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Abstract:

We review the growing literature on the relationship between venture capital booms and startup financing, focusing on three broad areas: First, we discuss the drivers of large inflows into the venture capital asset class, particularly in recent years -- which are related to but also distinct from macroeconomic business cycles and stock market fluctuations. Second, we review the emerging literature on the real effects of venture capital financing booms. A particular focus of this work is to highlight the potential impact that booms (and busts) can have on the types of firms that VCs choose to fund and terms at which they are funded, independent of investment opportunities -- thereby shaping the trajectory of innovation being conducted by startups. Third, an important insight from recent research is that booms in venture capital financing are not just a temporal phenomenon but can also be seen in terms of the concentration of VC investment in certain industries and geographies. We also review the role of government policy, exploring the degree to which it can explain the concentration of VC funding in the US over the past forty years in just two broad areas – information and communication technologies (ICT) and biotechnology. We conclude by highlighting promising areas of further research.

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1. Introduction

Venture capital is associated with some of the most innovative and high-growth companies in the economy. Scores of startups commercializing transformational technologies have been backed by venture capital. Although fewer than 0.5% of firms founded in the U.S. each year received venture capital financing (Puri and Zarutskie, 2012), venture-backed firms constitute nearly half of IPOs in the United States. Furthermore, Lerner and Nanda (2020) report that among firms that were publicly traded in the U.S. at the end of 2019, venture-backed companies accounted for half the revenue and over three-quarters of market capitalization and reported R&D expenditure, reinforcing the innovative nature of venture-capital backed firms.

The majority of venture capital investors raise money from, and invest on behalf of, "limited partners"—institutions such as pension funds, sovereign wealth funds and university endowments that allocate some of their capital to the broader private equity assets class to which venture capital belongs (Da Rin, Hellmann and Puri, 2013). An important feature of these arrangements between limited partners and VC fund managers is that they are structured as closed-end funds with a ten-year life (Sahlman, 1990; Gompers and Lerner, 2004). The capital raised by VCs is invested into young, innovative startups over the initial few years of the fund. VCs then govern and support these startups, helping them to grow and mature organizationally prior to an exit – either by sponsoring an initial public offering ("IPO") or selling the venture through an M&A transaction. Successful exits usually happen seven-to-ten years after investment and the resulting profits are then channeled back to limited partners.

In principle, the ten-year fund structure, and the fact that VCs are making investments into privately held startups, should make venture capital funds more immune to fluctuations in the equity and credit markets, enabling them to take a long-term perspective to building new companies. Yet, a growing academic literature has documented how booms and busts in financing are a prominent feature of the venture capital market (e.g., Lerner, 2002; Gompers and Lerner, 2001, 2004; Howell et. al, 2021). While the "internet bubble" of 1997-2000 is the most well-studied of these financing booms, there have been VC booms around the financing of electronics startups in the 1960s, personal computer and biotechnology ventures in the 1980s (Lerner 2002), and brief booms in clean energy from 2004-2006 (Nanda et al, 2015) and blockchain and cryptocurrencies in 2016-2018 (Howell et al, 2020). Aside from these fluxes in capital, there has been a sustained increase in capital deployed by VCs over the past ten years, rising from under $40 billion globally in 2009 to over $250 billion in 2019.

In this chapter, we review the nascent but growing literature that seeks to understand the relationship between venture capital booms and startup financing. In Section 2, we discuss the literature on the drivers of large inflows into the venture capital asset class, and the extent to which VC booms differ from those seen broadly in financial markets. While capital generally flows towards investment opportunities, some of the shifts in the supply of risk capital in venture have been driven by regulatory factors or structural elements of the venture capital industry that can amplify booms. Aspects such as the structure of closed ends funds, the need to exit within a certain period, as well as a more recent phenomenon of investors specializing in financing different stages of a startups' lifecycle, play a role in the venture capital fluctuations. We also highlight some of the literature on the life cycle of new industries, as well as the documented relationship between technological revolutions and speculative capital harking back as far as the late 1700s (see Perez, 2002; Goldfarb and Kirsch, 2019 for reviews). While not directly about venture capital booms, these studies provide an opportunity to understand the implications for venture capital today as well as put some the

boom and bust phenomenon seen in venture capital into historical perspective. This in turn helps develop a nuanced understanding of how policy can play a role in supporting commercialization of the technologies responsible for productivity growth and the degree to which we can also learn from historical studies of booms and startup financing.

In Section 3, we review the emerging literature related to the real effects of venture capital financing booms, through the effects they have on portfolio allocation strategies and other decisions made by partners in venture capital firms. A particular focus of this work is to highlight the potential impact this can have on the types of firms that venture capital investors choose to fund, independent of the investment opportunities that may be changing in these periods, thereby shaping the trajectory of innovation being conducted by startup firms.

An important insight from recent research work is that booms in venture capital financing are not just a temporal phenomenon but can also be seen in terms of the concentration of VC investment in certain industries and geographies. Our understanding of whether these are driven by a dearth of investment opportunities in certain industries and regions, or whether potential frictions may be causing this imbalance is leading to this is still in its infancy.

In Section 4, we look at the role of government policy, exploring the degree to which it can explain the concentration of VC funding over the past forty years in just two broad areas – information and communication technologies (ICT) and biotech. This is an important area of research, one that has received relatively little attention compared to government's role in alleviating financing constraints in small business lending. Section 5 concludes, while also pointing to what we believe are some promising areas of research related to VC booms and startup financing.

2. Drivers of Venture Capital financing booms:

2.1 *Shifts in Investment Opportunities and Demand for Risk Capital*

2.1.1 Technological revolutions

Perhaps the most salient channel driving booms in VC and startup financing is the arrival of new technologies and the deployment of risk capital to commercialize these. Indeed, a large body of research on the life cycle of a new technologies provides a useful baseline about the degree to which venture capital (and risk capital in general) merely follows a sharp rise and subsequent shakeout of startups at the birth of new industries versus actually driving a boom-and-bust cycle in the real economy.

For example, Gort and Klepper (1982) and Klepper and Graddy (1990) document an extremely consistent pattern of massive entry of new startups which is then followed by a "shakeout" over 46 different new products ranging from automobiles, lasers, radio transmitters and television to penicillin and DDT, that were commercialized well before a formal VC industry existed. Such patterns form the basis of the Product Life Cycle Theory (e.g., Abernathy and Utterback 1978, Anderson and Tushman, 1990), which explains the rapid increase and subsequent shakeout in firms by first noting the substantial uncertainty about consumer preferences related to new products and technologies, even among the consumers themselves. In fact, in many instances early in the life of a new technology, it was even unclear what the technology would be used for, indicating that "market risk"

– separate from technology risk – is a strategic issue for ventures attempting to commercialize innovative technology. For example, Nye (1992) outlines the several decades it took to settle on commercially viable applications of electric power, while Janeway (2018) notes that one of the early applications of the telephone was to broadcast entertainment to the home rather than point-to-point communication between individuals.

The Product Life Cycle Theory notes that because of the uncertainty in consumer preferences, several firms producing similar but somewhat different variants of the new product enter the market to learn about consumers' preferences. As consumers and producers experiment with the various versions of the product, a "dominant design" eventually emerges. Firms that are not producing the dominant design exit, which leads to a shakeout in the industry.[1]

It is noteworthy that this theory, as well as models by Jovanonic and McDonald (1994) and Klepper (1996) predict a sharp rise in entrants at the birth of an industry, followed by a shakeout, without any presence of finance or financial intermediaries. The huge increase in startup activity is driven by widespread experimentation as firms and consumers learn about the new technology; the shakeout arises once uncertainty is resolved, and a dominant design emerges.

Pastor and Veronesi (2009) is an important paper in this realm as it provides a rationale for why the uncertainty and learning can also impact the financial sector. Their model also involves uncertainty about a new technology and whether it should be adopted by a representative agent. The agent experiments with the new technology by making a small-scale investment to understand its average productivity and chooses to make an irreversible investment decision to adopt the technology at large scale if he learns that its productivity is sufficiently high. In their model, times when there is a shift from small scale "experimentation" with the new technology to large scale adoption leads to increases in predicted cash flows, but also changes the nature of risk being faced by the agent from initially being idiosyncratic to becoming systematic. This time-varying nature of risk associated with large scale adoption of new technologies, together with the predicted cash flows from adopting a more productive technology has non-monotonic implications for asset prices – leading to an initial rapid rise in prices, followed by a subsequent crash. Pastor and Veronesi (2009) emphasize that while this boom and bust in asset prices can appear to look like a bubble ex post, it nevertheless stems from a fully rational model where prices initially rise due to good news about cash flows and subsequently fall due to an increase in systematic risk.

Of course, models based on experimentation with new technology in the real economy are not necessarily inconsistent with "irrational exuberance" on the part of speculative capital financing these technological revolutions (Kindleberger, 1978; Shiller, 2000; Scheinkman 2014). With respect to the bursting of the dot com bubble, Ofek and Richardson (2003) link the timing of the dot com collapse to lockup expirations and the resultant selling by insiders. They show that distributions by VC funds to their limited (and general) partners rose from less than $4 billion in the third quarter of 1999 to more than $20 billion in the first quarter of 2000; the NASDAQ Index peaked in April 2000.

That said, while much research in venture capital and technological revolutions has looked at irrational exuberance during such financing booms (and bubbles), it is useful to recognize that several of the facts typically used to document the presence of a bubble –such as the financing of lots of seemingly very similar firms, followed by a subsequent crash in the number of entrants, as well as the boom and bust cycle associated with asset prices --- can emerge from models of learning

[1] Jovanonic and McDonald (1994) – who look at automobile tires and Klepper (1996) provide alternative models of entry and exit that are not related to learning about consumer demand, but that also generate sharp rise in entrants followed by a shakeout.

that are completely independent of any financial intermediaries or where they do not play any active role in propagating or participating in a bubble.

Goldfarb and Kirsch (2019) provide an important step in this direction, by examining fifty-eight technologies across 150 years, and studying the conditions under which some of these led to speculative bubbles while others did not. Beyond the underlying uncertainty of a new technology's commercial promise, they point to the presence of retail investors and the alignment of beliefs through narratives as ingredients that are needed for a speculative bubble to emerge. Understanding the implications for financing booms in venture capital, which is the dominant source of risk capital in the economy today, is particularly critical, given the changing organization of inventive activity over this long period and the greater capital intensity associated with commercializing many frontier technologies of the present day.

2.1.2 "Hot" (Stock and IPO) Markets

Beyond technological revolutions, public markets play an important role in providing signals of investment opportunities to venture capital investors. IPO markets themselves have been shown to be highly cyclical, with the number of new issues being clustered in certain periods of time (Lowry, 2002; Lowry and Schwert 2002). While a discussion of the drivers of "hot" and "cold" IPO markets is beyond the scope of this review, their presence has been shown to explain some of the same cyclicality of VC investment and provide a rationale for why venture capital is not insulated from financial market fluctuations despite long fund cycles.

Since many successful "exits" for venture capital investors are through taking their companies public and bargaining power of startups vis-à-vis acquirers is also tied to the outside option in the public market, the appetite of public market investors for particular types of investments likely has a direct impact on the investment choices of venture capital investors. Indeed, returns of venture capital investors have been shown to be highly correlated with the returns of the market (Cochrane, 2005; Korteweg and Sorensen, 2010; McKenzie and Janeway, 2011; Ewens, Jones and Rhodes-Kropf, 2014; Harris, Kaplan and Jenkinson, 2020).

Lerner (1994) shows that experienced venture capital investors seem particularly adept at taking companies public at market peaks. Moreover, looking at data between 1975 and 1998, Gompers et al (2008) show that venture capitalists with the most industry experience react to public market signals of investment opportunities by increasing investment in sectors that "heat up", with no negative impact in the performance of these investments. Their results are consistent with the most experienced venture capitalists "rationally" responding to signals of investment opportunity as opposed to "overshooting" investments in these sectors.

2.1.3 *Technological shocks to cost of starting new firms*

New technologies are a source of investment opportunities for venture capital investors, but also have the potential to impact the way in which VCs learn about their investment opportunities. A large literature has noted the extreme uncertainty facing investors in early stage ventures (e.g., Kerr, Nanda and Rhodes-Kropf, 2014) leading them to learn about the venture's prospects through a series of investments over time. This multi-stage financing into startups is equivalent to conducting a sequence of experiments that are akin to real options – where VCs retain the option to abandon the investment if initial prospects appear poor, as well as the right to invest more money into the next stage of financing should initial prospects seem promising (Cornelli and Yosha, 2003; Bergemann, Hege, Peng 2008). As with all real options, the cost of the option – in this case the

investment that VCs need to make into a venture at each round of financing to learn about its technology or appeal to a consumer – can play an important role in determining the value of the investment.

Ewens, Nanda and Rhodes-Kropf (2018) document how the advent of cloud computing in 2006 played a prominent role in substantially lowering the cost of starting new firms – by enabling startups to 'rent' hardware space in small increments and scale up as demand grew, instead of making large fixed upfront investments in hardware when success was still far from guaranteed. This allowed entrepreneurs and investors to learn cheaply about the viability of startups before making large fixed investments, enabling a small initial investment to help learn a lot about the ultimate potential of the venture. They document how this increased the number of new ventures that were profitable investments for VCs, leading to a substantial growth in early stage investment by VCs as well as new financial intermediaries such as accelerators who entered to meet the needs of these entrepreneurs (Hochberg, 2016).

2.2 Shifts in Available Supply of Risk Capital

While investment opportunities provide a natural and intuitive explanation for booms in venture capital financing, we turn next to examining factors that might contribute to shifts in the available supply of risk capital, independent of the investment opportunities that are available.

2.2.1 Regulations

Although risk capital to support the financing of innovation has been available for centuries (Lamoreaux and Sokoloff, 2007; Perez, 2002; Nicholas 2019), the rapid growth and institutionalization of venture capital as an asset class is a recent phenomenon arising just forty years ago. Kortum and Lerner (2000) trace the institutionalization of venture capital to a clarification of rule in the Employment Retirement Income Security Act (ERISA) in 1979, which allowed fund managers to factor in the role of portfolio diversification when deciding whether they were making "prudent" investments. This in turn enabled pension funds to allocate a small share of their portfolio to asset classes such as venture capital, which was riskier but also had the potential to generate higher returns. Initially, corporate pension funds made small allocations to venture capital in the 1980s. This was followed a decade later by U.S. public pension funds. The very large size of the assets held by corporate and public pension funds implies that even if they allocate a small share of their portfolio to the venture capital asset class, it adds up to a substantial amount of funds raised by venture capital investors. This has implied that in the subsequent forty years, venture capital has come to be the dominant source of risk capital for technology-intensive startups in the United States and even to a large extent globally.

More recently, there has been a substantial increase in capital available for more mature, late stage startups. Ewens and Farre-Mensa (2020) argue that this substantial increase in capital for more mature, "late stage" venture capital firms is due in part to deregulation in securities laws – in particular the National Securities Markets Improvement Act (NSMIA) of 1996—which made it easier for startups to raise large sums of capital without having to go public. Related to this, Ewens and Farre-Mensa (2020) argue that the particularly large decline in small-cap IPOs beginning in the 2000s, and the near doubling in the median age to IPO among firms that do go public (Gao, Ritter and Zhu, 2013) has been driven in part by this availability of private capital rather than higher costs associated with going public.

2.2.2 Asset allocation process of limited partners and attributes of VC asset class

Aside from regulatory drivers, the manner in which limited partners typically allocate capital to VC investors, combined with the way in which VCs call and distribute capital, can lead to shifts in the availability of capital that do not coincide cleanly with investment opportunities. Three key factors contribute to this mismatch.

First, limited partners (LPs) in venture funds attempt to make forward looking decisions about how much of their capital should be allocated to different asset classes, but typically can only rely on historical performance. While this challenge is shared with all asset classes, it is exacerbated in the context of venture capital by the long delays from investment to realized returns: VC returns in any given period are largely driven by initial investments made 7-10 years before, while the forecasting exercise LPs are trying to undertake relates to how investments made in the coming few years will perform over the following 7-10 year period. Like other asset classes, when venture capital returns are high -- due to successful investments in the past-- LPs tend to increase allocations to the asset class. But these periods of high inflows of capital to VC funds are far from the investment opportunities that generated the high returns. Thus, higher or lower historical performance tends to lead to higher or lower allocations to venture capital but is not necessarily followed by high or low returns. (Lerner, 2002; Gompers and Lerner, 2004)

Second, even when a limited partner does have insight into potential investment opportunities at a given moment, it is difficult to quickly change de-facto exposure to the venture capital asset class due to the manner in which VCs draw down committed capital and return capital that is invested. VCs typically draw down committed capital over a 3 to 5-year period and return the money to limited partners as they are able to exit the underlying startups (rather than recycling this in the fund). Thus, an LP who wanted to increase their allocation to venture capital could commit more capital today, but this would not be fully invested into startups until years in the future. The same is true if an LP wanted to reduce exposure to venture capital. They could commit less to the asset class now, but past commitments would still be called, and current investments cannot not be easily liquidated.[2]

This problem is exacerbated due to the timing of venture exits. Recall that returns from capital that VCs invest are not recycled into new investment but are returned as “distributions” to the limited partners. Moreover, as noted Section 2.1.2 above, exit markets also tend to exhibit cyclicality and are correlated with market valuation levels. Thus, at a moment where venture capital returns are high, LPs are receiving cash back from their venture capital investments. This leads to a smaller realized allocation to venture capital even if (and potentially exactly when) limited partners desire a higher allocation. The opposite occurs when venture capitalists are calling capital previously committed but returning little as they are exiting very few companies. In this case allocations may increase in the short term even though the desire of the LP may be to decrease them.

Finally, an LP’s investment into venture capital may be further altered by performance in asset classes that are potentially unrelated to the investment opportunities in venture capital due to the way in which VC portfolios are valued. To see this, suppose that a pension fund manager wishes to

[2] Some of this mismatch can potentially be reduced at the Intensive margin, with venture capital Investors pivoting funds to areas that have more Investment opportunities. This has shown to be possible especially true among more established funds (Gompers et al, 2010).

allocate 15% of their portfolio to venture capital and has achieved this target. Then, some other part of their portfolio (for example domestic equities) goes down in value. Due to the illiquid nature of VC investments, the dollar value of their portfolio may remain unchanged, leading pension fund managers to be over-allocated to venture capital in terms of the share of their portfolio. Even when portfolio managers attempt to mark their companies to market quarterly, these valuation marks are quite stale. (Ewens, Jones and Rhodes-Kropf, 2014, Korteweg and Sorensen, 2017). Due to this challenge, VC portfolio may not appear to be as volatile as the rest of the market, leading limited partners to perceive they are over- or under-allocated to venture capital.

Because of these factors, recent work by Brown et. al (2020) argues that because of the industry structure, the nature of the long commitments and timing of draws and returns, investors cannot actually time their investing into venture capital in order to create meaningful time varying exposure to the asset class.

2.2.3 Macroeconomic and Interest Rate environment

There has been a sustained rise in investments into VC-backed ventures since the mid-2000s, with an acceleration after the financial crisis. Starting in 2014, there has also been a sharp increase in the number of so called "unicorn financings" – extremely large rounds of private financing where VC-backed firms are valued above $1 billion. Some of the increases are likely due to the continued rise in the number of startups seeking venture capital, stemming from the technological shocks outlined in Section 2.1.3 as well as the fact that many of these are "winner take all" businesses that benefit from large infusions of capital. It is also likely that -- as outlined in Section 2.2.1 --the lower costs associated with being able to remain private while still raising capital have contributed to unicorn financings.

However, it is also possible that the sustained low interest rate environment has led to an increased appetite for investing in "alternative asset classes" among traditional investorsNarratives among practitioners point towards the fact that the zero and even negative real interest rate environment has led to more interest in seeking investment opportunities that can generate higher returns, which is consistent with fund managers reaching for yield in venture capital and private equity as a function of return expectations in other asset classes (Bergstresser, Rauh and Desai, 2006). A number of the limited partners that have historically only invested through venture capital funds also began to make direct investments in private markets (Fang, Ivashina and Lerner, 2015; Lerner et al, 2018; Chernenko Lerner and Zeng, 2019). Moreover, given the much larger differences in fund performance across venture capital investors than typical intermediaries and the tendency for these performance differences to persist (Kaplan and Schoar, 2005) has led to an increased concentration of capital in a relatively small number of venture capital investors. As Lerner and Nanda (2020) point out, over 50% of the venture capital raised from 2014-2018 were raised by the top 50 firms. This has implications not only for the available supply of capital relative to investment opportunities, but potential real effects in terms of what gets funded, given the small number of decision makers to hold and deploy these large pools of capital (Hellmann and Thiele, 2018).

2.3 Structure of Venture Capital Industry:

As noted above, there is substantial evidence of the pro-cyclicality of venture capital investment (Gompers and Lerner 2004; Gompers et al 2008). Howell et al (2021) further document that this strong procyclicality of venture capital funding is driven by early stage VC investment. While several factors might play a role in driving this phenomenon, Howell et al (2021) argue that at least part of the sensitivity of early stage VC to market cycles is due to the structure of the VC industry, in

particular the role of multi-stage financing with some degree of specialization in the capital supply chain.

To see why this might be the case, note the one of the unique elements of venture capital is that, due to the extreme uncertainty associated with the outcome of new products and technologies, financing for such startups is staged across a number of rounds (Da Rin, Hellmann and Puri, 2013; Metrick and Yasuda, 2010). Moreover, there is some degree of specialization in terms of the stage at which different investors tend to focus, with Angel investors, Seed Stage and Early Stage funds often specializing in selecting and financing startups in their earliest stage, while larger multi-stage or late stage funds specializing in funding the growth and scaling of these ventures (Hellmann and Thiele, 2015).

All VCs face a tradeoff between diversification and ownership – on the one hand the idiosyncratic risk of the ventures they back requires them to spread their bets. On the other hand, a handful of extremely successful ventures tend to drive the majority of returns, so that VCs also want to have sufficient ownership in the firms that ultimately succeed to generate the returns they need. This tradeoff is perhaps even more salient for those making early stage investments where uncertainty about which ventures are likely to succeed is greatest. Early stage investors therefore tend to rely on later stage investors to continue financing a startup through to an exit, and this "passing of the baton" often happens prior to a startup being cash flow positive, which implies that early stage investors need to forecast the types of ventures that will be more likely to be financed by later stage investors. It also points to the reason why VCs express a strong desire to coordinate their investments within certain sectors and periods of time Nanda and Rhodes-Kropf (2017). While such herding could have both rational and irrational elements to it (e.g. Scharfstein and Stein, 1990; Goldfarb, Kirsch and Miller, 2007), such a need to forecast later stage investors' preferences and react accordingly can also account for the strong sensitivity of early stage investors to boom or bust signals.

Overall, aside from demand side factors such as investment opportunities and supply side factors such as regulation or the way in which limited partners allocate capital, there is a growing understanding that the structure of the VC industry itself is prone to amplification of booms (and busts) due to the inherent need to coordinate investment across industries and periods of time. We discuss the potential real effects of these actions by VCs in the subsequent section.

3. Consequences of VC Financing Booms (and Busts)

Although growing work has examined the real effects of venture capital in terms of the role that VCs play in impacting startup outcomes, we focus in this section more narrowly on how deal-making by VCs might change across booms and busts, independent on the nature of opportunities that may also be changing.

3.1 Money chasing deals

Using data on over 4,000 ventures with reported valuations over the period 1987 to 1995, Gompers and Lerner (2000) document a robust relationship between increases in commitments to venture capital funds and the reported valuations of startups receiving funding from VCs. Although distinguishing supply from demand is challenging, they exploit the shifts in supply of capital independent of technological opportunities outlined in Section 2.2, finding that a doubling in

commitments to VC led to a 7%-20% increase in the reported valuations of startups. Consistent with this, Kaplan and Schoar (2005) also show the procyclical nature of venture capital fund starts that are associated with subsequent lower returns.

Ewens and Farre-Mensa (2020) report similar patterns for a more recent period, documenting an increasing trend in the ownership held by founders since the mid-2000s. As they point out, this could be driven by several factors; however at least part of this appears to be driven by the extremely high valuations being received by late stage startups, linked to the deregulation in private markets that enabled startups to remain private for longer on attractive terms. Consistent with this, Gornall and Strebulaev (2020) analyze the valuations of 135 "unicorn financings" and document that the reported post-money valuations are nearly 50% above fair market value when analyzed using a contingent claims valuation framework.

3.2 Money Changing Deals? Real effects of financing booms

Although not explicitly about financing booms, Ewens, Gorbenko and Korteweg (2020) discuss how splits in equity and other contractual terms between entrepreneurs and investors can impact a venture's success through the role they play in shaping incentives. Other work has noted that beyond high valuations, "founder friendly" terms such as dual class stock have become more prevalent in recent years (Aggarwal et al, 2020). This is related to anecdotal accounts and statements in the press that in booming market, venture capital firms try outdo each other in the extent of pitching themselves as being willing to exercise less control, in order to get access to deals – which in turn can lead to entrenched founders who cannot easily be replaced. Understanding the underpinnings to such actions by VCs appears to be a promising area of further inquiry, particularly in light of the large body of work documenting the important role that VC monitoring and governance plays in the success of startup ventures (Hellmann and Puri 2000, 2002; Sorensen 2007; Chemmanur, Krishnan and Nandy, 2011; Bernstein, Giroud and Townsend, 2016).

The research noted above documents changes at the intensive margin of deals that are struck. In particular, booms can 'lower the discipline' on the part of investors as they compete to gain access to the best potential deals. However, VCs indicate that deal selection is among the most important drivers of their success (Gompers et al, 2020). There is also growing evidence that booms and busts can also shape the *extensive* margin of deals, independent of investment opportunities that may also change in these times.

For example, Nanda and Rhodes-Kropf (2013) document that the firms backed by VCs during booms are more likely to fail, but conditional on survival, are more likely to be in the upper tails of the distribution in terms of stock market value (holding constant year of IPO) and in terms of innovation as measured by patenting. This pattern holds when including VC firm fixed effects as well as using the exogenous shifts in capital supply used by Gompers and Lerner (2000), suggesting that VCs are willing to back riskier, more innovative startups during boom times. This suggests that while booms may lower the discipline of VCs, it may have another (not mutually exclusive) impact – making VCs more willing to experiment. While Nanda and Rhodes-Kropf (2013) look only at VC investments, Howell et al (2021) compare innovation by VC-backed startups to innovation in the broader economy using the universe of patents in the US Patent and Trademark Office. They find that VC-backed firms account for a disproportionate share of patents in the tails of the citation distribution when compared to innovation in the broader economy but that this disproportionate role of VC in innovation is strongly procyclical – it falls during downturns and is even higher during booms.

Showing shifts in the type of innovation relative to the universe of innovation in the economy provides further evidence of VCs changing investments at the extensive margin.

Why might VCs shift the types of firms they choose to fund during booms and busts? One explanation stems from either actual, or anticipated shifts in the ability and willingness of VCs to fund risky innovation during busts. For example, Townsend (2015) shows that VCs who were more exposed to IT investments during the dot com bubble were more likely to terminate funding for non-IT companies (e.g., biotechnology), suggesting as in Section 2 above that the retrenchment by limited partners is not necessarily aligned with investment opportunities and can lead VCs to invest in a constrained manner during busts. Howell et al (2021) document that during downturns VC investors appear to focus their capital on startups that will either achieve cash flow breakeven more quickly or alternatively reserve their capital for financing startups in their own portfolios.

Related to these potential frictions in the supply of capital, Nanda and Rhodes-Kropf (2017) introduce and discuss the potential impact of "financing risk" in venture capital, in a spirit similar to rollover risk (Acharya, Gale, and Yorulmazer 2011). They show how an increase in financing risk can lead otherwise healthy startups to not receive financing even if the VC firm itself is not constrained, due to a forecast of limited future funding from other venture firms prior the startups achieving positive cash flow from operations. On the other hand, a forecast of abundant future funding – such as during booms – leads VCs to be more willing to fund radical innovation. Their model provides a rationale for fluxes in the supply of capital leading to shifts in the types of startups VCs choose to back, independent of the investment opportunities. It is also consistent with more risky, innovative firms being financed during financing booms, as shown in Nanda and Rhodes-Kropf (2013) and the relative decline in innovativeness of VC-backed firms during downturns documented in Howell et al (2020).

More generally, Hellmann and Thiele (2015) also model the frictions arising from multi-stage financing, highlighting how early stage investors and late stage investors need to co-ordinate (Hochberg, Ljungqvist, and Lu, 2007), but also highlighting that investment by early stage investors is sunk by the time the startup needs to raise late stage capital. This creates agency conflicts that can lead late stage investors to "cram down" early stage investors ex post. The degree to which this is feasible is likely to vary across VC cycles.

The reaction of early stage investors to changes in the late stage market is also the focus of Bernstein et al (2021), who document that the substantial increase in late stage capital associated with unicorn financings since 2014 has been associated with a simultaneous decline in the number of startups that are being financed at the early stage. This pattern holds within industry and moreover is stronger in sectors that experienced larger infusions of late stage capital. Bernstein et al (2021) provide a model that links these two phenomena, showing that if late stage capital is concentrated in a hands of a few partners -- leading them to deploy to larger rather than more late stage rounds of financing – this gives a disproportionate advantage to the set of startups receiving large infusions of late stage capital. Early stage investors in turn find it advantageous to coordinate in backing startups showing early promise, instead of backing a larger number of potential ventures experimenting with different approaches to addressing customer needs. In this way, the concentration of capital in the hands of a small number of late stage partners can end up lowering the choice set available to customers in determining the best venture in the product market. If on the other hand the large infusion of capital at the late stage leads to more (rather than bigger) rounds of financing, then their model predicts an increase in capital leads to more early stage experimentation as might be typically expected. In this way, the structure of the VC industry – the prevalence of multi-stage financing and the fact that the number of partners in VC firms don't scale

proportionately with the size of the VC funds -- can lead in certain circumstances to inefficiently low funding of experimentation relative to what would have been optimal for a social planner.

Dicks and Fulghieri (2021) and focus on waves of innovation, by formalizing the notion of uncertainty aversion among investors, and document that in such contexts, uncertainty averse investors prefer to contemporaneously hold multiple uncertain assets in a portfolio rather than just an uncertain asset in isolation. Their model shows that this can lead to waves of innovation in sectors that are uncorrelated with aggregate economic activity. Formalizing the nature of uncertainty facing venture capital investors and the impact this has on their portfolio choices is a promising area of future work.

3.3 Concentration of Capital

Lerner and Nanda (2020) document that in addition to capital being concentrated in the hands of a relatively small number of investors, VC financing has been concentrated in a few broad industries and geographies. An important question in this area is whether this concentration is driven by a lack of good investment opportunities or frictions that may lead to a dearth of capital for good ideas in other industries or regions.

One friction that might be at play relates to the coordination required by VC investors outlined above– both within rounds in terms of their syndication patterns as well as over time through multi-stage financing. For example, Ewens, Nanda and Rhodes-Kropf (2018) point to a decline in the cost of learning about the potential of businesses that benefited from being able to test quickly and cheaply using cloud computing services. While this did not necessarily impact the attractiveness of other types of businesses, it is possible that benefit from specializing in certain sectors or geographies, together with the need to coordinate with other VCs (and the related search costs) can lead to an under-provision of capital to sectors where there is less overall interest from VCs.

Similarly, successful exits of startups lead to a lot of wealth creation in a given geography, as founders and early employees get to monetize their paper wealth (Stuart and Sorenson, 2003). They individuals in turn often become investors, but due to information frictions, will often invest close to where they are located themselves. Such frictions could lead to a disproportionate focus of investors on investment opportunities within tech clusters rather than outside them (Glaser and Hausman, 2020; Guzman and Stern, 2020; Kerr and Robert-Nicoud, 2020). Understanding the nature and implications of these potential frictions in greater detail appears to be a promising area of further inquiry.

4. Government role in VC booms

4.1 Government's role in addressing Market Failures

Given the important role that venture capital plays in financing innovation, an obvious question that arises is the role that government might play in helping to stimulate booms in venture capital, both in economies without a well-functioning VC system and in periods of time when risk capital is not flowing as easily. For example, the billions of dollars that have been committed to help support venture-backed firms in Europe, North America and beyond since the onset of the COVID-19 crisis underscore the policy interest in venture capital.

Lerner (2009) documents the large number of policies undertaken by governments in trying to promote entrepreneurship, including programs targeting high-growth and VC-backed startups. He notes a number of pitfalls these programs fall into, including blanket policies to increase allocations to venture capital and creating tax incentives to invest into startups. Other work has also pointed to the challenges associated with such approaches – for example Denes et al (2020) exploit the staggered implementation of angel investment tax credits across the US and find that while these tax credits increase angel investment, they don't appear to stimulate entrepreneurial activity. The investors who benefit most from this are either those who were already investing or inexperienced local investors. Hargadon and Kenny (2012) point to the disappointing results from the US Department of Energy's loan guarantee program for more mature businesses when trying to promote clean tech investment of VC. In studying the role of government backed VC funds, Brander, Du and Hellman (2015) VC perform worse if they don't syndicate with private VCS, but do as well when do they syndicate with private VCs.

One program that has been shown to be effective is Phase 1 of the Small Business Innovation Research (SBIR) program. SBIR Phase 1 grants have been associated with greater patenting activity by recipients versus matched non-recipients; SBIR recipients have also enjoyed a substantially higher likelihood of venture capital investment (Lerner, 1999; Howell, 2017).

4.2 Catalytic role of Government for VC

While program evaluation type studies have not found widespread benefit of government involvement in stimulating VC investment, there are other roles that government can play and appears to have had more success.

The first is the role of the state is backing "mission-driven initiatives" (Mowery, 2010; Mazzucato, 2015) which have subsequently been shown to catalyze high tech innovation and entrepreneurship, even if not directly planned that way. Mazzucato (2015) notes the spillovers to information and communication technologies from the NASA's decade long mission to put a man on the moon. She also shows in a compelling case study of the iPhone how several of its key components from GPS, touchscreen glass, accessibility of the internet and voice-recognition technology benefited either directly or indirectly from state funding. There is evidence that federal investment crowded in private sector investment (Gross and Sampat, 2020). It is also suggested that a very substantial increase in Federal investment in the life sciences and the growth of the biotechnology revolution was triggered by President Nixon's declaration of "War on Cancer" in 1971 and the substantial commitments to federal funding of biomedical science in the subsequent years through the National Institutes of Health.

A second important role the government has played is as a customer. For example, Mowery (2010) discusses the role of the US Military R&D and procurement budgets in driving substantial innovation and technological change in the US in the post-World War II era. The government's role as a customer was very important to the semiconductor industry in the 1960s and 1970s, the one sector downstream from materials science where venture capitalists have profited at scale. The US Department of Defense along with NASA played the role of collaborative customer, pulling the new industry down the learning curve to low cost, reliable production, as military customers had done for the preceding micro-electronics industry up to and during World War II (Lecuyer, 2005). Similarly, the US government's role in reimbursement of new drugs and devices through Medicare and Medicaid substantially reduces market risk for drug development implying that biotechnology ventures have enjoyed very high rates of access to the IPO market, despite the very high degree of

technology risk, the very long and expensive path to regulatory approval and hence substantial cash flow deficits (Pisano, 2006)

A third area that government involvement seems to have been extremely valuable is in outlining property rights, particularly those that help to level the playing field and enable innovation by startups. Program managers of the Defense Advanced Research Projects Agency ("DARPA"), especially in its early years when they were funding general purpose IT-related research, conceived of their mission to include protection of the new entrants from the established incumbents (Azoulay, et al, 2019). The Justice Department's settlement of its anti-trust litigation against ATT in 1956 led to the licensing of all of ATT's patents to US companies, royalty-free. The threat of anti-trust litigation induced IBM to unbundle software from its computers and initiated the creation of an independent software industry. State involvement in these instances transformed these firms' proprietary intellectual property into public goods. Similarly, the creation of the Internet – initially as ARPAnet within the Department of Defense and then under the supervision of the NSF – was characterized by a commitment to open protocols and open procedures for agreeing technical standards (Greenstein, 2010). The Bayh-Dole Act of 1980 is believed to have played a key role by allowing recipients of government funding, notably universities, to patent the output of their research and license such patents including to new ventures (Hausman, Fehder and Hochberg, 2020), although evidence from Norway suggests this is not always to be expected (Hvide and Jones, 2018).

Beyond these three broad areas that appear to have played a substantial role in catalyzing venture capital, Lerner (2009) provides other specific suggestions to policy makers as they consider designing initiatives to support the financing of high growth ventures.

5. Conclusions and New Research Frontiers

Venture capital has grown over the past forty years from a cottage industry to a prominent asset class, annually deploying around $300 billion dollars worldwide. The boom in venture capital financing in recent years, as well as the regular boom and bust cycles around technological revolutions raise a number of important research questions, which we have only begun to scratch the surface in understanding.

First, understanding the degree to which the tremendous growth in allocations to VC is driven by investment opportunities alone versus other supply side factors is important, as is an understanding of the distribution of this capital across funds. Recent years have seen the simultaneous rise of "micro-VCs" and "mega funds" driven by important changes in both the early and late stage markets respectively.

Second, risk capital has flowed towards financing technological revolutions over centuries, and several papers examining firm dynamics at the birth of new industries have shown massive rise and shakeouts completely independent of finance or financial intermediaries. Yet, understanding how the structure of VC may be interacting with this process and the impact this has on the commercialization of new ideas and technologies is a question of growing importance. The broader range of VCs involved in financing startups (from micro VCs to mega funds), each with their own sets of incentives has increased coordination frictions both within and across rounds of financing (Nanda and Rhodes-Kropf, 2019). The degree to which VCs select different startups across cycle, as well as structure their contracts and govern differently can impact not just the rate, but also the trajectory

of startup innovation, given the industry's outsized role in financing innovative high growth ventures.

Third, while the success of US venture capital when commercializing fundamental science should not underestimate the foundational and catalytic role of the US government, it is worth noting that the state has only been the primary source of science funding since World War II. Prior technological revolutions in science-based industries, such as chemicals and electrical engineering, were initiated by giant corporations such as Dupont and General Electric. Yet, recent research documents a decline in the science component of corporate R&D spending (Arora et. al 2017; 2020) as well as declining federal funding of R&D in percentage terms. The question arises whether venture capital, as it has grown in scale, can play a direct role in financing a broader scope of fundamental technological innovations as it has in biotechnology.

In fact, a particular challenge facing society at the present is climate change, which seems comparable in scale to the national security challenges that induced the radical increase in the US Government's commitment to funding science and aggressively sponsoring technological innovations downstream from the laboratory. What role can VC play and moreover, which government policies might best catalyze VC commercialization of "green" technologies? For example, would a commitment by the US Government to being a customer of such technologies contribute to a VC boom in this sector that is more sustained than the surge in clean-tech VC in the mid-2000s? More generally, understanding the reasons why VC has only successfully invested in a narrow band of technological innovation – and largely in sectors that have had significant government involvement as a catalyst for reducing both technology and market risk – is worth understanding for its own sake, as well as in relation to the more patchy success of government involvement in specific, smaller scale efforts to reduce market failures in VC.

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