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Regional Variation in Venture Capital: Causes and Consequences

Venture capital plays an important role in funding high risk and high potential innovations in new start-up firms. Venture capital backed investment is a rather small part which is, however, disproportionately effective in generating employment and growth. The experimental and high risk nature of start-up investment makes it unsuitable for more conservative bank financing and requires active venture capital support with a participation in the upside potential of the firm. The experimental nature of investment typically calls for staged financing. Venture capitalists save scarce capital resources by abandoning unsuccessful projects early on and continue financing in later stages as more reliable information becomes available.

Moving to the Innovation Frontier

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4.1 Introduction

Entrepreneurship is a central element of the Schumpeterian process of creative destruction (Schumpeter, 1942). Startups have been associated with the birth of important new industries such as semiconductors and computers, the internet and biotechnology, and there is increasing evidence of the important role that startup firms play in driving aggregate productivity growth in the economy (Aghion and Howitt, 1992; King and Levine, 1993; Foster et al., 2008).

The availability of finance, and in particular venture capital (VC), seems to be an important part of this phenomenon, despite its extremely small size. Kerr et al. (2014b) highlight that there are less than 500 active VC firms investing in startup ventures across the United States in a given year, and Ewens and Rhodes-Kropf (2015) find that approximately 2,000 individuals accounted for 84% of all dollars invested in venture capital in the United States between 1987 and 2012. In fact, only about 1,000 of the 600,000 new firms that are founded each year receive initial venture capital financing, but VC backed firms constitute over 50% of the initial public offerings (IPOs) on US stock markets (Kaplan and Lerner, 2010) and about 10% of private sector employment (IHS, 2011),[2] highlighting the disproportionate impact that this industry has on the economy.

Several papers have documented the role that VC plays in the economy. For example, Kortum and Lerner (2000) find that increased VC availability leads to increased levels of patenting. Samila and Sorenson (2011) find that an expanded supply of VC raises employment and aggregate income within different regions in the United States. This work also suggests that in most regions even within the United States, an increase in VC of a dollar would lead to an increase of more than a dollar in local employment. Kerr et al. (2014b) use census data in the United States to compare startups that received VC with those that did not. Looking at firms founded in the period, 1986-1997, they find that by 2007, 75% of the VC-backed firms had shut down, compared to 66% of the non-VC-backed firms. The surviving VC-backed firms had grown to the point where their total employment was equal to 364% of the total employment of the original firms at the time of VC investment (including those that eventually failed). On the other hand, the

1 The ideas contained in this chapter arise from a number of other pieces we have written, including a similar brief written for the NBER's Innovation Policy and Economy Working Group entitled "Financing Entrepreneurial Experimentation", Kerr et al. (2014b) and Nanda (2015) . All errors are our own.
2 Based on data provided by the National Venture Capital Association.

larger number of non-VC-backed firms still employed only 67% of the original sample. Puri and Zarutskie (2012) also find that venture-backed firms grow larger and employ more people. Chemmanur et al. (2011) report that venture backing improves the efficiency of firms. Several other papers have documented the role that VC plays in driving innovation through venture capitalists' roles in monitoring and governing startup ventures (Hellmann and Puri, 2000, 2002; Sorensen, 2007; Chemmanur et al., 2011; Puri and Zarutskie, 2012; Bernstein et al., 2014). This suggests that the availability of VC may be a central factor that determines the degree to which radical new ideas are commercialised in a given region or at a given point in time.

A notable feature of venture capital is the uneven nature of VC investment across regions and time. For example, VC investment per capita is a lot larger in the United States than in Europe, and within the United States, Silicon Valley, New York and Boston account for the lion's share of VC investment. In addition, VC investment has been documented to occur in cycles, where certain industries receive a disproportionate share of investment relative to others across time (Gompers and Lerner, 2004; Kaplan and Schoar, 2005; Gompers et al., 2008).

This chapter develops a framework for understanding the uneven distribution of venture capital across industries, regions and time periods. We highlight how the extreme uncertainty facing startup ventures at their earliest stages leads venture capitalists to engage in a process of experimentation across multiple rounds of funding, abandoning investments where intermediate information is negative and investing more in startups where intermediate information is positive. While these real options are a central element of the investment process, we also point out that financiers, rather than markets, dictate investment and continuation decisions as they choose which experiments to attempt, how to interpret the results, and whether to continue with or abandon the investment. These financiers' actions are impacted by a myriad of incentive, agency and coordination problems that shape their ability to effectively experiment. We document two important costs to experimentation: constraints to exercising abandonment options when intermediate information is poor, and shocks to the supply of capital that impact the ability to raise capital even when intermediate information is positive. We show how these can vary across regions and time, thereby not only impacting the distribution of venture capital across regions but also, in doing so, impacting the rate and trajectory of startup innovation.

The financial benefit of running an experiment stems from an ability to abandon the investment if intermediate information is poor, or to replace the founder with a new CEO (e.g. Hellmann and Puri, 2002; Kaplan et al., 2009; Ewens and Marx, 2014). The first constraint we consider is that it is often difficult or costly to shut down a firm. One cost from quickly shutting down a firm, for example, is the disutility felt by the entrepreneurs who suddenly lose their jobs. This and other costs create a trade-off between the rapid abandonment of projects, which encourages investors, and tolerance of failure, which encourages entrepreneurs (Manso, 2011). In Nanda and Rhodes-Kropf (2015), we note that this trade-off is even more troublesome when it cannot be solved optimally for each project, and is instead set by a law, culture or level of bureaucracy that will apply to all projects. Countries with laws designed to make it difficult to fire employees and shut down firms may encourage innovation, but financiers in these countries will be unwilling to back very experimental projects. This may help explain the remarkable dearth of VC backing of innovation in some

European countries (Nanda and Rhodes-Kropf, 2015). More generally, this work develops how formal and informal institutions in an economy play an important role in the level of innovation through their role in promoting the amount of experimentation that investors undertake.

The next constraint on the use of abandonment options is that those experiments that turn out well will need to be funded in a future, unknown capital market. The financing available for startups engaged in innovation is notoriously volatile (Gompers and Lerner, 2004; Kaplan and Schoar, 2005; Gompers et al., 2008), leading entrepreneurs and VC investors to worry about the availability of capital even if initial experiments go well. In Nanda and Rhodes-Kropf (2014), we model investors' responses to this financing risk. We show that times or places with high financing risk (low capital availability) are also the times/places that high expected value – but safe – projects will be run. This fits the intuition that good, solid firms are funded when capital is not freely available. The results also suggest, however, that investors are more willing to experiment in boom times or in places with a great deal of capital.

In Nanda and Rhodes-Kropf (2013), we examine early stage investments between 1984 and 2004 and follow them to 2010 to allow time for exits. We find that increased VC availability leads to increased rates of failure among venture-backed firms, but also that those that succeed are more successful and more innovative.[3]

This suggests that increases in capital caused investors to back not just riskier firms, but more innovative firms. Money not only chased deals (Gompers and Lerner, 2000), but also changed the deals that were funded to more innovative projects.

The results from Nanda and Rhodes-Kropf (2013, 2014) suggest that the most innovative startups may need hot financial markets to facilitate their initial diffusion. Investors cannot fund experiments in areas with low capital availability because there is no future funding. This creates a ‘chicken and egg' problem in that available capital in an area cannot be deployed if there is not enough other capital in the same area. Therefore, policies may have larger effects if they are able to encourage a concentration of investors that breaks the bad equilibrium. Alternatively, policies that help the local successful experiments reach the resources they need may allow much more local experimentation.

Overall, our framework can be used to help guide policy by helping to provide an understanding of where the costs of experimentation can be reduced.

4.2 The importance of experimentation

High-impact entrepreneurship requires, almost by definition, going against the grain. Rajan (2012) argues that an entrepreneur "must be willing to strike out, largely on the basis of intuition, on courses of action in direct opposition to the established settled patterns". A consequence of this environment is extreme

3 In the paper, we show that firms financed at more active times have higher valuations when they go public, controlling for the level of the stock market and the year they go public. Thus, the finding compares firms funded in hot times to those funded in cold times that go public at the same time. Furthermore, those funded in hot markets filed for more patents and their patents were more highly cited.

uncertainty over whether a particular technology, product or business model will be successful.

In this context of extreme uncertainty, experimentation plays a powerful role in increasing the chances that the most promising ideas succeed. One form of experimentation entails a variety of different entrepreneurs commercialising what they believe to be the superior product or technology, and where the ensuing competition leads to the 'survival of the fittest'. As Stern (2006) argued, "a favorable environment for entrepreneurship and a high level of economic experimentation go hand in hand". For example, Klepper (1996) has documented a consistent pattern in which a multitude of new startups emerge at the birth of an industry, followed by a shakeout once the dominant technology has been found. Indeed, Rosenberg (1994) has argued that one of the defining features of capitalism is the freedom it provides entrepreneurs to pursue novel approaches to value creation in the pursuit of economic gain. The promise of large rewards drives entrepreneurs to experiment with new ideas, helping to create a dynamic and growing economy. An institutional environment that facilitates this form of experimentation is thus central to maintaining a vibrant entrepreneurial ecosystem. This not only requires an environment in which it is easy to start new ventures, but also one in which it is easy to shut ventures down (given the high failure rates of startup ventures).

This first form of experimentation depicts experimentation at the level of the economy. A second form of experimentation is one in which investors learn about the potential of individual startups over time, by investing in stages instead of providing the full amount upfront. The ability to invest in stages, with the possibility to abandon the investment along the way,[4] is particularly valuable for high-potential ventures where it is extremely hard, even for professional investors, to know the true potential of a startup without providing money and to learn about the startup's viability over time. A good example of the difficulty in determining how well a new venture will do comes from Kerr et al. (2014b), who study internal data from a single large and successful US VC firm. They look at ratings the partners at this firm gave each deal at the time of the first investment and study how this score relates to the ultimate outcome of the same startups. They find that the correlation between these initial scores and the ultimate performance of the startups was 10%, showing how even successful professional investors have a hard time distinguishing among the most promising startups at the earliest stages of investment. Using similar data from an angel investment group, Kerr et al. (2014a) find the correlation between the interest levels assigned to funded deals and their ultimate success to be less than 10%. More generally, the fact that the majority of VC investments fail – nearly 60% of this VC firm's investments returned less than the money invested – is itself indicative of the difficulty in predicting which firms will be successful and which will fail.

VC firms therefore invest in stages, and learn about the viability of startups through a sequence of investments over time. Since each stage of financing is typically tied to achieving milestones that create information about the future prospects of the venture, each round of funding can be seen as an experiment that generates information about the venture's probability of success and its value conditional on that success. Experiments that generate positive information therefore increase the value of the company and allow the entrepreneur to seek

4 See, for example, Gompers (1995), Cornelli and Yosha (2003), Bergemann and Hege (2005), Fluck et al. (2007) and Bergemann et al. (2008).

the next round of funding without giving up as much equity. On the other hand, experiments that generate negative intermediate information allow the investor to abandon the investment without have committed the full amount upfront. Therefore, this process of experimentation – whereby investors learn about the viability of a radical new idea through an initial investment, interpret intermediate results, and decide whether to continue with or abandon their investment – is a key aspect of entrepreneurial finance. It is this second aspect of experimentation that is the focus of this chapter, although we also highlight important interactions and policy implications that stem from the first notion of experimentation.

4.3 A simple model of multi-stage financing

In this section, we set up a simple model of multi-stage financing that we use to demonstrate the key benefits and costs associated with experimentation across rounds of funding. We use this to highlight how costs from such experimentation that can arise in certain regions or points in time can have important implications for the degree to which investors are willing to finance startups commercialising the most radical innovations. In doing so, we hope to demonstrate that costs of and constraints to experimentation can play a first-order role in impacting the supply of VC, and hence play a central role in driving the rate and trajectory of innovation – independent of the availability of novel ideas and talent to commercialise such ventures.

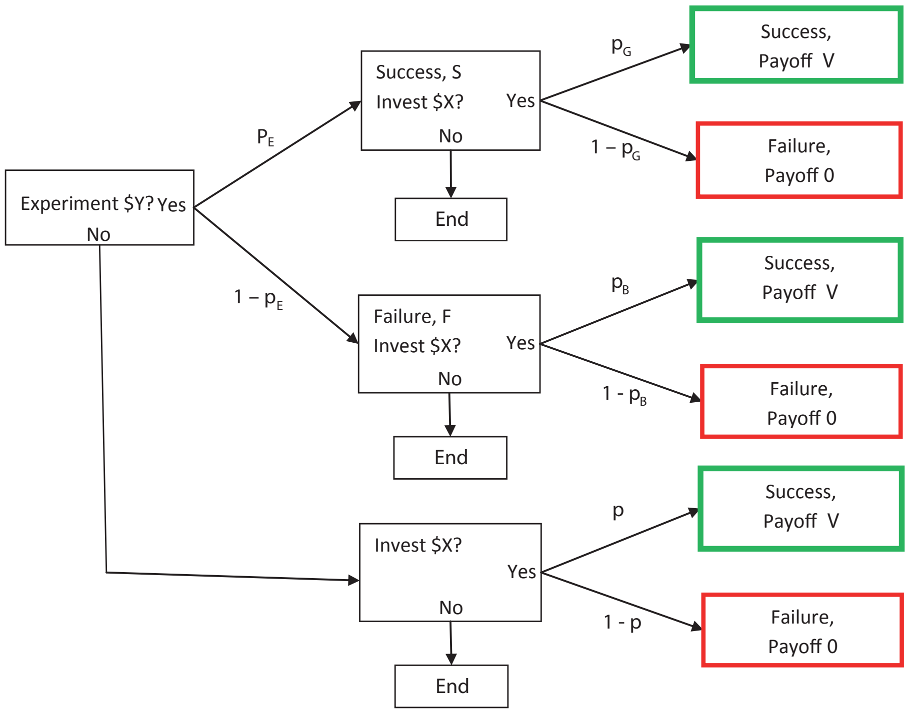
Consider the following investment. A startup requires *\$X* to commercialise its technology that may or may not work. The probability it will be successful and worth V is p, while the probability it will be worth nothing is $(1 – p)$. The expected value of the project is $pV – X$. Thus, this project will not be financed if $X > pV$.

Then imagine that the entrepreneur can conduct an experiment before fully funding the startup. The likelihood that the experiment generates positive intermediate information is p_E, while the likelihood of the intermediate information being negative is $(1 – p_E)$. If the results from the experiment look promising (the "Good" outcome), the chance of ultimate success is p_G, while if the the results from the experiment are not promising (the "Bad" outcome), the chance of success is p_B. The experiment costs *\$Y* to run. To be equivalent to the project when no experiment is run, $p_G * p_E + p_B * (1– p_E) = p$, i.e. the unconditional probability of success is the same whether or not the experiment is run. Thus, the experiment reveals information about the quality of the project.

To make this example concrete, consider a project that requires \$11 million (X) to be commercialised and that has a 99% probability of being worth \$0, and a 1% (p) probability of being worth \$1 billion (V). This project will not be pursued as its expected value is negative (–\$1 M), i.e. *\$11M > 0.01 * \$1B*. But what if the entrepreneurs could conduct an experiment that will reveal that the project either has a 10% (p_G) chance of working or a 0% chance of working (p_B)? Furthermore, assume this experiment will reveal the more promising news with a 10% probability. Thus, the ex ante probability of success is the same whether or not the entrepreneurs conduct the experiment, i.e. $0.10 * 0.10 + 0 * (1 – 0.1) = .01 = p$. The decision tree of the investor is shown in Figure 4.1.

The question facing the investor is whether it is worthwhile to finance the initial experiment. Intuition might suggest that since running the experiment increases the amount the investor has to pay from *$X* to *$X* + *$Y*, the experiment is not worth pursuing. However, the value in the experiment arises because it may prevent the investor from spending *$X* at all.

Figure 4.1 The investor's decision tree



The experiment can thus be thought of as an investment that pays off $p_G *V - X$ *($89M)* with probability p_E, and pays off Max$[p_B *V - X,0]$ *($0)* with probability $(1 - p_E)$. Note that if the results of the experiment are not promising, the investor will only invest *$X* if the project has an expected value greater than zero – the max function accounts for this decision. In our example, p_E = 10%, and therefore the expected value of the experiment is 10% * $89 million = $8.9 million. Thus, as long as the experiment costs less than $8.9 million, it should be run.

Even though the original investment of $11 million (*X*) was not a good idea, an investment of up to $8.9 million, followed by an investment of $11 million if the experiment is successful, is a good idea – it represents positive expected value. Spending an additional $8.9 million to learn about the viability of the project is more valuable than simply spending $11 million directly. This is the benefit of experimentation.

We emphasise that the value of experimentation is not driven by the specific numbers chosen in this example. Rather, the experiment is valuable any time when:

$$p*V - X < p_E* (p_G* V - X) + (1 - p_E) \text{ Max}[p_B*V - X, 0] - Y \tag{1}$$

i.e. when the expected value without the experiment is less than the expected value with the experiment. When is this true? This cannot hold, for example, for any project that has a positive expected value even after the experiment fails. In this case, $Max[p_B*V - X, 0] = p_B*V - X$. Since $p_G* p_E + p_B* (1 - p_E) = p$, we see that $p_E* (p_G*V - X) + (1 - p_E)(p_B*V - X) = p*V - X$ and running the experiment is really just a waste of resources. This is because it changes no decision, as the investor invests $\$X$ no matter what the experiment reveals. However, if $p_B*V - X < 0$ then the investor would like to avoid investing when the true probability of success is p_B. The investor would therefore be willing to pay to learn whether the probability is p_G or p_B. How much the investor is willing to pay depends on how much the investor learns from the experiment.

In an extreme case, an experiment might demonstrate nothing, i.e. $V*p_G = V* p_B$. That is, the probability of earning V is the same no matter the experiment's outcome. Alternatively, the experiment might provide a great deal of information. In this case, $V*p_G$ would be much larger than $V*p_B$. We can think, therefore, of $V*p_G - V*p_B$ as the amount or quality of the information revealed by the experiment. $V*p_G - V*p_B$ is larger if the experiment revealed more about what might happen in the future.[5],[6]

Overall, we see that experimentation is very valuable in situations when an investment of relatively few dollars can reveal information that results either in a valuable project going forward or a mistaken investment being prevented. We next demonstrate two important constraints to experimentation and document how institutional features that govern experimentation can play a role in leading these costs to be systematically different across regions. This naturally sets up potential roles for policy.

Costs of exercising abandonment options

As was seen above, the benefit of running an experiment from the investor's perspective stems from an ability to abandon the investment if intermediate information is poor (or to replace the founder with a new CEO). This form of failure can be frustrating to entrepreneurs, who often tend to feel that a breakthrough requires only a little more funding and patience. Thus, entrepreneurs often look for investors willing to allow them a second go if the intermediate information is negative, or even look for investors who are willing to fund the project more fully up front. In an extreme case, entrepreneurs may not be willing to take an investment from investors who have a reputation for exercising their abandonment options.

To incorporate this idea into our simple model, we will assume that the effort decision by the entrepreneurs is all or nothing, i.e. they either start the new venture or they do not. They also face a cost of u_F if the project is shut down after the experiment. This can be thought of as the disutility they experience when they fail. In this case, even for firms where experimentation may be valuable $(p_B*V - X < 0)$, disutility for failure may hamper experimentation.

5 Note that we can think of p_G and p_B as posterior probabilities with a prior of p. Thus, one special case is martingale beliefs with prior expected probability p and updating that follows Bayes' rule. In this case, projects with weaker priors would have more valuable experiments.

6 Note also that the experiment is no more or less important if the project is riskier. A riskier project might be one with a larger V and smaller probabilities of success, pG and pB, but the information revealed by the experiment, $V*p_G - V*p_B$, could be the same. Thus, the value of the experiment and the risk of the project are related but are not the same.

The total value of experimentation, including both the financial payoff and the costs borne by the failed entrepreneur, is:

$$p_E * (p_G * V - X) - Y - (1 - p_E) * u_F \qquad (2)$$

Including a cost of early failure reduces the value of experimentation by $(1 - p_E)*u_F$. Note that this will also affect the financier even though they do not directly pay the failure costs. This is because the financier and entrepreneur must negotiate over any surplus generated by the project. The loss from early failure lowers the entrepreneur's expected payoff. If the total expected value of the project does not generate enough to cover the costs borne by both the entrepreneur and investor, then the entrepreneur and investor will not be able to find a deal that will induce them to both participate.

If the costs of early failure are too high, then the entrepreneur will not participate in the project if it is funded via experimentation. For example, one can imagine that an aspiring entrepreneur who could receive a \$100,000 investment but then may be forced to shut down in six months due to a lack of further funding may be less willing to quit his day job than if funded with millions of dollars, even if the quality of the project is the same in either case. This is the intuition of failure tolerance – an investor may have to agree to fund the project significantly in order to induce the entrepreneur to start the project. In Manso (2011), for example, principals decide how to reward agents in an interim period as well as when the final output is revealed. Manso (2011) demonstrates how the optimal payments may involve leniency in the case of bad interim outcomes. This reduces incentives for effort, but simultaneously induces the agent to experiment. Hellmann and Thiele (2011) also suggest that low-powered incentives may induce low effort in standard tasks but may encourage experimentation. This is a very intuitive result, and a number of empirical papers consider the impact on innovation of policies that create a failure tolerance.[7]

Interestingly, however, many innovations are commercialised by new ventures that are backed by VC investors, who tend to be remarkably intolerant of early failure (Hall and Woodward, 2010). It is standard for venture capitalists to negotiate control rights that allow the investors to fire management and/or abandon the project (Gompers and Lerner, 2004; Sahlman, 1990; Hellmann, 1998). Even among venture backed firms that are 'successful', Hellmann and Puri (2002) and Kaplan et al. (2009) show that many end up with CEOs who were not the founders.

In Nanda and Rhodes-Kropf (2015), we explain this apparent contradiction by arguing that the principals who are financing innovation (Venture capitalists, corporations, and even governments) cannot set an optimal failure tolerance policy on a project-by-project basis. Bureaucratic constraints, laws, policies, or possibly a desire to maintain a consistent reputation lead investors to fix an 'innovation policy' upfront.[8]

7 See, for example, Burkart et al. (1997), Myers (2000), Acharya and Subramanian (2009), Ferreira et al. (2011), Aghion et al. (2009) and Tian and Wang (2014).

8 For example, the manifesto of the VC firm the Founders Fund (investors in Facebook) reads "companies can be mismanaged, not just by their founders, but by venture capitalists who kick out or overly control founders in an attempt to impose 'adult supervision.' Venture capitalists boot roughly half of company founders from the CEO position within three years of investment. Founders Fund has never removed a single founder..." (emphasis added); see http://www.foundersfund.com/the-future.

They may do so by committing not to shut down projects quickly. Alternatively, a company culture or level of bureaucracy will apply to all projects. Or, for example, a government looking to stimulate innovation may pass laws making it harder to fire employees. These levels of 'failure tolerance' will apply to all employees, regardless of the project. Put differently, a principal often has an innovation policy that is set ex ante – one that is a blanket policy that covers all projects in the principal's portfolio.

This pre-set policy, culture or bureaucracy may then affect what projects the principal chooses to pursue. Intuition can again be gained from our simple model by assuming that a failure-tolerant investor commits to funding the project regardless of the outcome of the experiment. Thus, the expected value of the project if run by a committed investor is $p*V - X$ (because the experiment is not run). With the alternative uncommitted strategy, the expected value of the project is as in equation (2). Thus, a project will be done by an uncommitted investor if:

$$p*V - X < p_E*(p_G*V - X) - Y - (1 - p_E)*u_F \tag{3}$$

In this case, the value of the project is large enough with an uncommitted investor that enough value can be shared with the entrepreneur to make up for their potential disutility from failure.

When will this be the case? In those companies where the experiment reveals a large amount of information. As we saw above, when the value of the experiment is high, then $p*V - X < p_E*(p_G*V - X) - Y$. Since entrepreneurial disutility lowers the value of the experiment, the information from the experiment has to be even more valuable to be financed. Thus, it is the uncommitted, failure-intolerant investors that will select the most experimental projects. Meanwhile, those organisations that are more tolerant of failure will only be willing to back the less experimental projects, because with safer projects they will not need to extract value by terminating if bad information occurs.

Combining this with the idea of tolerance of failure in Manso (2011), we should expect that large, bureaucratic corporations may encourage innovation, but will be unwilling to back very experimental projects, as it would imply a negative expected value to do so without shutting them down after early bad news. Venture capitalists, on the other hand, will choose to fund radical experiments, but many entrepreneurs may be unwilling to leave safe jobs to pursue these projects since they have a significant chance of early failure. Interestingly, corporate venture capitalists are thought to be more tolerant of failure than regular venture capitalists, and Chemmanur et al. (2012) report that this encourages greater innovation. In Nanda and Rhodes-Kropf (2015), we suggest that this might explain why corporate VC earns lower returns than typical VC.[9]

In the same vein, countries with laws designed to make it difficult to fire employees and shut down firms may encourage innovation, but financiers in these countries will be unwilling to back very experimental projects – again, those that would have a negative expected value if they could not be shut down after

9 Corporate venture capitalists do not seem to have had adequate financial performance, but Dushnitsky and Lenox (2006) have shown that corporations benefit in non-pecuniary ways (see the theory by Fulghieri and Sevilir, 2009).

early experiments. This may help explain the remarkable dearth of innovation in some European countries (Saint-Paul, 1997; Bozkaya and Kerr, 2014).

The standard culprit for the lack of entrepreneurship in Europe is that there is thought to be a higher stigma attached to failure (Landier, 2002). We can see the intuition for this from equation (2): if u_F is larger, then the value of experimentation is lower. Thus, there will be a tendency towards more certain, or less experimental, projects. However, although the stigma of failure can explain a reduction in entrepreneurship, it has more challenges explaining the virtual absence of radical new economy companies emerging from many countries. Surely some entrepreneurs are willing to take the risk? In fact, what entrepreneurs complain about in many countries is that they cannot get their idea funded. Even Skype, a huge venture-backed success that was started by European entrepreneurs Niklas Zennström and Janus Friis, received its early funding from US venture capitalists Bessemer Venture Partners and Draper Fisher Jurvetson.

A stigma of failure cannot explain this phenomenon by itself . In an environment with a high stigma of failure, capital will be even cheaper as it fights to attract entrepreneurs (Landier, 2002). But European entrepreneurs complain that they cannot find capital to fund their novel ideas even if they are willing to take the risk and potentially suffer the consequences of failure. In Nanda and Rhodes-Kropf (2015), we build on Landier (2002) to show that the problem is two-sided: venture capitalists look for less experimental projects to help them form a reputation for being tolerant of failure, because most entrepreneurs want a more failure-tolerant backer. But doing so potentially results in an equilibrium with no investor willing to fund radical experiments, even if they have positive expected value and the entrepreneur is willing to take the risk. Martin Varsavsky, one of Europe's leading technology entrepreneurs, noted in an interview with *Fortune* magazine that "Europeans must accept that success in the tech startup world comes through trial and error. European [investors] prefer great plans that don't fail".[10]

More generally, this work implies that formal and informal institutions in an economy can play an important role in the level of innovation through their role in promoting the amount of experimentation that investors undertake. First, certain financial intermediaries are, by design, limited in the amount of experimentation they can engage in. Banks, for example, do not share proportionately in the benefits when a startup does extremely well, but do suffer the losses when the startup fails. Banks cannot, therefore, fund an experiment with a high chance of failure, even if it is a positive expected-value experiment. Indeed, Black and Gilson (1998) argue that bank-oriented economies are less likely to encourage startups engaged in innovation. In a similar vein, regulations surrounding the amount of money that can be committed by pension funds to asset classes such as VC can have important implications for the amount of capital available to support the financing of experimentation (Kortum and Lerner, 2000).

Second, policies that are aimed at motivating experimentation by entrepreneurs can limit the degree to which investors are willing to finance this experimentation. For example, lenient bankruptcy laws may encourage entrepreneurs to take on bolder experiments, but at the same time make investors less willing to fund the experimentation, since their return if things go badly is reduced (Guler, 2007a,b;

10 http://tech.fortune.cnn.com/2012/08/14/europe-vc/

Cerqueiro et al., 2013; Nanda and Rhodes-Kropf, 2015;). On a similar note, employment protection laws might encourage employees in large companies to engage in more experimentation, but can limit the attractiveness for VC investors who need to hire and fire employees to effectively engage in experimentation (Bozkaya and Kerr, 2014).

Finally, societal norms can have important interactions with the formal institutional environment and with the organisational strategies of investors. Cultures in which there is a high stigma attached to failure are ones in which entrepreneurs are less likely to want financing from investors with a reputation for shutting down projects. This can lead investors to pick more failure-tolerant strategies and, in doing so, only finance the less-experimental startups in the economy. Thus, programmes aimed at celebrating the entrepreneur and venture investors, even if unsuccessful, may have important effects.

4.4 Shocks to the availability of capital

Having discussed the costs associated with exercising abandonment options when intermediate information is bad, we turn next to constraints associated with experimentation even when intermediate information is positive. This is because the financing available for startups engaged in innovation is notoriously volatile (Gompers and Lerner, 2004; Kaplan and Schoar, 2005; Gompers et al., 2008), leading entrepreneurs and VC investors to worry about the availability of capital even if initial experiments go well. Venture capialists refer to this concern as 'financing risk' – the risk that the survival of an otherwise healthy startup might be threatened by a negative shock to the supply of capital in its sector when it is looking for the next round of funding.11

This worry seems rational given the ebbs and flows of capital that have occurred within various venture sectors at different times and in distinct places.

In Nanda and Rhodes-Kropf (2014), we model investors' responses to financing risk and explain why investors' responses have a larger effect on the most novel technologies in the economy. Investors can respond to financing risk by providing firms more upfront funding, thus making startups less vulnerable to the future state of the capital markets. This response can effectively eliminate financing risk, but it also comes at a cost – providing firms greater upfront funding reduces investors' ability to abandon their investment if intermediate information on its prospects is poor. In fact, the value of the lost real option can be high enough that it makes the investment unviable. This trade-off between wanting to protect firms from financing risk and wanting to preserve the option to abandon the investment is most salient for firms engaged in radical innovations. Thus, the startups most susceptible to financing risk are those commercialising radical innovations – these are the ventures that are most likely to be funded when financing risk is low, and are most likely to be constrained when financing risk is high. Their work thus provides an intuitive mechanism linking hot and cold financial markets to innovation in the real economy.

In Nanda and Rhodes-Kropf (2014), we show how investors with small pools of capital, who depend more on other investors' willingness to fund the startup in its next round of funding, are more exposed to financing risk. Regions with

11 Large firms who finance with debt face a similar risk, referred to as 'rollover risk', when trying to issue new bonds to replace maturing bonds (Acharya et al. 2011; He and Xiong, 2012a,b).

a small number of investors and investors with small funds are therefore more likely to be subjected to financing risk. As shown by Kortum and Lerner (2000), the Prudent Man Rule in the United States, which allowed pension funds and other large institutional investors to make substantial commitments to private equity, seems to have been pivotal in generating a large pool of capital to fund innovation. A big distinction between the United States and Germany, for example, is the number of active 'large' VC firms (i.e. with more than $300 million under management). The size of the fund can have a direct bearing on the degree to which venture capitalists push for bold commercialisation strategies but, as seen above, can be reinforced by the presence of financing risk, which is much more salient for smaller VC investors.

This insight from Nanda and Rhodes-Kropf (2014) can be seen in the context of our model by assuming that there is a probability ($1 - \theta$) that the firm cannot find *$X* when it is ready for the next round of funding. Since $\theta < 1$, including financing risk in the model shows how it reduces the value of experimentation:

$$p_E{*}\theta{*}(p_G{*}V - X) - Y < p_E{*}(p_G{*}V - X) - Y \tag{4}$$

The introduction of θ implies that some experimental projects will no longer be undertaken. These are firms that were not viable without an experiment (that is, the most novel investments), but are now also not profitable even with an experiment, because of the presence of financing risk. Other startups are likely to be financed with all-or-nothing bets. These latter startups are firms for which:

$$p{*}V - X > p_E{*}\theta{*}(p_G{*}V - X) - Y \tag{5}$$

i.e. rising financing risk (smaller θ) causes the expected value with the experiment to be less than without the experiment. These are startups that were not particularly novel, so that the value of the lost abandonment option is not as high. They are better off being protected against financing risk and being funded all in one go.

These results show that times or places with high financing risk (times with low capital availability) are the times/places when high expected value – but safe – projects will be run. This fits the intuition that good, solid firms are funded when capital is not freely available. The results also suggest, however, that investors are more willing to experiment in boom times or places with a great deal of capital. Thus, these become times when, or places where, more novel, experimental startups are financed. Startups funded in boom times/places should be more likely to fail (when investors exercise their abandonment options), but are also likely to have bigger successes. This is what locations with limited capital available for new ideas miss out on – the great success that comes from the few remarkable outcomes (Nanda and Rhodes-Kropf, 2013).

This way of thinking about the funding of innovation suggests that there can be a 'good' equilibrium that increases innovation in places like Silicon Valley and in booming time periods, and alternative equilibria that are bad for innovation in other places and times. If we believe that this is an important part of the phenomena, then policy designed to increase innovation should be aimed at trying to break the 'bad' equilibria and switch it to the 'good' equilibria. This is easier said than done, as there are many arguments for why one equilibrium or another might currently exist. However, two notions are helpful guides to thinking about policy in this context.

First, concentrated policies are likely to have a larger effect. That is, something that encourages investment in a particular area or sector is more likely to have an impact than a broad-based initiative. In this framework, a policy will have a large impact if it increases the perception that several investors are interested in backing a certain sector, thereby lowering potential shocks to the availability of capital. Thus, a broad policy designed to have a small effect on many companies seems fundamentally less likely to engineer a regime switch. The analogue to policies aimed at encouraging innovation are those aimed at popping technology 'bubbles' or preventing investors from losing money in risky ventures. What may look to policymakers as unsound investments in areas with a great deal of failed companies may be vital to experimentation and innovation. In fact, the results from Nanda and Rhodes-Kropf (2014) suggest that the most innovative startups may even need hot financial markets to facilitate their initial diffusion.

The second notion that stems for our model's intuition is that local areas could potentially break the 'bad' equilibrium and encourage local innovation by, counterintuitively, creating a mechanism to help the best local companies leave to go to innovation hubs. This should encourage local entrepreneurs and small investors to fund and start companies locally, because they would know if the companies work locally they could be moved to areas where they could get the funding and other resources needed to scale the idea. Once a vibrant startup community has formed locally, investors would naturally arise trying to fund the best before they moved away. Thus, this idea breaks the 'chicken and egg' problem.

4.5 Conclusion

A large body of literature in entrepreneurial finance has shown how financing frictions arising from asymmetric information between entrepreneurs and VC investors can lead to credit constraints for high-potential ventures. This chapter complements prior research by focusing on another possible source of financing frictions: the fundamental uncertainty facing startups in their earliest stages, when neither the entrepreneur nor the investor knows about the true potential of the venture without investing in learning about its viability. In this context of extreme uncertainty, multi-stage financing allows investors to learn about a venture's potential over time, without committing the full amount upfront. These real options can be particularly valuable in the context of entrepreneurship, because most new ventures fail completely and only a few go on to become extremely successful. We have shown how constraints to staged financing reduce the value of these real options, and thus influence the degree to which investors can effectively experiment. We show how this has important consequences for the degree to which radical new technologies are commercialised across regions, with important consequences for policies looking to stimulate high potential entrepreneurship.

Formal regulations and informal cultural institutions that make it harder to abandon investments when intermediate information is bad can lead investors to only finance startups when the value of abandonment options is low. These are startups with safer, less novel innovations, with the implication that regions or firms where it is harder to engage in experimentation are likely to see fewer startups engaged in innovation. In addition, potential shocks to the availability of capital can reduce the value of staged financing. This risk is more salient in regions with a small number of investors, or investors with smaller funds. Again, these constraints to experimentation impact the most novel startups in the economy. Overall, these insights also suggest caution in trying to prevent failure of startup ventures. Failure is a natural part of the experimental process and, in fact, extreme failure and extreme success may be two sides of the same coin.

References

Acharya, V. and K. Subramanian (2009), "Bankruptcy Codes and Innovation", *Review of Financial Studies* 22(12), pp. 4949-4988.

Acharya, V., D. Gale and T. Yorulmazer (2011), "Rollover risk and market freezes", *Journal of Finance* 66(4), pp. 1177-1209.

Aghion, P. and P. Howitt (1992), "A Model of Growth through Creative Destruction", *Econometrica* 60(2), pp. 323-351.

Aghion, P., J. Van Reenen and L. Zingales (2009), "Innovation and Institutional Ownership", Harvard University Working Paper, Cambridge, MA.

Bergemann, D. and U. Hege (2005), "The Financing of Innovation: Learning and Stopping", *RAND Journal of Economics* 36(4), pp. 719-752.

Bergemann, D., U. Hege and L. Peng (2008), "Venture Capital and Sequential Investments", Working Paper.

Bernstein, S., X. Giroud and R. Townsend (2014), "The impact of venture capital monitoring: Evidence from a natural experiment", Journal of Finance, forthcoming

Black, B.S. and R.J. Gilson (1998), "Venture capital and the structure of capital markets: banks versus stock markets", *Journal of Financial Economics* 47(3), pp. 243-277.

Bozkaya, A. and W.R. Kerr (2014), "Labor Regulations and European Venture Capital", *Journal of Economics and Management Strategy* 23(4), pp. 776-810.

Burkart, M., D. Gromb and F. Panunzi (1997), "Large Shareholders, Monitoring and the Value of the Firm", *Quarterly Journal of Economics* 112(3), pp. 693-728.

Cerqueiro, G., D. Hegde, M.F. Penas and R. Seamans (2013), "Debtor Rights, Credit Supply and Innovation", SSRN Working Paper No. 2246982, Rochester, NY.

Chemmanur, T., K. Krishnan and D. Nandy (2011), "How does venture capital financing improve efficiency in private firms? A look beneath the surface", *Review of Financial Studies* 24(12), pp. 4037-4090.

Chemmanur, T.J., E. Loutskina and X. Tian (2012), "Corporate Venture Capital, Value Creation and Innovation", Working Paper, Boston College.

Cornelli, F. and O. Yosha (2003), "Stage Financing and the Role of Convertible Securities", *Review of Economic Studies* 70(1), pp. 1-32.

Dushnitsky, G. and M.J. Lenox (2006), "When does corporate venture capital investment create firm value?", *Journal of Business Venturing* 21, pp. 753-772.

Ewens, M. and M. Rhodes-Kropf (2015), "Is a VC Partnership Greater than the Sum of its Partners?", NBER Working Paper No. 19120, Cambridge, MA (forthcoming in *Journal of Finance*).

Ewens, M. and M. Marx (2014), "Executive Replacement in Venture Capital-Backed Startups", MIT Working Paper, Cambridge, MA.

Ferreira, D., G. Manso and A. Silva (2011), "Incentives to Innovate and The Decision to Go Public or Private", LSE Working Paper, London.

Fluck, Z., K. Garrison and S .Myers (2007), "Venture Capital Contracting: Staged Financing and Later-Stage Syndication of Venture Capital Investments", MIT Working Paper, Cambridge, MA.

Foster, L., J. Haltiwanger and C. Syverson (2008), "Reallocation, Firm Turnover and Efficiency: Selection on Productivity or Profitability", *American Economic Review* 98(1), pp. 394-425.

Fulghieri, P. and M. Sevilir (2009), "Organization and Financing of Innovation and the Choice between Corporate and Independent Venture Capital", *Journal of Financial and Quantitative Analysis* 44(6), pp. 1291-1321.

Gompers, P. (1995), "Optimal Investment, Monitoring and the Staging of Venture Capital", *Journal of Finance* 50(5), pp. 1461-1489.

Gompers, P. and J. Lerner (2000), "Money chasing deals? The impact of fund inflows on private equity valuations", *Journal of Financial Economics* 55(1), pp. 281-325.

Gompers, P. and J. Lerner (2004), *The Venture Capital Cycle*, Cambridge, MA and London: MIT Press.

Gompers, P., A. Kovner, J. Lerner and D. Scharfstein (2008), "Venture capital investment cycles: The impact of public markets", *Journal of Financial Economics* 87(1), pp. 1-23.

Guler, I. (2007a), "An Empirical Examination of Management of Real Options in the U.S. Venture Capital Industry", in J.J. Reuer and T.W. Tong (eds), *Real Options Theory (Advances in Strategic Management, Volume 24),* Emerald Group Publishing Limited, pp.485-506.

Guler, I. (2007b), "Throwing Good Money After Bad? A Multi-Level Study of Sequential Decision Making in the Venture Capital Industry", *Administrative Science Quarterly* 52(2), pp. 248-285.

Hall, R.E. and S.E. Woodward (2010), "The Burden of the Nondiversifiable Risk of Entrepreneurship", *American Economic Review* 100(3), pp. 1163 -1194.

Hellmann, T. (1998), "The Allocation of Control Rights in Venture Capital Contracts", *RAND Journal of Economics* 29(1), pp. 57-76.

Hellmann, T. and M. Puri (2000), "The Interaction between Product Market and Financing Strategy: The Role of Venture Capital", *Review of Financial Studies* 13(4), 959-984.

Hellmann, T and M Puri (2002), "Venture Capital and the Professionalization of Start-Up Firms: Empirical Evidence", *Journal of Finance* 57(1), 169-197.

Hellmann, T. and V. Thiele (2011), "Incentives and Innovation: A Multitasking Approach", *American Economic Journal: Microeconomics* 3(1), pp. 78-128.

He, Z. and W. Xiong (2012a), "Dynamic debt runs", *Review of Financial Studies* 25(6), pp. 1799-1843.

He, Z. and W. Xiong (2012b), "Rollover Risk and Credit Risk", *Journal of Finance* 67(2), pp. 391-429.

IHS Global Insight (2011), *Venture Impact* (6th edition), Waltham, MA.

Kaplan, S. and A. Schoar (2005), "Private Equity Performance: Returns, Persistence and Capital Flows", *Journal of Finance* 60(4), pp. 1791-1823.

Kaplan, S., B. Sensoy and P. Stromberg (2009), "Should Investors Bet on the Jockey or the Horse? Evidence from the Evolution of Firms from Early Business Plans to Public Companies", *Journal of Finance* 64(1), pp. 75-115.

Kaplan, S.N. and J. Lerner (2010), "It Aint Broke: The Past, Present and Future of Venture Capital", *Journal of Applied Corporate Finance* 22(2), pp. 36-47.

Kerr, W., J. Lerner and A. Schoar (2014a), "The consequences of entrepreneurial finance: Evidence from angel financings", *Review of Financial Studies* 27(1), pp. 20-55.

Kerr, W., R. Nanda and M. Rhodes-Kropf (2014b), "Entrepreneurship as Experimentation", *Journal of Economic Perspectives* 28(3), pp. 25-48.

King, R. and R. Levine (1993), "Finance and Growth - Schumpeter Might Be Right", *Quarterly Journal of Economics* 108(3), pp. 717-737.

Klepper, S. (1996), "Entry, Exit, Growth and Innovation Over the Product life Cycle", *American Economic Review* 86(3), pp. 562-583.

Kortum, S. and J. Lerner (2000), "Assessing the impact of venture capital on innovation", *Rand Journal of Economics* 31(4), pp. 674-92.

Landier, A. (2002), "Entrepreneurship and the Stigma of Failure", MIT Working Paper, Cambridge, MA.

Manso, G. (2011), "Motivating Innovation", *Journal of Finance* 66(5), pp. 1823 -1860.

Myers, S. (2000), "Outside Equity", *Journal of Finance* 55, 1005-1037.

Nanda, Ramana. 2015. "Experimentation and Real Options in Entrepreneurial Finance." Harvard Business School Note 815-056, 1–35

Nanda, R. and M. Rhodes-Kropf (2013), "Investment Cycles and Startup Innovation", *Journal of Financial Economics* 110(2), 403-418.

Nanda, R. and M. Rhodes-Kropf (2014), "Financing Risk and Innovation", Harvard University Working Paper, Cambridge, MA.

Nanda, R. and M. Rhodes-Kropf (2015), "Innovation Policies", Harvard University Working Paper, Cambridge, MA.

Puri, M. and R. Zarutskie (2012), "On the lifecycle dynamics of venture-capital- and non-venture-capital-financed firms", *Journal of Finance* 67(6), pp. 2247-2294.

Rajan, R. (2012), "The corporation in finance", *Journal of Finance* 67(4), pp. 1173-1217.

Rosenberg, N. (1994), "*Economic Experiments",* in N. Rosenborg, *Inside the Black Box: technology and experiments*, Cambridge, UK: Cambridge University Press.

Sahlman, W.A. (1990), "The Structure and Governance of Venture-Capital Organizations", *Journal of Financial Economics* 27(2), pp. 473-521.

Saint-Paul, G. (1997), "Is labour rigidity harming Europe's competitiveness? The effect of job protection on the pattern of trade and welfare", *European Economic Review* 41(3), 499-506.

Samila, S. and O. Sorenson (2011), "Venture capital, entrepreneurship and economic growth", *Review of Economics and Statistics* 93(1), pp. 338-349.

Schumpeter, J. (1942), *Capitalism, Socialism and Democracy*, New York: Harper.

Sorensen, M. (2007), "How smart is smart money? An empirical two-sided matching model of venture capital", *Journal of Finance* 62(6), 2725-2762.

Stern, S. (2006), "Economic Experiments: The role of Entrepreneurship in Economic Prosperity", *Melbourne Review: A Journal of Business and Public* Policy 2(2), pp. 53-56.

Tian, X. and T.Y. Wang (2014), “Tolerance for Failure and Corporate Innovation”, *Review of Financial Studies* 27(1), pp. 211-255.

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