geq c_v} h(z,c) d\Phi(z,c) = H \tag{2.52}$$

so that a higher supply of venture capitalists' effort lowers the shadow cost v.

The shadow cost v affects venture-funded projects in two ways. On the extensive margin, founders who have lower management cost c and used to find venture capitalists' effort more expensive will now find it more profitable to finance with venture capitalists than the bank given the lower shadow cost v. On the intensive margin, each venture-funded project now gets more effort, since,

$$h = z\Big(\frac{\alpha\delta\epsilon\theta}{v(1-\delta s_e)}\Big)^{\frac{\theta+\chi}{\chi}} \Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}} \gamma^{\frac{\theta\sigma}{\chi(\sigma-1)}} \Big[1+\gamma^{-\sigma}\Big(\frac{v}{c}\frac{1-\alpha}{\alpha}\Big)^{\sigma-1}\Big]^{\frac{\theta}{\chi(\sigma-1)}-1}, \qquad \frac{\partial h}{\partial v} < 0 \tag{2.53}$$

As each venture-funded project gets higher effort h, managerial productivity F becomes higher. The marginal product of labor thus increases, raising the demand for labor. Wage w therefore increases, and so is labor productivity.

On the other hand, the effect on the total mass of entrepreneurs, M, is unclear. Although venture-funded entrepreneurs get a higher surplus due to higher effort, bank-funded entrepreneurs may get lower payoffs due to higher wages. Summarizing the results, we have

Proposition 2.6.3 *A decrease in venture capitalists' entry cost κ_v leads to*

1. *a reduction in the entry threshold c_v for venture financing.*
2. *an increase in effort h spent on each project.*
3. *an increase in the total supply of venture capitalists effort H.*
4. *an increase in labor productivity, $\frac{Y}{L}$.*

Figures 2.13 and 2.14 illustrates the effect of a lower entry cost κ_v from the numerical example. Figure 2.13 shows how venture capitalists' effort provision and entrepreneur's surplus vary by founder's effort cost c, for a given feasible productivity level z. Each project now gets more effort and higher surplus for the entrepreneur. Figure 2.14 further shows that the entry threshold c_v is now lower following a decrease in the entry cost.

Figure 2.13: Effects of decrease in κ_v - optimal effort and entrepreneur's surplus

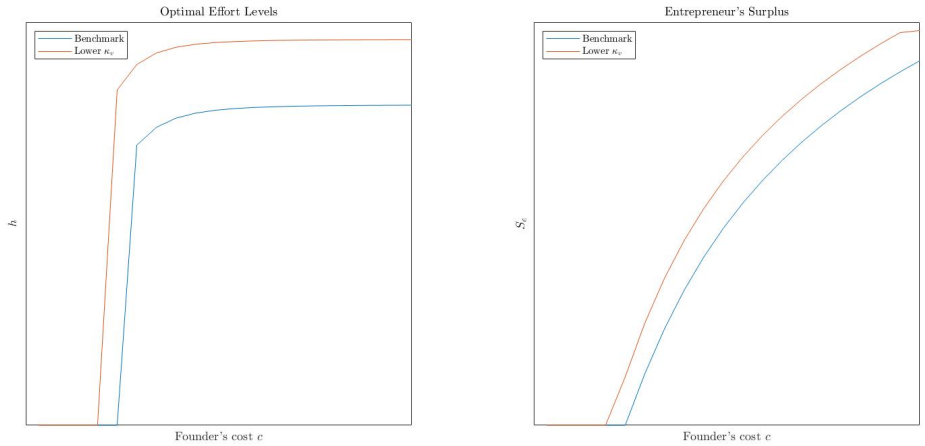
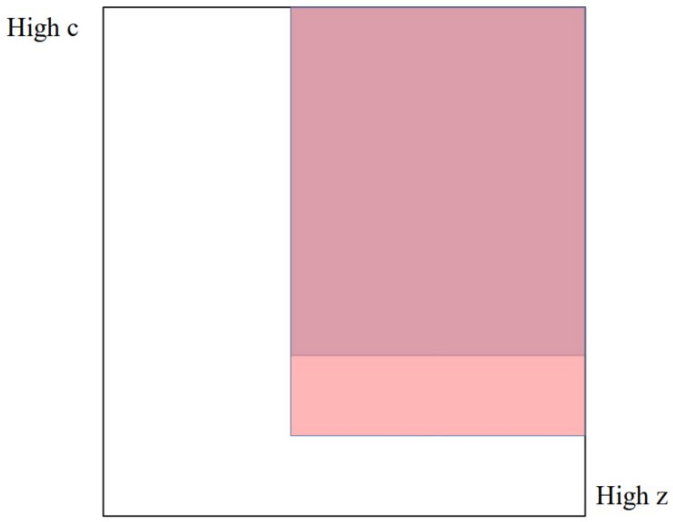


Figure 2.14: Effects of decrease in κ_v - venture-funded region



The predictions of the model are in line with the recent findings in Ewens and Farre-Mensa (2020). The authors analyze the impact of a deregulation event, the National Securities Market Improvement Act (NSMIA), on venture capitalists' funding behavior. NSMIA has made it easier for startups to raise private capital from out-of-state investors in a few ways, such as exempting private firms from complying with the blue sky laws of every new state where they issue securities. The removal of restrictions reduces the entry cost especially for out-of-state investors. The authors find an increase in the funding amount to late-stage startups. Moreover, they document an increase in scale in startups, as seen from higher employment and sales. In my model, late-stage startups resemble low c type entrepreneurs[12], and therefore benefit from a lower entry cost. The increase in employment is also reflected in my model, as higher effort provision by venture capitalists raise the management productivity of projects and subsequently labor demand becomes higher.

2.7 Conclusion

This chapter writes a general equilibrium model that focuses on venture capitalists' effort supply and its impact. The key assumption is that venture capitalists' effort increases firm's managerial productivity, and its supply is determined using a free entry condition. Model predictions are in line with several empirical observations, so are the comparative statics. My model shows that although venture capitalists have positive effects on labor productivity, they face a supply constraint that limits their ability to assist more firms. This study has two implications. First, it shows the importance of understanding the time use of venture capitalists, and urges future data collection effort to better understand how venture capitalists optimize their effort among different types of firms and investment activities. Second, it shows that under

[12]Late-stage startups often have already developed a mature system of business operations, hence the cost to raise management productivity is lower.

current low interest rate environment, policymakers should focus more on venture capitalists' time constraint, rather than the inflow of funds, as the former is more likely to be the bottleneck to the growth of entrepreneurship.

Chapter 3

Lottery Experiment on Entrepreneurs' Financing Constraint

3.1 Introduction

Entrepreneurs play an important role in job creation in the US economy. Business startups contribute to about 20% of US gross job creation (Decker, Haltiwanger, Jarmin, and Miranda (2014)). The Small Business Administration (SBA) therefore set in place several policies dedicated to support young businesses. Some of the policies include helping small businesses win federal contracts[1], providing SBA-backed loans[2], and various tax credit programs[3]. During the recent pandemic, small businesses received paycheck protection and other COVID 19 relief packages. Motivated by the recent rise in studies on nationwide lottery programs and entrepreneurship (Fagereng, Holm, and Natvik (2021), Bermejo, Ferreira, Wolfenzon, and Zambrana

[1]https://www.sba.gov/federal-contracting/contracting-assistance-programs
[2]https://www.sba.gov/funding-programs/loans
[3]https://home.treasury.gov/policy-issues/coronavirus/assistance-for-small-businesses/small-business-tax-credit-programs

(2018), Kuhn, Kooreman, Soetevent, and Kapteyn (2011)), I explore the question, "What will happen to entrepreneurship if the US were to run a lottery sector like Norway's?" I layout a standard Bewley model with an entrepreneur sector and a lottery sector, to understand how winning a lottery prize affects agent's consumption, saving, and occupation choices. Results of the model help to inform how effective public cash transfer programs like lottery would be to incentivize entrepreneurship, and provide lessons about its implementation.

My model is based on Kitao (2008), in which parameters are set to match selected moments of the US economy. On top of that, there is a lottery sector, which is calibrated based on the lottery sector revenue in Norway and prize distributions in Fagereng, Holm, and Natvik (2016). Agents in the economy participate in lottery every period and buy the same amount of lottery tickets.

The theoretical insight from the model is that winning lottery prizes will increase entrepreneurs' investment for sure. On the other hand, its effect on the probability of entering business depends on abilities of would-be entrepreneurs. This is in line with empirical findings in Holtz-Eakin, Joulfaian, and Rosen (1994a) and other recent lottery studies.

One limitation of the model is that entrepreneurial ability is modeled using a discrete grid of four levels. There are not enough moments on entrepreneurial dynamics available to allow for a denser grid. The consequence is that there might be fewer entrepreneurs on the margin. As a result, the model might underestimate the effect of lottery prizes on the probability of entering entrepreneurship, and the total amount of entrepreneurs.

The key contributions of this chapter is that it provides a benchmark model that can be used to study the potential effect of a lottery program in the US. Moreover, it suggests that while lottery programs are getting popular in several countries, their

effectiveness is not guaranteed. The ability of marginal entrepreneurs, and the size of the lottery program, are both important in determining success.

3.2 Literature Review

This paper is related to the following three strands of literature. The first is the empirical literature that uses wealth shocks as natural experiments to study to what extent financing constraints affect the probability of starting businesses. My model sheds theoretical insight on the possible explanation for the mixed empirical results in the current literature. Hurst and Lusardi (2004) challenges the prevailing opinion (Evans and Leighton (1989), Holtz-Eakin, Joulfaian, and Rosen (1994a), Holtz-Eakin, Joulfaian, and Rosen (1994b)) that entrepreneurs are financially constrained by showing that there is no significant relationship between household wealth and the probability to start a business over most of the wealth distribution. They further show that alternative proxies for liquidity, such as inheritance and regional house price gains, do not change the result. However, subsequent studies using inheritance and regional house price gains as wealth shocks suggest otherwise. Andersen and Nielsen (2012) finds receiving windfall inheritance due to sudden death of parents increases the probability of becoming an entrepreneur. Corradin and Popov (2015) exploits regional house price variations and shows the probability of starting a new business is strongly, positively correlated with the value of home equity. And Adelino, Schoar, and Severino (2015) finds larger employment growth among the self-employed and small businesses in areas with steeper house price appreciation. My model shows that pure transitory income shocks do not necessarily increase the likelihood to enter entrepreneurship. It depends on the ability of entrepreneurs at the margin. Thus, it is likely that mixed results are obtained, as the distributions of entrepreneurial ability at the margin are different.

My paper is also inspired by the recent literature on nationwide lottery programs. Compared to inheritance and home equity, lottery prizes are a better proxy for transitory increases in disposable income, especially when almost every one in the economy plays lottery games and purchases similar amount of tickets. My paper could be a benchmark theory model for settings in Bermejo, Ferreira, Wolfenzon, and Zambrana (2018) and Cespedes, Huang, and Parra (2021). In addition to confirming their empirical results, my paper shows that if the US were to start a nationwide lottery program like Norway, the number of entrepreneurs in steady state will likely to be little affected. Among others, Kuhn, Kooreman, Soetevent, and Kapteyn (2011) uses lottery programs to study the effect of prizes on the consumption of durables and find social effects of lottery winnings.

Lastly, my paper is related to the broad question of what factors determine the decision to become an entrepreneurs. Similar to Evans and Jovanovic (1989) and Quadrini (2000), personal wealth affects occupation choice in my model. On the other hand, other factors, such as non-pecuniary benefits (Hurst and Pugsley (2011)) and downside insurance (Hombert, Schoar, Sraer, and Thesmar (2020)) are also shown to affect the motivation to become entrepreneurs. My paper does not touch on these dimensions, as lottery prizes bring mostly pecuniary benefits.

3.3 The Model

Based on Kitao (2008), I numerically solve an incomplete market model with an entrepreneur sector and a lottery sector, simulate lottery outcomes, and study how entry to entrepreneurship changes in response to winning a lottery. The model environment and parameters are close to Kitao (2008) and match moments of the US economy.

3.3.1 Endowment

Agents are infinitely-lived. Each agent enters a period with an occupation chosen in the previous period. There are two types of occupations. The worker supplies labor for a wage in the market, and the entrepreneur owns a business, uses his managerial ability and labor, and hires capital and labor for production. I assume that entrepreneurs can only manage one business at a time.

Each agent is endowed with labor productivity η, which represents efficiency units per unit of work hours. Agents are also endowed with entrepreneurial ability θ. η and θ are assumed to be independent. Both follow a finite-state Markov process.

3.3.2 Preference

Preferences are time-separable with a constant subjective discount factor β. Agents have expected discounted utility given as

$$E_t\Big\{\sum_{t=0}^{\infty}\beta^t u(c_t)\Big\} \tag{3.1}$$

The utility function takes the standard CES form, $u(c) = c^{1-\sigma}/(1-\sigma)$. σ is the coefficient of relative risk aversion.

3.3.3 Technology and Production

The economy has two sectors of production. One is the entrepreneurial sector, the other is the corporate sector.

Entrepreneurial sector: each entrepreneur combines his managerial ability, capital, and labor and produces output according to the production function,

$$y = f(k, l, \theta) = \theta(k^{\alpha}l^{1-\alpha})^{v} \tag{3.2}$$

where $v < 1$, capturing the entrepreneur's limited "span of control".

Corporate sector: the production function is also Cobb-Douglas except that it is constant returns to scale.

$$Y = F(K, L) = AK^{\alpha}L^{1-\alpha} \tag{3.3}$$

Capital in both sectors depreciate at a rate δ. α is the capital share.

3.3.4 Borrowing Sector

The borrowing sector consists of competitive banks, which collect deposits from households and lend to both the entrepreneurial and corporate sectors. Workers face a no-borrowing constraint and cannot hold negative assets. Entrepreneurs can borrow, but their borrowing cost is higher than the corporate sector with a spread ι, so that the total borrowing cost is $r_d = r + \iota$, where r is the risk free rate, the rate at which banks pay for households for deposits and lend to the corporate sector.

I also assume that due to unobserved managerial ability, entrepreneurs can only borrow up to the maximum leverage at d of their net worth, and they are not allowed to default.

3.3.5 Lottery Sector

Each period, the lottery sector takes payment τ from households and distributes three types of prizes ψ: small, medium, and large, randomly to a subset of agents in the economy. I assume that all agents participate in the lottery, and each agent can only buy one lottery ticket at a time.

3.3.6 Government

The government raises tax revenues to finance its expenditure G. A balanced budget is imposed every period. The government takes consumption tax at constant rate τ_c, and an individual income tax as a function $T(I)$ of income I of the agent. To approximate the US income tax system, the parametric form of the tax schedule is

$$T(I) = a_0\{I - (I^{-a_1} + a_2)^{-1/a_1}\} + \tau_I I \tag{3.4}$$

3.3.7 Household Problem

Timing of events: The occupation of each agent is pre-determined from the previous period. At the beginning of each period, a pair of idiosyncratic shocks (labor productivity η and entrepreneurial ability θ), together with the outcome of lottery, are realized. Given the shocks and lottery outcomes, workers then choose their consumption and saving, while entrepreneurs make the additional decisions on the amount of labor and capital. Production then takes place in both the corporate and entrepreneurial sectors, followed by factor payments and loan repayments. Workers and entrepreneurs pay income taxes. There is no aggregate uncertainty. Lottery prizes are independent and identically distributed across agents and over time.

Optimization problem. Given assets a, labor productivity η, managerial ability θ, lottery prize ψ, and prices r, w, households choose consumption, savings, and next period's occupation to maximize the present value of discounted utility. Denote worker's and entrepreneur's value functions by V^W and V^E respectively, the recursive problem is defined as,

Worker's problem

$$V^W(a,\theta,\eta,\psi) = \max_{c,a',i}\{u(c) + i\beta EV^W(a',\theta',\eta',\psi') + (1-i)\beta EV^E(a',\theta',\eta',\psi')\} \quad (3.5)$$

subject to

$$(1+\tau_c)c + a' = \eta w + (1+r)a + \psi - \tau - T(I) \quad (3.6)$$

$$I = \eta w + ra + \psi - \tau \quad (3.7)$$

$$a' \geq 0, \quad c \geq 0, \quad i \in \{0,1\} \quad (3.8)$$

where i is an indicator function that equals 1 if the agent is a worker in the next period and 0 otherwise. The worker's taxable income consists of labor income, capital income from savings, and net lottery income.

Entrepreneur's problem

$$V^E(a,\theta,\eta,\psi) = \max_{c,a',i}\{u(c) + i\beta EV^W(a',\theta',\eta',\psi') + (1-i)\beta EV^E(a',\theta',\eta',\psi')\} \quad (3.9)$$

subject to

$$(1+\tau_c)c + a' = \pi^E(a,\eta,\theta,\psi) + \psi - \tau \quad (3.10)$$

$$a' \geq 0, \quad c \geq 0, \quad i \in \{0,1\} \quad (3.11)$$

where π^E is the after tax income to the entrepreneur and determined as,

$$\pi^E(a,\theta,\eta,\psi) = \max_{k,n}\{f(k,n,\theta) + (1-\delta)k - (1+\tilde{r})(k-a) - w\max\{n-\eta,0\} - T(I)\} \quad (3.12)$$

where

$$I = f(k, n, \theta) - \delta k - \tilde{r}(k - a) - w \max\{n - \eta, 0\} - \tau + \psi \tag{3.13}$$

$$k \leq (1 + d)(a - \tau + \psi) \tag{3.14}$$

and

$$\tilde{r} = \begin{cases} r & \text{if } k \leq a \\ r + \iota & k > a \end{cases}$$

Entrepreneur's income consists of output from production, net of depreciation cost, net labor cost, and loan repayments. If entrepreneur is a net borrower, $k > a$, then he pays interest at rate $r + \iota$ for the borrowing. If he is a net saver, then he earns interest at rate r on the remaining assets $a - k$.

Winning a lottery prize, ψ, adds to entrepreneurs' current period income I and relaxes borrowing constraint.

3.3.8 Stationary Competitive Equilibrium

At the beginning of each period, the state vector is $s = (a, \eta, \theta, \psi, \epsilon)$, i.e. asset holdings, labor productivity, entrepreneurial ability, lottery prizes, and occupation $\epsilon \in \{W, E\}$. Let $a \in \mathbb{A}, \eta \in \mathbb{H}, \theta \in \Theta, \psi \in \Psi$ and $\epsilon \in \xi$. Denote the entire state space by $\mathbb{S} = \mathbb{A} \times \mathbb{H} \times \Theta \times \Psi \times \xi$. An equilibrium consists of prices $\{r, w\}$, policy functions of workers and entrepreneurs, government tax system, intermediaries, lottery sector, value functions and the distribution of agents over state space $\mathbb{S}$ given by $\Phi(s), s \in \mathbb{S}$, such that

1. Given the prices and tax, the policy functions solve the household optimization problem for each state s.

2. The prices satisfy the marginal productivity conditions, i.e. $r = F_K(K, L) - \delta$, and $w = F_N(K, L)$.

3. The intermediary sector is competitive. Banks receive deposits from households and pay interest r, and offer loans to the corporate sector and entrepreneurs at rate r and $r + \iota$ respectively.

4. Capital and labor markets clear:

$$K + \int k d\Phi(s) = \int a d\Phi(s)$$
$$N + \int n d\Phi(s) = \int \eta(s) d\Phi(s)$$

5. The lottery sector clears total rewards with revenue:

$$\tau = \int \psi(s) d\Phi(s)$$

6. Government budget is balanced:

$$G = \int [\tau_c c(s) + T(I(s))] d\Phi(s) \tag{3.15}$$

7. The distribution Φ is time-invariant. The law of motion for the distribution of agents over state space $\mathbb{S}$ satisfies

$$\Phi = Q_\Phi(\Phi)$$

where Q_Φ is the one-period transition operation on the distribution.

3.4 Calibration

I will be calculating and comparing two steady state economies, one with and one without the lottery sector. The benchmark economy is without the lottery sector and resembles the current US economy. Table 3.1 gives the set of a priori parameters and are based on Kitao (2008). These parameters are set to match moments such as capital-output ratio, government expenditures, and entrepreneur dynamics.

Table 3.1: A Priori Parameters

Parameter	Description	Values
Preference		
σ	relative risk aversion	2.0
β	discount factor	0.9575
Production technology		
α	capital share in the corporate sector	0.36
v	entrepreneur's span of control	0.88
δ	depreciation rate of capital	0.06
Labor and entrepreneurship		
η	efficiency unit	Appendix
θ	entrepreneurial ability	Appendix
Tax system		
τ_c	consumption tax rate	0.0567
τ_I	proportional tax rate on income	0.0316
$\{a_0, a_1, a_2\}$	nonlinear tax schedule	$\{0.258, 0.768, 0.438\}$
Intermediary sector		
ι	loan premium	0.05
d	maximum leverage ratio	0.5

Lottery Sector: in order to set up the winning probabilities, I use the distribution of lottery prizes, shown in Fig 3.1, from Fagereng, Holm, and Natvik (2016), as it is the only paper that provides detailed description of the lottery sector and prize distributions. To simplify the computation, I discretize the lottery prize distribution as follows. First, the sizes come in small, medium, and large, as the prize distribution features three intervals (0 to 20,000, 20,000 to 40,000, 40,000 to 60,000) with distinctly different winning probabilities. Then, I set the relative prize magnitudes to be 1, 3, and 6, as the largest prize is about 60,000 USD.

Based on Fagereng, Holm, and Natvik (2016), the fraction of winners is 0.5%. I make 94% of the winners win the small prize, corresponding to the total fraction of winners with prizes less than 20,000 USD in Figure 3.1. 5% of the winners win a medium prize, corresponding to the total fraction of winners with prizes between 20,000 to 40,000 USD, and 1% of the winners win a large prize, corresponding to the total fraction of winners with prizes between 40,000 to 60,000 USD. The size of the smallest prize is to be calibrated in order for total prize amount to match total lottery revenue.

To set the lottery ticket price, I refer to the Norwegian Gambling Authority's statistics on gambling revenue, which states that in 2017, gross revenue in the regulated gambling market is 43.7 billion NOK.[4] This is about 1.32% of Norwegian GDP (3,299 billion NOK) in 2017. The average amount spent on regulated gambling market is 10,600 NOK, which is abou 3.3% of the average net disposable income in Norway. Assuming that each adult spend the same amount on gambling, I back out the population that participate in gambling to be around 4.1 million - about 80% of the Norwegian population. This almost includes every working adult, or individuals above 18 years old. Thus, τ is set to match 1.32% of total output in the model. Assume that the US has a lottery sector that's identical to Norway's, τ should be set to match 1.32% of the output.

Table 3.2: Lottery Sector Parameters

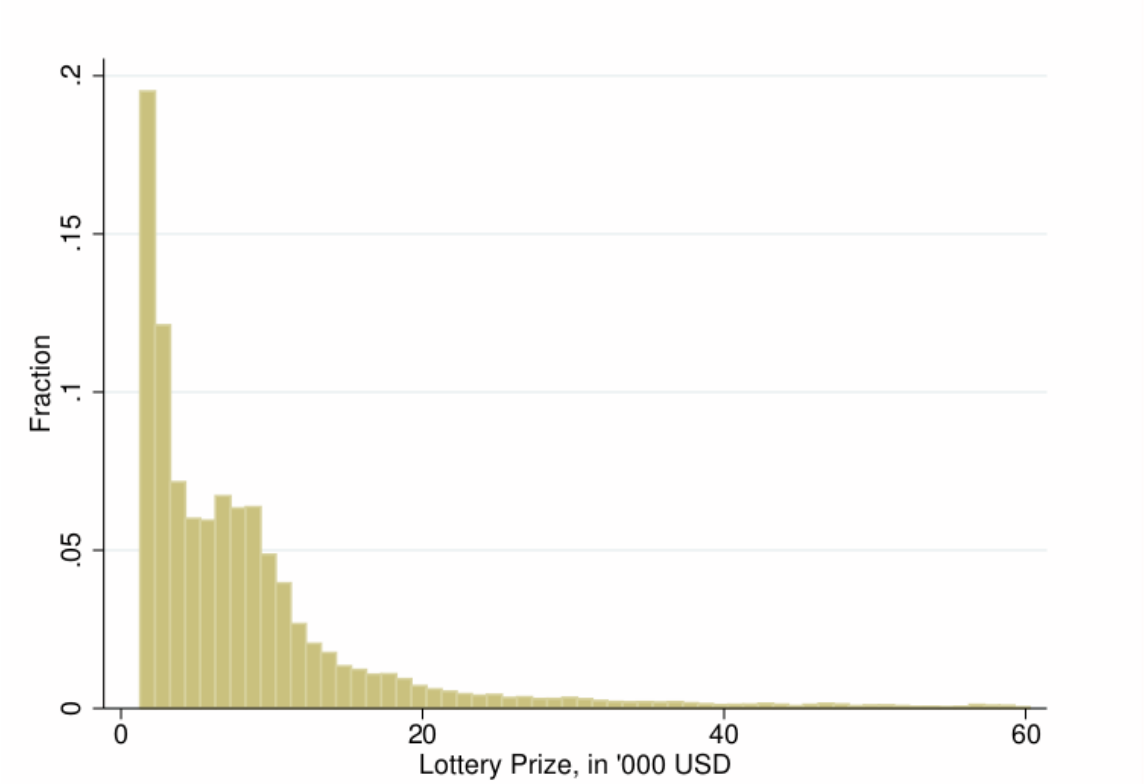
Parameter	Description	Values
τ	lottery ticket price	0.0292^a
p_1	non-winning probability	0.9950
$\{p_2, p_3, p_4\}$	winning probability	$\{0.0047, 0.00025, 0.00005\}$
ψ	single prize unit	5.08
$\{\psi_1, \psi_2, \psi_3, \psi_4\}$	relative prize magnitude	$\{0, 1, 3, 6\}^b$

[a] In equilibrium, this is about 0.24% of a median worker's income.

[b] The smallest prize is about 42% of a median worker's income, and the largest prize is about 2.5 times of a median worker's income.

[4] https://lottstift.no/pengespel/pengespelstatistikk/norsk-pengespelmarknad-i-2017/

Figure 3.1: Lottery Prize Distribution - Fagereng, Holm, and Natvik (2016)



Notes: Lottery prizes are in thousands of 2000 USD. Each bin is 1,000 USD wide, starting from USD 1,100.

3.5 Benchmark Economy

Table 3.3 compares the moments generated by the benchmark economy without the lottery sector and US data. Moments about aggregate capital to output ratio, entrepreneur investment, entry and exit to entrepreneurship, and taxation are fairly close to the US economy. We will compare this steady state with the one with a lottery sector later.

We then examine the composition of entrepreneurs. Figure 3.2 shows the distribution of entrepreneurial abilities θ in the economy, workers and entrepreneurs respectively. Agents with the highest ability are almost all entrepreneurs, and the lowest abilities are all workers. The percentage of entrepreneurs increases with ability.

Table 3.3: Benchmark Model Moments and Data

	US Data	Model
capital-output ratio	2.65	2.60
government expenditure/GDP	18%	17.58%
income tax/total tax revenue	65%	64.57%
fraction of entrepreneurs	12%	13.74%
share of entrepreneur's income	27%	26.79%
exit rate	20%	21.30%

Figure 3.2: Benchmark model: distribution of abilities θ

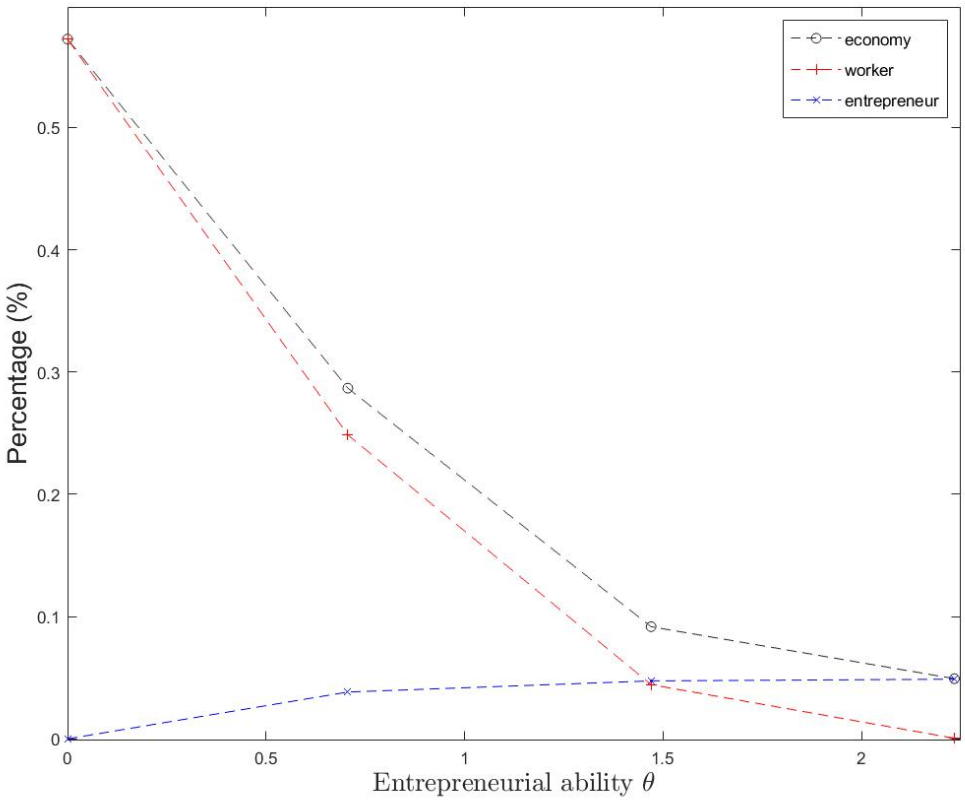


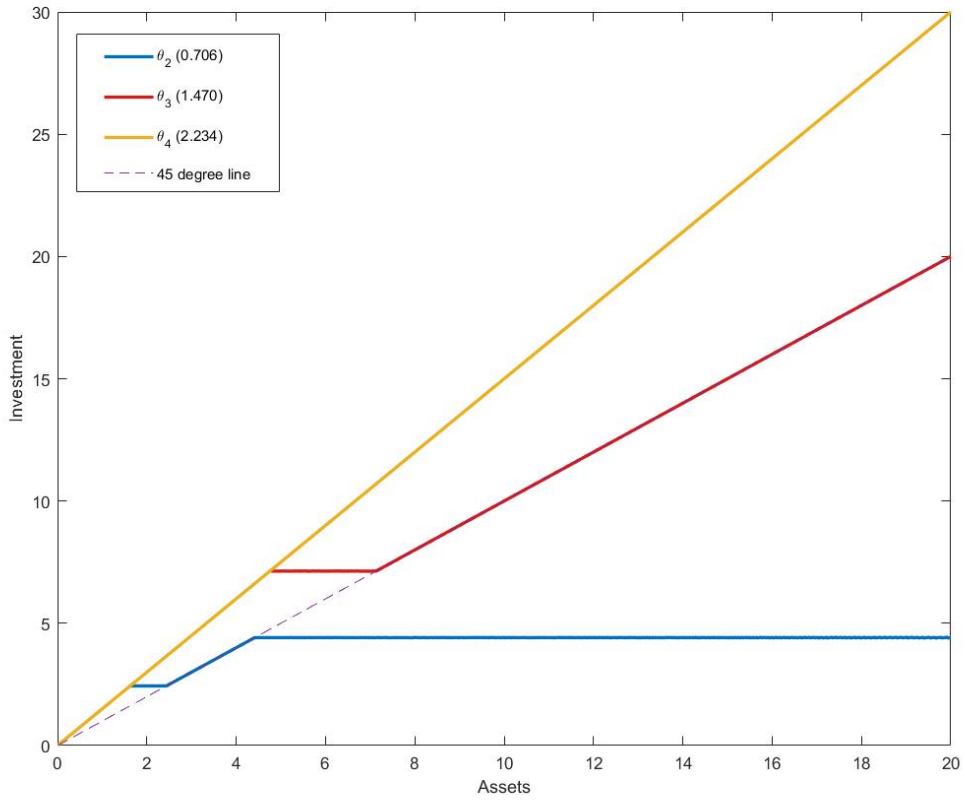
Table 3.4 gives a detailed description of entrepreneurs' activities by ability. Leverage ratio is defined as the percentage of assets borrowed from the intermediaries to put into investment. High ability entrepreneurs invest more into their projects and take on the maximum leverage allowed.

Table 3.4: Benchmark model: entrepreneurial activities by ability θ

θ	% in pop.	% entrep.	avg. investment	avg. assets	avg. leverage ratio
0.000	0.00%	0.00%			
0.706	3.81%	27.71%	3.15	6.84	1.15%
1.470	4.79%	34.89%	8.78	8.05	20.39%
2.234	5.14%	37.41%	16.26	10.84	50.00%

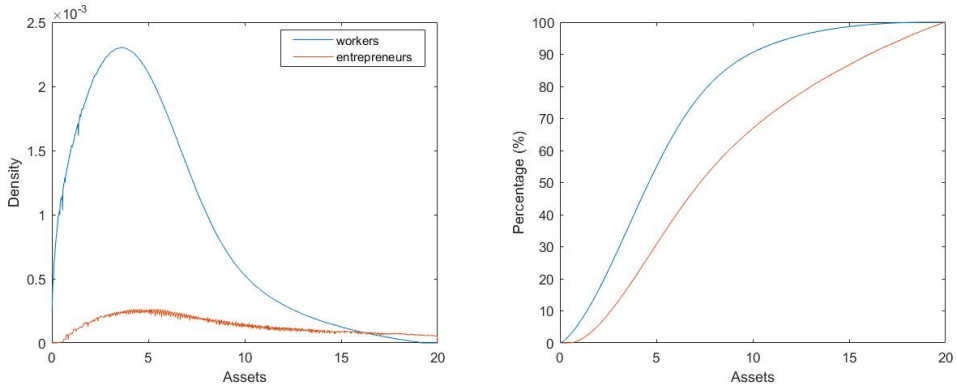
Figure 3.3 shows entrepreneurs' investments by asset and ability. With the decreasing scales to return technology, low ability entrepreneurs (θ_2) reach the optimal firm size at a small asset level. Medium ability entrepreneurs (θ_3) with smaller assets borrow up to the borrowing limit, but those with larger assets do not borrow beyond their assets due to the borrowing premium ι. High ability entrepreneurs expand until they reach the borrowing constraint.

Figure 3.3: Benchmark model: investment by asset and ability



Entrepreneurs own a higher level of assets. Figure 3.4 compares the asset distribution between workers and entrepreneurs. The left panel shows that the density of workers is concentrated in asset values less than 10 (maximum asset holdings is 20).

Figure 3.4: Benchmark model: density and CDF of assets by occupation



3.6 Lottery Experiments

I then solve the steady state for an economy with a lottery sector, using parameters in both Tables 3.1 and 3.2. First, I compare moments of aggregate output, investment, consumption, and entrepreneur dynamics with the benchmark economy. Then, I simulate a panel of households, and run a regression to test whether the probability to enter entrepreneurship increases after winning a lottery prize. Lastly, I test different lottery prize structures to see if the distribution of prizes affect agent's behavior in equilibrium.

3.6.1 Steady State Results

Table 3.5 compares steady state moments between the lottery and benchmark economies and calculates the percentage change. The two economies are very similar. The lottery economy has a slightly higher aggregate output and capital, and lower

consumption. It also has fewer entrepreneurs, less income and investment made by entrepreneurs, and higher exit rate. The magnitudes of change are all within 5%.

Table 3.5: Steady State Moments

	Lottery	Benchmark	% change
aggregate output	2.18	2.17	+0.46%
aggregate capital	5.79	5.65	+2.48%
aggregate consumption	1.37	1.37	-0.64%
capital-output ratio	2.65	2.60	+1.92%
government expenditure/GDP	17.54%	17.58%	-0.23%
income tax/total tax revenue	64.77%	64.58%	+0.29%
fraction of entrepreneurs	13.52%	13.74%	-1.60%
share of entrepreneur's income	26.24%	26.79%	-2.05%
share of entrepreneur's asset	20.71%	21.32%	-2.86%
share of entrepreneur's investment	23.63%	24.39%	-3.12%
exit rate	21.40%	21.30%	+0.47%

I then look at entrepreneur's activities in more detail and compare it with the benchmark economy. Table 3.6 lists entrepreneur's composition, investment, asset, and leverage ratio by ability, and these results are similar to the benchmark results, within 3% of difference. There is a slight drop in the number of entrepreneurs, but each type of entrepreneurs on average has slightly larger investment and asset.

Table 3.6: Lottery economy: entrepreneurial activities by ability θ

θ	% in pop.	% entrep.	avg. investment	avg. assets	avg. leverage ratio
0.000	0.00%	0.00%			
0.706	3.77%	27.91%	3.20	6.99	1.21%
1.470	4.73%	34.98%	8.90	8.17	19.98%
2.234	5.02%	37.11%	16.47	10.95	50.00%

Within the lottery economy, I compare the behavior between winners and non-winners. Figure 3.5 shows the consumption and savings policy of winners and non-winners. For the ease of illustration, I take the mean across prizes at each asset level for winners. In line with the permanent income hypothesis, winners save a fraction of the prizes and consumes the rest, hence having higher consumption and saving levels than non-winners.

Figure 3.5: Lottery economy: savings and consumption policy by winning status

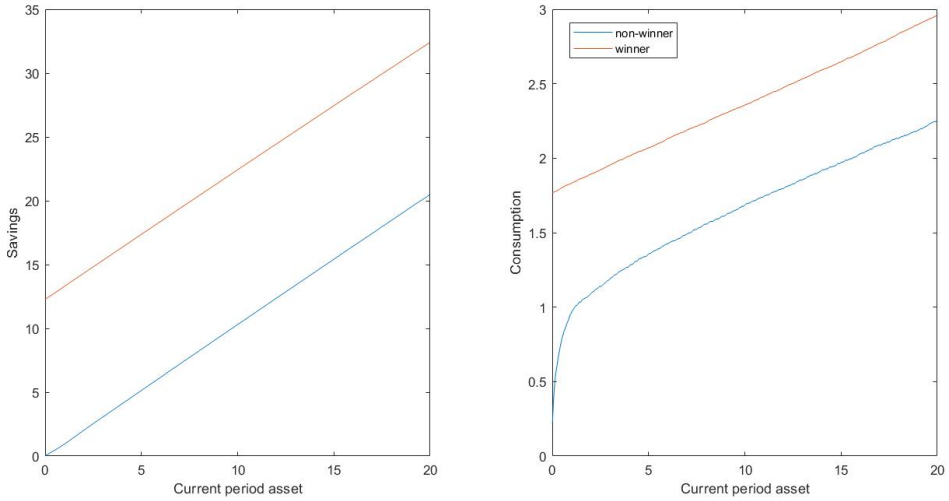


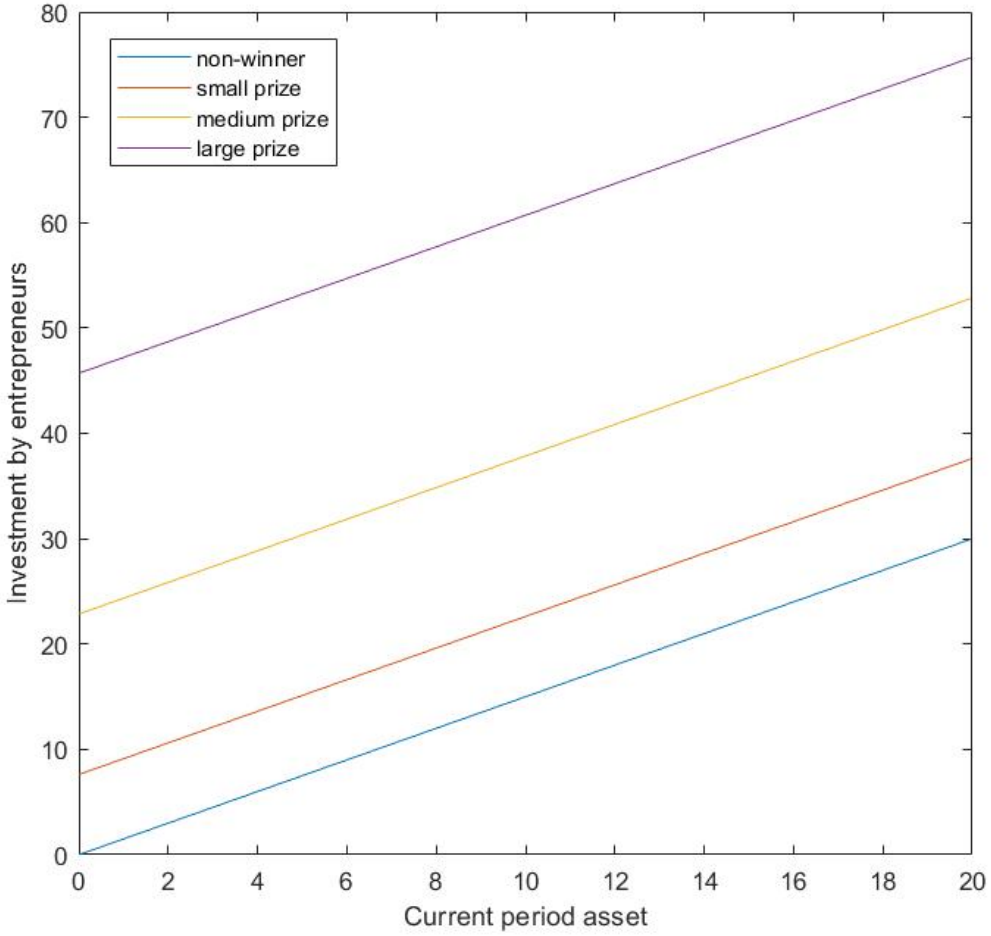
Figure 3.6 shows entrepreneurs' investment policy across different prizes. Entrepreneurs who win prizes invest much more than those who do not, and those who win a larger prize invest more than those who win a smaller prize. Lottery prizes increases the collateral entrepreneurs can put up, relaxes the borrowing constraint, hence allowing entrepreneurs to borrow more capital. Table 3.7 compares the average leverage ratio across different prizes. As lottery prize gets larger, the more capital entrepreneur is allowed to borrow, and the more likely that his business will reach optimal size give his ability. Thus, leverage ratio decreases with the size of prizes.

Table 3.7: Lottery economy: leverage across prizes

prize	zero	small	medium	large
ave. leverage	25.91%	18.73%	18.55%	18.55%

At the extensive margin, agents with abilities above certain threshold will become an entrepreneur even with the minimum amount of assets (0.05), when they win a lottery prize. On the other hand, for non-winners, they would have to accumulate enough assets to become entrepreneurs and have a high enough ability.

Figure 3.6: Lottery economy: entrepreneur's investment policy by winning status



3.6.2 Simulation

Given the consumption and savings policy functions, and occupation decisions in steady state, I simulate a panel of 400,000 households over 200 time periods[5], and run the following regressions for the last period,

$$Entrepreneur_{i,t} = \beta_1 \phi_{i,t} + \beta_2 a_{i,t-1} + \epsilon_{i,t} \tag{3.16}$$

[5]Average asset in the economy converge after 100 periods.

$$k_{i,t} = \beta_1 \phi_{i,t} + \beta_2 a_{i,t-1} + \epsilon_{i,t} \tag{3.17}$$

The first regression tests the hypothesis that winning a lottery prize will increase agent's propensity of becoming an entrepreneur. And the second regression tests whether winning a lottery prize increases entrepreneur's investment, conditional on being an entrepreneur. I do not include ability (θ) in the regressions as θ is not directly observable outside the model context.

Table 3.8: Regression: entrepreneur decision, consumption, and investment

	Entrepreneur	Consumption	Investment
prize, ψ	0.003	0.047***	0.418***
	(0.010)	(0.004)	(0.095)
wealth, a	0.046***	0.077***	0.921***
	(0.000)	(0.000)	(0.003)
N	400000	400000	63440
R^2	0.068	0.600	0.810

Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.8 displays the regression results. Surprisingly, winning a lottery prize does not significantly influence the decision to become an entrepreneur. On the other hand, higher asset levels increase the probability of entrepreneurship. This is because when ability is not included in the regression, wealth becomes a proxy for ability. A higher wealth level not only loosens financing constraints, but is also associated with higher ability. Moreover, as seen in the model, ability is the dominant factor for entrepreneurship. Thus, the extensive margin depends on wealth levels, but not lottery prizes.

On the other hand, winning a lottery prize significantly increases entrepreneur's investment. Getting \$1 more prize increases investment by \$0.42. For agents with high enough ability (θ) to start businesses, winning a lottery prize increases their borrowing capacity and allows them to increase investment. As a robustness check, winning a lottery prize significantly increases agent's consumption as expected.

3.6.3 Different Lottery Prize Structures

As robustness checks, I experiment with different lottery prize structures. I keep the lottery ticket price, τ, unchanged, and vary the size of lottery prizes. Table 3.9 shows two examples. The small prize structure keeps the percentage of winner unchanged at 0.5%, but every winner is getting the same prize, 5.84, which is about the size of the smallest prize in the lottery economy. The large prize structure gives every winner a large prize, 58.4, that is ten times the smallest prize in the lottery economy, but concentrates winners to 0.05% of the population. These two examples are used to examine if the size of lottery prizes and the distribution of prizes has an effect on the decision to entrepreneurship. I simulate the same panel of households with the same sequence of shocks[6] and run the same regressions.

Table 3.9: Alternative Lottery Structure

Parameter	Description	Values
Small prize		
$\{\phi_1, \phi_2\}$	prizes	$\{0, \phi\}, \phi = 5.84$
$\{p_1, p_2\}$	prize probability	$\{0.9950, 0.005\}$
Large prize		
$\{\phi_1, \phi_2\}$	prizes	$\{0, \phi\}, \phi = 58.4$
$\{p_1, p_2\}$	prize probability	$\{0.9995, 0.0005\}$

Table 3.10 and Table 3.11 shows the results for the small and large prize structures respectively. I obtain the same result that winning a lottery prize only increases investment for entrepreneurs at the intensive margin, but not the decision to become an entrepreneur (extensive margin).

3.7 Results Discussion

The lottery sector randomly redistributes capital. It takes a small amount of income from each agent and concentrates the combined income on a much smaller

[6] I have to regenerate the shocks for lottery prizes because the number of prizes is different.

Table 3.10: Entrepreneur decision, consumption, and investment - Small Prize

	Entrepreneur	Consumption	Investment
prize, ψ	0.003	0.074^{***}	0.615^{***}
	(0.011)	(0.005)	(0.066)
wealth, a	0.105^{***}	0.106^{***}	1.000^{***}
	(0.001)	(0.000)	(0.003)
N	400000	400000	62606
R^2	0.050	0.526	0.857

Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.11: Entrepreneur decision, consumption, and investment - Large Prize

	Entrepreneur	Consumption	Investment
prize, ψ	0.001	0.059^{***}	0.381^{**}
	(0.004)	(0.007)	(0.133)
wealth, a	0.026^{***}	0.064^{***}	0.852^{***}
	(0.000)	(0.000)	(0.004)
N	400000	400000	63913
R^2	0.050	0.664	0.753

Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

sub-population, the 0.5% winners in the economy. High ability agents might thus receive a large enough income to either overcome the financing constraint at entry, or expand firm size to the optimum given a higher borrowing limit. I observe both effects in the lottery economy. On the margin, high ability agents ($\theta > 1.47$) choose entrepreneurs as their next period's occupation after winning a prize, even though they are at a low asset level. Moreover, agents invest \$0.4 more for every \$1 more prize given.

However, entrepreneurial ability is the dominant factor in deciding entrepreneurship. Even though marginal entrepreneurs can use lottery prizes to overcome financing constraints, their abilities decide how profitable their businesses will be. As a result, winning lottery prizes may or may not increase entry to entrepreneurship, depending on the distribution of ability for marginal entrepreneurs. It will, however, increase investment for entrepreneurs conditional on entry.

Overall, the steady state moments in the lottery economy are very similar to those in the benchmark economy. It could be that the model uses a discrete ability (θ) grid so that not a lot of entrepreneurs are on the margin, or that the size of the lottery sector is not large enough.

3.7.1 Connecting Model with Literature

The model environment is closest to the empirical setting in Bermejo, Ferreira, Wolfenzon, and Zambrana (2018). The paper documents the effect of winning lottery prizes from the Spanish Christmas Lottery on entrepreneurship. The Spanish Christmas Lottery is a national lottery game that takes place every year. It covers about 75% of the population. Players are ordinary citizens, and the amount of money spend is similar across individuals. The only difference is that prizes are distributed to the entire province, and the winning province gets 5.65% of its gross domestic product (GDP), a higher proportion of GDP than what the theoretical model assumes. The paper shows that lottery prizes have a positive effect on the rate of firm creation and wages. Moreover, conditional on entry, assets of firms are higher in winning provinces. Thus, the empirical findings are in line with the predictions of my model.

Cespedes, Huang, and Parra (2021) discusses a US setting, although the targeted population is the retail businesses. Retailers that sell jackpot tickets for Powerball and Mega Millions receive bonuses, which is a percentage of the winning prize, when they have sold winning tickets. Similar to model predictions, cash windfalls increase investments into existing business and spur new business creation. The advantage of distributing random bonuses to the retailers is that bonuses are more likely to be used for entrepreneurial activities, since retailers are already self-selected entrepreneurs with high enough entrepreneurial ability. That is, would-be entrepreneurs on the margin are more likely to be financially constrained rather than having low abilities. In the model, some prizes are distributed to workers with low entrepreneurial ability,

and hence have no impact on entrepreneurial activities. The disadvantage of focusing on retailers is that the type of business started is likely limited to a certain industry. Thus, policymakers should weigh the pros and cons when considering the target population for similar cash transfer programs.

3.7.2 Policy Implications

Results from the lottery economy have the following lessons for policy aimed at spurring entrepreneurship. If the US government would like to initiate a cash transfer program similar to the nationwide lottery program in Spain, the size of lottery prizes and total amount of cash being redistributed have to be large enough to overcome the fixed cost of starting a business. Secondly, the target population of the cash transfer program should cover those with entrepreneurial experience, so that they have high enough ability to start businesses after winning prizes. The cash transfer program will not work if the barrier to entry is due to a lack of entrepreneurial ability.

3.8 Conclusion

This chapter augments a standard Bewley model with an entrepreneurial sector and lottery sector to study how nationwide lottery programs like those implemented in Norway or Spain affect entrepreneurial dynamics and aggregate variables. The quantitative analysis shows that after winning a lottery prize, the likelihood of becoming an entrepreneur depends on the abilityof would-be entrepreneurs on the margin. On the other hand, investments by existing entrepreneurs always increase after winning lottery prizes. Results of the model explain why public cash transfer programs may not increase the number of new businesses and only modestly increase aggregate productivity and output.

Appendix A

Appendices for Chapter 1

A.1 Merging Compustat and VentureXpert

The VentureXpert dataset is combined with Compustat using probabilistic name matching. The first step is to standardize the firm name in the two datasets to facilitate matching. After creating a list of unique firm names for each dataset, I apply the following procedures to both lists. All firm names are changed to upper case, with no unwanted spaces in between or in the front and back. The suffixes are standardized as such: "Limited" is changed to "LTD", and "Corporation", "Corporate", "Corp" are all changed to "CO". Suffixes such as "-ADR", "-CL", or "-OLD" are removed instead. Lastly, I remove all symbols, such as "&" and "/".

Then, I use Stata's *reclink2* package to merge the two name lists. To ensure a higher accuracy of matches, I set the *minscore* to be 0.7. The merge gives 12185 matched venture-funded firms in Compustat out of the total 84542 venture-funded firms in VentureXpert. The results make sense as IPO rate is less than 30%. Among these matches, 5643 matches (about 50% of total matches) are exact, and the rest matches are assigned a probabilistic score in between 0 and 1. I set the cutoff for the

probabilistic score to be above 0.8. If there are multiple matches to one firm, I keep the match with the highest score.

My final matched sample contains 11800 venture-funded firms identified in Compustat.

A.2 Merging WMS and VentureXpert

The only firm identifier in the World Management Survey is Compustat ID. Therefore, I am only able to identify venture-funded firms in World Management Survey that exist also in Compustat. First, I merge the World Management Survey with the matched VentureXpert-Compustat dataset using year and Compustat ID. Then, I cross check the matches using the 3-digit SIC code and drop those matches with different SIC codes in the World Management Survey and Compustat. I am able to identify 131 observations in the World Management Survey that correspond to venture-funded firms.

Appendix B

Appendices for Chapter 2

B.1 Merging NETS and VentureXpert

Before carrying out the merging procedure, I apply standardization to firm identifiers in VentureXpert and NETS. All firm names are changed to uppercase, and unwanted spaces are removed. The suffixes for firm names are standardized to an abbreviated form, for example, "Limited" is changed to "LTD", and "Corporation" is changed to "CO", and so on. The suffixes for firm addresses are similarly standardized, for example, "Drive" is changed to "DR". Lastly, I create a list of unique firm identifiers for each dataset, by dropping duplicates of name, state, city, zipcode, and SIC combinations.

The merging procedure is carried out in two steps. The first step is direct merge using identifiers, in nine passes. The first pass uses all identifiers, which are name, state, city, zipcode, address, and SIC. The second pass leaves out address. The third pass uses name, state, city, and SIC. The fourth pass uses name, state, zipcode, and SIC. The fifth to seventh pass use name and SIC, plus one of the identifiers from city, zipcode, and state. The eighth pass uses name and SIC. And the last pass matches on name.

The second step is fuzzy names matching using the Python package *fuzzymatcher*. The algorithm generates a probabilistic match score in between 0 and 1 for each pair of names. To keep only one match, I pick the matched pair with the maximum score if there are multiple matched pairs. Moreover, I set the minimum score to be 0.5.

A filtering procedure is applied after the merging procedure, to verify the matched NETS establishment is indeed venture-funded. First, I check the SIC codes for the matched pairs to make sure they are identical for the first two digits. Second, I drop matched pairs if the year that the establishment first appears in NETS and the year that the firm is first founded in VentureXpert is more than five years apart. Lastly, I drop matched pairs if the last year that the establishment appears in NETS is more than five years earlier than the last year that the firm receives funding in VentureXpert. The percentage of merged firms by merge type is presented in Table B.1

Table B.1: Composition of Merged Names in NETS and VentureXpert

Merge Type	Frequency	Percent	Cumulative
name, state, city, zipcode, address, SIC	483	2.70	2.70
name, state, city, zipcode, SIC	1323	7.38	10.08
name, state, city, SIC	343	1.91	11.99
name, state, zipcode, SIC	44	0.25	12.24
name, state, SIC	688	3.84	16.08
name, SIC	742	4.14	20.22
fuzzy name	1133	6.32	26.54
name	13165	73.46	100.00
Total	17921	100.00	100.00

17921 venture-funded firms are matched with a NETS establishment. This corresponds to a 50% match rate, given the total number of unique venture-funded firms is 35675.

B.1.1 Limitation of NETS

NETs is a private source of US business microdata. Previous studies (Barnatchez, Crane, and Decker (2017),Crane and Decker (2019)) have compared NETS to official sources of business data and reached the following conclusions. First, NETS uses a different definition for business, and thus have a different establishment count compared to Census. This will underestimate the percentage of venture-funded establishments, if majority of them are too young or too small to be counted in the NETS definition. Puri and Zarutskie (2012) counts 0.11% of newly founded venture firms in NETS, whereas NETS only counts 0.01%.

Second, business dynamics in NETS is "muted". NETS misses a lot of dispersion in employment growth for young firms, mostly due to the large amount of missing employment data in firms' early years. Following the literature's guide, I refrain from drawing conclusions using growth data. Moreover, I also do not use sales data as it is entirely imputed from employment and has little dispersion.

B.2 Proofs

B.2.1 Proof for Proposition 2.4.1

In equation 2.17, differentiating h with respect to z, c, v respectively, we have

$$\frac{\partial h}{\partial z} = \Big(\frac{\alpha\epsilon\theta}{v(1+r)}\Big)^{\frac{\theta+\chi}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}}\gamma^{\frac{\theta\sigma}{\chi(\sigma-1)}}\Big[1 + \gamma^{-\sigma}\Big(\frac{v}{c}\frac{1-\alpha}{\alpha}\Big)^{\sigma-1}\Big]^{\frac{\theta}{\chi(\sigma-1)}-1} > 0 \quad \text{(B.1)}$$

$$\frac{\partial h}{\partial c} = z\Big(\frac{\alpha\epsilon\theta}{v(1+r)}\Big)^{\frac{\theta+\chi}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}}\gamma^{\frac{\theta\sigma}{\chi(\sigma-1)}}\Big[1+\gamma^{-\sigma}\Big(\frac{v}{c}\frac{1-\alpha}{\alpha}\Big)^{\sigma-1}\Big]^{\frac{\theta}{\chi(\sigma-1)}-2}$$
$$\Big(\sigma-1-\frac{\theta}{\chi}\Big)\gamma^{-\sigma}\Big(\frac{v(1-\alpha)}{\alpha}\Big)^{\sigma-1}c^{-\sigma} > 0, \qquad \text{if} \quad \frac{\theta}{\chi} < \sigma-1 \quad \text{(B.2)}$$

$$\frac{\partial h}{\partial v} = -\Big(1+\frac{\theta}{\chi}\Big)z\Big(\frac{\alpha\epsilon\theta}{(1+r)}\Big)^{\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}}\gamma^{\frac{\theta\sigma}{\chi(\sigma-1)}}\Big[1+\gamma^{-\sigma}\Big(\frac{v}{c}\frac{1-\alpha}{\alpha}\Big)^{\sigma-1}\Big]^{\frac{\theta}{\chi(\sigma-1)}-1}+$$
$$z\Big(\frac{\alpha\epsilon\theta}{v(1+r)}\Big)^{\frac{\theta+\chi}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}}\gamma^{\frac{\theta\sigma}{\chi(\sigma-1)}}\Big[1+\gamma^{-\sigma}\Big(\frac{v}{c}\frac{1-\alpha}{\alpha}\Big)^{\sigma-1}\Big]^{\frac{\theta}{\chi(\sigma-1)}-2}$$
$$\gamma^{-\sigma}\Big(\frac{(1-\alpha)}{c\alpha}\Big)^{\sigma-1}\Big(\frac{\theta}{\chi}+1-\sigma\Big)v^{\sigma-2} < 0, \qquad \text{if} \quad \frac{\theta}{\chi} < \sigma-1 \quad \text{(B.3)}$$

where the condition $\frac{\theta}{\chi} < \sigma - 1$ is satisfied given parameter estimates of θ, χ, and σ in Bloom, Sadun, and Van Reenen (2016).

B.2.2 Feasibility Region

From equation 2.9, we have

$$\frac{\partial z_s}{\partial c} = \frac{\theta}{\chi}\frac{I}{\chi}\theta^{-\frac{\theta}{\chi}}c^{\frac{\theta}{\chi}-1}\Big(\frac{\epsilon}{1+r}\Big)^{-1-\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{-\frac{\beta}{\chi}} > 0 \quad \text{(B.4)}$$

Thus, the higher c is, the higher the threshold z_s for the project to be feasible under bank financing. This gives the blue dashed line in Figure 2.7.

Using equation 2.18 and equation 2.9, we have,

$$\frac{\epsilon}{1+r}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}}z^{\frac{\chi}{1-\beta}}F^{\frac{\theta}{1-\beta}} - I \geq \max\Big\{z\chi\Big(\frac{\theta}{c}\Big)^{\frac{\theta}{\chi}}\Big(\frac{\epsilon}{1+r}\Big)^{1+\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}} - I, 0\Big\} \quad \text{(B.5)}$$

When the project is feasible under bank financing, that is, $z\chi\Big(\frac{\theta}{c}\Big)^{\frac{\theta}{\chi}}\Big(\frac{\epsilon}{1+r}\Big)^{1+\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}} - I > 0$, we have,

$$\frac{\epsilon}{1+r}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}}z^{\frac{\chi}{1-\beta}}F^{\frac{\theta}{1-\beta}} - I \geq z\chi\Big(\frac{\theta}{c}\Big)^{\frac{\theta}{\chi}}\Big(\frac{\epsilon}{1+r}\Big)^{1+\frac{\theta}{\chi}}\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{\chi}} - I \quad \text{(B.6)}$$

Substitute in the expression for F, the inequality becomes,

$$z\frac{\epsilon}{1+r}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}}\Big\{(\theta+\chi)\Big(\frac{\alpha\theta}{v}\Big)^{\frac{\theta}{\chi}}\gamma^{\frac{\sigma\theta}{\chi(\sigma-1)}}\Big[1+\gamma^{-\sigma}\Big(\frac{v}{c}\frac{1-\alpha}{\alpha}\Big)^{\sigma-1}\Big]^{\frac{\theta}{\chi(\sigma-1)}}-\chi\Big(\frac{\theta}{c}\Big)^{\frac{\theta}{\chi}}\Big\}\geq 0 \tag{B.7}$$

$$\frac{\theta+\chi}{\chi}c^{\frac{\theta}{\chi}}\Big(\frac{\alpha}{v}\Big)^{\frac{\theta}{\chi}}\gamma^{\frac{\sigma\theta}{\chi(\sigma-1)}}\Big[1+\gamma^{-\sigma}\Big(\frac{v}{c}\frac{1-\alpha}{\alpha}\Big)^{\sigma-1}\Big]^{\frac{\theta}{\chi(\sigma-1)}}\geq 1 \tag{B.8}$$

Equation (B.8) says that among projects that are feasible under bank financing, there exists a threshold c_v that separates out projects that are more profitable under venture capitalist financing. Further differentiate the left hand side (LHS) of equation (B.8) with respect to c and leave out constant terms, we have,

$$\frac{\partial \text{LHS}}{\partial c}=\Big[1+\gamma^{-\sigma}\Big(\frac{v}{c}\frac{1-\alpha}{\alpha}\Big)^{\sigma-1}\Big]-\gamma^{-\sigma}\Big(\frac{v(1-\alpha)}{\alpha}\Big)^{\sigma-1}c^{1-\sigma}=1>0 \tag{B.9}$$

Thus, the left hand side is strictly increasing in c. For $c\geq c_v$, projects that are already feasible under bank financing will be more profitable under venture capitalist financing.

When the project is not feasible under bank financing, but venture capitalists are more efficient, this makes,

$$\frac{\epsilon}{1+r}(1-\beta)\Big(\frac{\beta}{w}\Big)^{\frac{\beta}{1-\beta}}z^{\frac{\chi}{1-\beta}}F^{\frac{\theta}{1-\beta}}-I\geq 0 \tag{B.10}$$

This inequality gives combinations of (z,c) that is feasible under venture capitalist financing but not under bank financing.

B.3 Numerical Example

To illustrate the effect of changes in certain parameters, I solve the general equilibrium model. Although some model parameters have to come from a priori assumptions, the following parameters in Table B.2 can be empirically determined.

Table B.2: Main Parameters

Parameter	Value	Source
σ	5	Bloom, Sadun, and Van Reenen (2016)
θ	0.1	Bloom, Sadun, and Van Reenen (2016)
β	0.6	Bloom, Sadun, and Van Reenen (2016)
ϵ	0.57	VentureXpert 1985-2015[a]
s_e	0.96	Akcigit, Dinlersoz, Greenwood, and Penciakova (2019)
s_v	0.8	VentureXpert 1985-2015

[a]This includes mergers and acquisitions. IPO rate is 17%.

B.3.1 Computation Algorithm

1. Guess the total mass of entrepreneurs and venture capitalists, M, H.

2. Guess wage w.

3. Given H, solve for $h(z, c)$ by guessing shadow cost v so that the demand for venture capitalists effort equals supply.

4. Check if labor market clears, if not, go back to Step 2 to update the guess for w.

5. Check if entrepreneur and venture capitalists' expected value of entry equal to the entry cost, if not, go back to Step 1 to update the guess for M, H.

The equilibrium values of the numerical examples are listed below in Table B.3.

Table B.3: Steady State Values

	Benchmark	Lower I	Lower r	Lower κ_v
w	1.14	1.26	1.26	1.15
v	1.27	1.38	1.54	1.13
H	1.36	1.41	1.37	1.63
M	10.54	12.29	12.44	10.58
$\frac{Y}{L}$	1.90	2.11	2.10	1.92

Appendix C

Appendices for Chapter 3

C.1 Computation Algorithm

C.1.1 Benchmark Economy Steady State

I use bisection on capital-labor ratio to clear the capital and labor markets. Given the non-linearity of the problem, I solve for the stationary equilibrium by value function iterations in a discretized state space. The asset space has 1000 discrete points and ranges from 0.01 to 20. Entrepreneurs choose capital and labor from 1000 points respectively.

- Step 1: Guess a set of value functions for workers and entrepreneurs, capital-labor ratio in the corporate sector and use it to compute r and w.
- Step 2: Given r and w, solve the household optimization problem using the value function iteration and derive policy functions for each state.
- Step 3: Given the transition rules of asset and occupation derived in Step 2, compute the invariant distribution by discretizing the density function (histogram method).

- Step 4: Compute aggregate capital and labor using the invariant distribution derived in Step 3 and compute a new capital-labor ratio. Check if it is close to the initial guess of capital-labor ratio, if not, update the guess and go back to Step 2.

C.1.2 Lottery Economy Steady State

Use bisection method with the outer loop on targeted capital output ratio, and the inner loop on equilibrium interest rate. I use 100 points on the asset grid to speed up convergence, thus the wealth distribution is not that smooth.

- Step 1: Guess a set of value functions for workers and entrepreneurs, lottery ticket price, capital-labor ratio in the corporate sector and use it to compute r and w.

- Step 2: Given r and w, solve the household optimization problem using the value function iteration and derive policy functions for each state.

- Step 3: Given the transition rules of asset and occupation derived in Step 2, compute the invariant distribution by discretizing the density function (histogram method).

- Step 4: Compute aggregate capital and labor using the invariant distribution derived in Step 3 and compute a new capital-labor ratio. Check if it is close to the initial guess of capital-labor ratio, if not, update the guess and go back to Step 2.

- Step 5: Compute aggregate output using the invariant distribution derived in Step 3 and get a new lottery ticket price. Check if it is close to the initial guess of lottery ticket price, if not, update the guess and go back to Step 2.

C.1.3 Simulation

Initialize a panel of 400,000 households,

- Step 1: In period 1, initialize households' first period ability and efficiency, θ, η, by randomly sampling from the stationary distribution of θ and η respectively. Initialize every household to be a worker (so there will not be entrepreneurs with ability zero) with an asset endowment, a, at the steady state capital.

- Step 2: Starting in period 2, update households' θ and η by drawing on the transition matrix, given last period's values. Distribute lottery prizes ψ randomly by the winning probability distribution. Then update households' savings, consumption, occupation, and investment (if entrepreneur) choice, given a, θ, η, ψ, using the policy functions solved in steady state.

- Step 3: repeat Step 2 and move forward until period 200. Check if aggregate capital converges.

I use the results from the last two periods for the regression.

C.2 Markov processes for η and θ

The Markov process for the labor productivity η and θ are as follows:

η grid $= [0.646, 0.798, 0.966, 1.169, 1.444]$,

$$\text{transition matrix } P_\eta = \begin{bmatrix} 0.731 & 0.253 & 0.016 & 0.000 & 0.000 \\ 0.192 & 0.555 & 0.236 & 0.017 & 0.000 \\ 0.011 & 0.222 & 0.533 & 0.222 & 0.011 \\ 0.000 & 0.017 & 0.236 & 0.555 & 0.192 \\ 0.000 & 0.000 & 0.016 & 0.253 & 0.731 \end{bmatrix}$$

stationary distribution = $[0.166, 0.218, 0.232, 0.218, 0.166]$.

θ grid = $[0.000, 0.706, 1.470, 2.234]$,

transition matrix P_θ= $\begin{bmatrix} 0.780 & 0.220 & 0.000 & 0.000 \\ 0.430 & 0.420 & 0.150 & 0.000 \\ 0.000 & 0.430 & 0.420 & 0.150 \\ 0.000 & 0.000 & 0.220 & 0.780 \end{bmatrix}$

stationary distribution = $[0.554, 0.283, 0.099, 0.064]$.

C.3 Gambling in Norway

Only the two state-owned entities, Norsk Tipping and Norsk Rikstoto, are allowed to offer gambling services. The aim of these two companies is to provide entertainment within responsible limits, with the profits going to charitable causes. Unregulated gaming accounts for 14.0% of the total gambling market. According to Norsk Tipping's 2012 Annual Report, 70% of Norwegians above the age of 18 gambled in 2012 through their services. In 2016, customer growth has increased though both physical and digital distribution channels. Lottery gaming accounts for the largest share of sales, and represents 65% of the gross gaming revenues in 2016.

It is important to understand why people buy lotteries to identify any potential difference from the general population. Norsk Tipping claims that its task is to channel Norwegians' desire to play to legal, regulated games in Norway. It advertises its games as fulfilling the majority of customers' entertainment needs while counteracting the negative impacts of irresponsible gambling behavior. In 2014, Norsk Tipping introduced applications that provide players with improved insight into their own gaming habits and conduct. Thus, it is reasonable to view gambling through these

two companies as a pure entertainment activity. The risk-loving is more likely to self-select into the unregulated market.

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