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Risky Business: Venture Capital, Pivoting and Scaling

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Abstract: The creation and scaling of startups are inherently linked to risk-taking, with various types of owners handling these risks differently. This paper investigates the influence of an active venture capital (VC) market on startups' decisions regarding research and scaling. It outlines conditions under which VC-backed startups prefer riskier, yet potentially more rewarding strategies compared to independent startups. VC firms, by means of temporary ownership and compensation structures, introduce "exit costs" that make high-risk strategies more attractive to VC-backed startups. Moreover, an active VC market prompts startups to undertake higher initial risks, as VC firms provide support for pivoting after setbacks. Additionally, the presence of VC intensifies research risk among established firms, as their research initiatives are strategic complements to the risk choices of startups.

Keywords: Entrepreneurship, pivoting, research, scaling, venture capital.
JEL Classification: G24, L26, M13.

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1 Introduction

The scale-up of promising startups is crucial in today's digitized global market, necessitating an efficient venture capital (VC) market (Hellmann and Puri, 2002; Hsu, 2004). Recently, VC activities have concentrated on identifying startups ready for scaling. As EQT Ventures articulates, "Scaling a company that isn't ready to be scaled is one of the startup world's deadliest sins. But not scaling one that is ready is even deadlier." However, the impact of an active VC market on startup research, scaling and pivoting strategies is still not well understood (Lerner and Kortum, 2000; Hellmann and Puri, 2000a; Chemmanur, Krishnan and Nandy, 2011; Coviello, 2019; Shepherd and Patzelt, 2020). This paper seeks to explore these dimensions.

We develop a theoretical model influenced by recent research on innovation within the industrial organization literature, emphasizing risk as a pivotal factor in the research, scaling and pivoting behavior of various firm types. This model integrates aspects of scaling and the dynamics of a VC market. We propose that the VC market introduces three critical elements influencing risk-taking behaviors: temporary ownership, incentive structures for VC firms, and pivot opportunities for startups.

In our model, an entrepreneur-owned startup embarks on a research project to develop a new product or service. The research phase encompasses a wide range of activities beyond mere invention, including product development, market trials, marketing, sales efforts, and the launch of initial beta versions to gauge the business idea's traction. Startups face a variety of research strategies, each characterized by a specific probability of success and the potential returns associated with that success. Strategies targeting more innovative and lucrative business ideas typically present lower success probabilities, rendering them riskier.

Should a research project falter and venture capitalists (VCs) be available, the entrepreneur might seek VC support to pivot the startup in a new direction. Pivoting is a well-documented phenomenon in startup ecosystems. Bandera and Thomas (2019) note that slightly over one-fifth of all U.S. startups in the Kauffman Firm Survey underwent at least one pivot, a finding echoed by Slávik, Bednár and Mišúnová Hudáková (2021), who observed that a quarter of Slovakian startups significantly altered or developed their business concept. VCs uniquely contribute by recognizing the entrepreneur's value-creation potential and understanding why the initial research effort did not succeed and what aspects can be repurposed. Further evidence underscores the importance of the top management team in startups. Gompers, Gornall, Kaplan and Strebulaev (2021) concluded that VCs value both "the jockey" (the founding management team) and "the horse" (the business plans), but ultimately, they consider the founding management team more critical. Given the scarcity of talented management teams and lacking evidence that the initial project's failure was due to poor management, VCs are likely to see value in retaining the firm's assets and offering the team a second-chance.

The decision on the pace of scaling presents a fundamental dilemma for today's startups, balancing between high returns at high risk and low returns at low risk. Successful scaling can lead to significant payoffs, but failure may risk bankruptcy. For an independent startup that successfully completes its research project, the next step involves scaling up business operations and production to meet market demand. However, for VC-backed startups, the venture capital firm dictates the scaling strategy, aiming for an exit through an IPO or a trade sale. This paper posits that the decision to scale, particularly in relation to growth, revolves more around the choice of scaling intensity. Aggressive scaling strategies are inherently riskier, bearing a lower probability of success, unlike decisions purely about growth, which do not necessarily alter success probabilities.

The initial findings from our analysis pertain to how the establishment of a VC market influences the research and scaling decisions made by startups that secure VC funding.

First, VC-backed startups tend to adopt riskier scaling strategies compared to their independent counterparts. This difference in approach stems from the unique objectives of VC-backed startups, influenced primarily by two factors: temporary ownership and distinctive compensation structures that encompass hurdle rates and catch-up provisions. First, VC firms typically engage in temporary ownership of assets, investing through venture capital funds with a predetermined contractual lifespan, usually around 10 years. This temporary nature necessitates consideration of transaction costs associated with the acquisition and subsequent resale of shares in the startups they support. Consequently, exit costs emerge, particularly related to initial public offerings (IPOs) or mergers and acquisitions, should the startups prove successful. Second, VC firms secure funding from institutional investors to invest in startups, earning their compensation through standard contracts. The distribution of returns from successful exits follows a ”2/20” model: a 2% management fee on the committed capital to the fund and 20% of the profits surpassing an 8% hurdle rate. ”Catch-up provisions” ensure that, immediately after surpassing the hurdle rate, the VC firm receives up to 100% of returns, leading to an eventual 80/20 split of profits between the investors and the VC firm. As we formally show, these compensation agreements introduce exit costs analogous to those produced by temporary ownership.

When exit costs, attributed to temporary ownership and compensation structures, are significant, VC-backed startups are prompted to adopt riskier scaling strategies with higher potential returns compared to independent startups. This inclination towards risk is due to the fact that higher risk levels decrease the expected exit costs. To illustrate this mechanism, consider a simplified scenario involving two distinct scaling strategies. Aggressive scaling, denoted as A, yields a payoff of 100 with a 0.5 probability and 0 with the same probability. Conversely, safe scaling, labeled S, guarantees a payoff of 50 with certainty. An entrepreneur who maintains control over her startup bypasses the exit cost, rendering her indifferent between strategies A and S. However, a VC-backed startup facing an exit cost of 10 will favor the aggressive scaling strategy A over the safer option S, as the calculation $(100-10)\times 0.5+0\times 0.5>50-10$ demonstrates. Opting for a riskier approach effectively reduces the expected exit cost from 10 to 5, considering the exit cost is payable only upon successful scaling.

Second, exit costs also influence the choice of research strategy. Specifically, our model demonstrates that VC-backed startups are inclined to select research strategies with greater potential but lower success probabilities than those chosen by independent startups in the absence of VCs. This phenomenon is termed the *VC big-exit effect*. The preference of VCs for "big exits" is well-documented; Gompers et al. (2021) observed that "VCs understand that their most successful M&A and IPO exits are the real driver of their returns. Although most investments yield very little, a successful exit can generate a 100-fold return. Because exits vary so much, VCs focus on finding companies that have the potential for big exits rather than on estimating near-term cash flows."

Third, the form of financing matters for risk-taking in research and scaling decisions. We formally model the impact of debt financing on a startup's scaling incentives. In the baseline scenario without external capital, the startup's initial costs are considered sunk by the time scaling decisions are made. However, when utilizing bank financing, loan repayments are scheduled post-scaling, contingent on the success and profitability in the product market. This structure incentivizes entrepreneurs to pursue more aggressive scaling strategies, as loan repayments with interest are due only upon successful scaling. The propensity for aggressive scaling is amplified with higher interest rates and lower equity contribution from the entrepreneur. When comparing VC financing with bank loans, our analysis suggests that, notwithstanding similar choices in research projects across different financing types, VC-backed startups exhibit a higher risk appetite in scaling compared to those relying on bank financing or internal funding. This distinction underscores a unique dynamic introduced by external capital in bridging research and scaling decisions, with VC backing encouraging more pronounced risk-taking in scaling choices.

The subsequent findings from our analysis address how the emergence of a VC market influences the research and scaling decisions made by agents and firms that do not secure VC funding.

First, a robust VC market affects startup pivoting behavior. Notable startups like Groupon, Twitter, and Slack underwent significant pivots before achieving success, transitioning from a social network platform, a podcasting platform, and an online game development, respectively. Our analysis reveals a strategic effect: an active VC market may encourage startups to adopt riskier initial research strategies, even if they ultimately do not secure VC funding. The potential for future VC support provides a safety net, allowing startups to consider more daring research approaches. This safety net reduces the perceived cost of failure, as the option of VC backing offers a second-chance. We term this the *VC second-chance effect*. Additionally, we explore scenarios where this option to pivot not only offers an alternative to exiting to wage employment but also makes taking higher risks more appealing. The logic is that failure in a high-risk venture could enhance the probability of receiving VC support, as opposed to failure in a safer project, which might make transitioning to a salaried position more attractive.

Second, the advent of VC in an industry can elevate research risk levels among these established players as well. This phenomenon arises because the research strategies of entrepreneurs and incumbents are strategically interlinked, operating as complements. When entrepreneurs opt for riskier research endeavors, their probability of success diminishes. This reduction in success probability lowers the anticipated cost of failure for incumbents, thereby incentivizing them to undertake greater risks in their own research efforts. Consequently, the introduction of a VC market can stimulate an overall increase in risk-taking and, potentially, productivity across the entire innovation ecosystem, by rendering higher-risk ventures more appealing to both new entrants and established firms.

In Section 6, we conduct robustness analysis to further validate our core finding: VC-backed startups adopt riskier scaling strategies in response to exit costs. This finding remains robust not only under variable exit costs but also when riskier research projects correlate with increased scaling opportunities. Additionally, we introduce a scenario wherein independent founders are afforded a 'second-chance' option through finding paid employment. Also in this scenario, a VC-provided 'second-chance' incentivizes independent founders towards riskier research strategies.

The structure of this paper is organized as follows: The subsequent section relates our paper to the existing literature. Section 3 presents the formal model. In Section 4, we analyze this model and outline our primary findings. Section 5 explores model extensions, providing additional insights. Robustness analyses are conducted in Section 6, ensuring the validity of our results under various conditions. Finally, Section 7 concludes the paper and acknowledges its limitations.

2 Literature review

Our main contribution is to merge three related strands of literature: the management and entrepreneurship literature on scaling, the industrial organization literature on innovation and ownership, and the financial economics literature on VC.

2.1 Management and entrepreneurship literature on research and scaling

Closest to our paper in the literature on management and entrepreneurship is work on conceptualizing what it means to scale firms and what defines a scalable firm and that also implements a theoretical framework (DeSantola and Gulati, 2017). Here, Giustiziero, Kretschmer, Somaya and Wu (2021) provides a resource-based theory of the digital firms emphasizing that digital firms tend to be narrow in vertical scope and large in scale. Without a formal model, Coviello (2019) emphasizes that scaling involves standardizing and automating processes, having a diverse management team, having a high absorptive capacity, and tend to go international quickly. Shepherd and Patzelt (2020) underscores organizational scaling as key, defined as "spreading excellence within an organization as it grows", Cubero and Segura (2020) studies the optimal timing of when scaling should take place, and Nielsen and Lund (2018) emphasize developing platform models and leveraging the work of customers and other partners.

Despite these insights, the literature largely lacks a formal examination of what scaling means and the role of the VC market in startups' incentives to innovate, pivot, and scale. Our paper addresses this gap by developing a formal model that highlights risk as a central component of research and scaling decisions of startups. This contribution is important, as it introduces a comprehensive, formal framework for analyzing risk-taking, innovation, scaling, and pivoting in the presence of VC firms. This framework is not only valuable for future theoretical endeavors but also serves as a foundation for empirical research into innovation, scaling, pivoting, and VC activities. Additionally, it offers a basis for the formulation of models aimed at evaluating policy measures designed to facilitate firm scaling and innovation.

2.2 Industrial organization literature on innovation and ownership

With regards to the industrial organization literature, our model incorporates insights from the theoretical literature on firm development, economic of scale and market structure (Gilbert, 2006). Despite the richness of this field, the literature has sparingly addressed firm asymmetries within these contexts, particularly lacking in discussions on scaling. Addressing asymmetries, Cabral (2003) shows that smaller firms may lean towards riskier development strategies due to strategic output effects in the product market. Specifically, smaller firms eschew low risk-return projects as they cannot fully leverage improvements across large outputs, highlighting a divergence in development behaviors between small and large firms based on their potential post-development market outputs.

Further, Färnstrand Damsgaard, Hjertstrand, Norbäck, Persson and Vasconcelos (2017) study the decision-making processes regarding success probabilities by newcomers and established firms, finding that higher commercialization costs for newcomers incentivize them towards more groundbreaking projects. Haufler, Norbäck and Persson (2014) extends this analysis by integrating the effects of taxation, while Henkel, Rønde and Wagner (2015) investigates the dynamics of entrants innovating to sell in direct competition with established entities, revealing a propensity for entrants to adopt more novel research methodologies, thus enhancing the probability of achieving high-value innovations. Norbäck, Persson and Svensson (2016) study a model entrepreneurial innovation for entry and sale into oligopolies (without risk) showing that the expected consumer welfare can be higher under sale than under entry despite increased market power.

This literature has not studied how VC firms influence startups' risk-taking behaviors in research and scaling decisions. Moreover, it has not analyzed asymmetries among firms arising from differences in ownership duration—distinguishing between long-term and temporary owners aiming to resell. This gap extends to compensation contracts among various stakeholders (specifically VC firms and outside investors), and the unique value some actors bring by offering pivoting opportunities. The temporary nature of VC ownership, as highlighted by Norbäck and Persson (2009), Norbäck, Persson and Tåg (2018), and Baziki, Norbäck, Persson and Tåg (2017), alongside the formal modeling of compensation contracts within the VC sector, represents a key novel contribution of our model and is key to our findings on risk, pivoting, and scaling. The significance of this contribution is profound, given that VC firms play a key role in nurturing high-potential startups, particularly in scaling digital firms and helping them go global (Hellmann, 2002). Therefore, a model of innovation and risk-taking that excludes such entities would be notably incomplete.

2.3 Financial economics literature on innovation, scaling and VC

Our paper also intersects with the financial economics literature focusing on the role of VC in the innovation process. For instance, Kortum and Lerner (2000) demonstrated that increased VC activity within an industry is correlated with significantly higher patenting rates. Similarly, Hellmann and Puri (2000b) found that VC involvement substantially shortens the time required to bring a new product to market. Hellmann (2002) observed that startups tend to seek support from VC funds when their products act as substitutes for those of incumbents, whereas they seek support from incumbent firms when their products are complementary. Additionally, Norbäck and Persson (2009) identified that VC-backed startups are more inclined to develop commercialized innovations than incumbent firms, driven by strategic product market effects on the sales price of the VC-backed startup. Ewens, Nanda and Rhodes-Kropf (2018) explored how technological shocks influence VC funds' investment strategies, prompting a shift towards greater experimentation. Finally, Hellmann and Thiele (2019) examined government policies aimed at supporting either entrepreneurs or the investors backing them, highlighting the multifaceted influence of VC in the innovation landscape.

While extensive research has explored the role of VC firms in the economy, there is a notable gap in understanding how VC presence influences the research and scaling decisions of firms. Our study addresses this gap by demonstrating that VC-backed startups tend to adopt riskier, potentially more rewarding research and scaling strategies. This inclination is particularly pronounced when exit costs are concave with respect to risk levels, as it makes substantial (and risky) exits more financially viable. Furthermore, we illustrate that a vibrant VC market encourages even independent startups to pursue riskier research strategies, given the potential for VC support to facilitate a strategic pivot in the event of initial setbacks. These insights underscore the significant impact of VC firms on the growth and strategic direction of startups, highlighting previously unexplored dimensions of their contribution to the startup ecosystem.

3 Model

3.1 An overview and key assumptions

In an industry, an independent entrepreneur (I) possesses a firm-specific asset essential for developing a new startup. The entrepreneur has the opportunity to create a new product or service through a research strategy. This strategy entails generating ideas to integrate new technologies, existing assets, startup skills, and market knowledge to devise a novel business model, product, or service, which includes investments in sales and marketing. Subsequently, this innovation can be introduced to the market through a scaling strategy.

Figure 1 illustrates the interactions. At Stage 0, the entrepreneur can allocate funds to a fixed research cost, G, representing the establishment of a research lab, the recruitment of skilled labor for research ac-

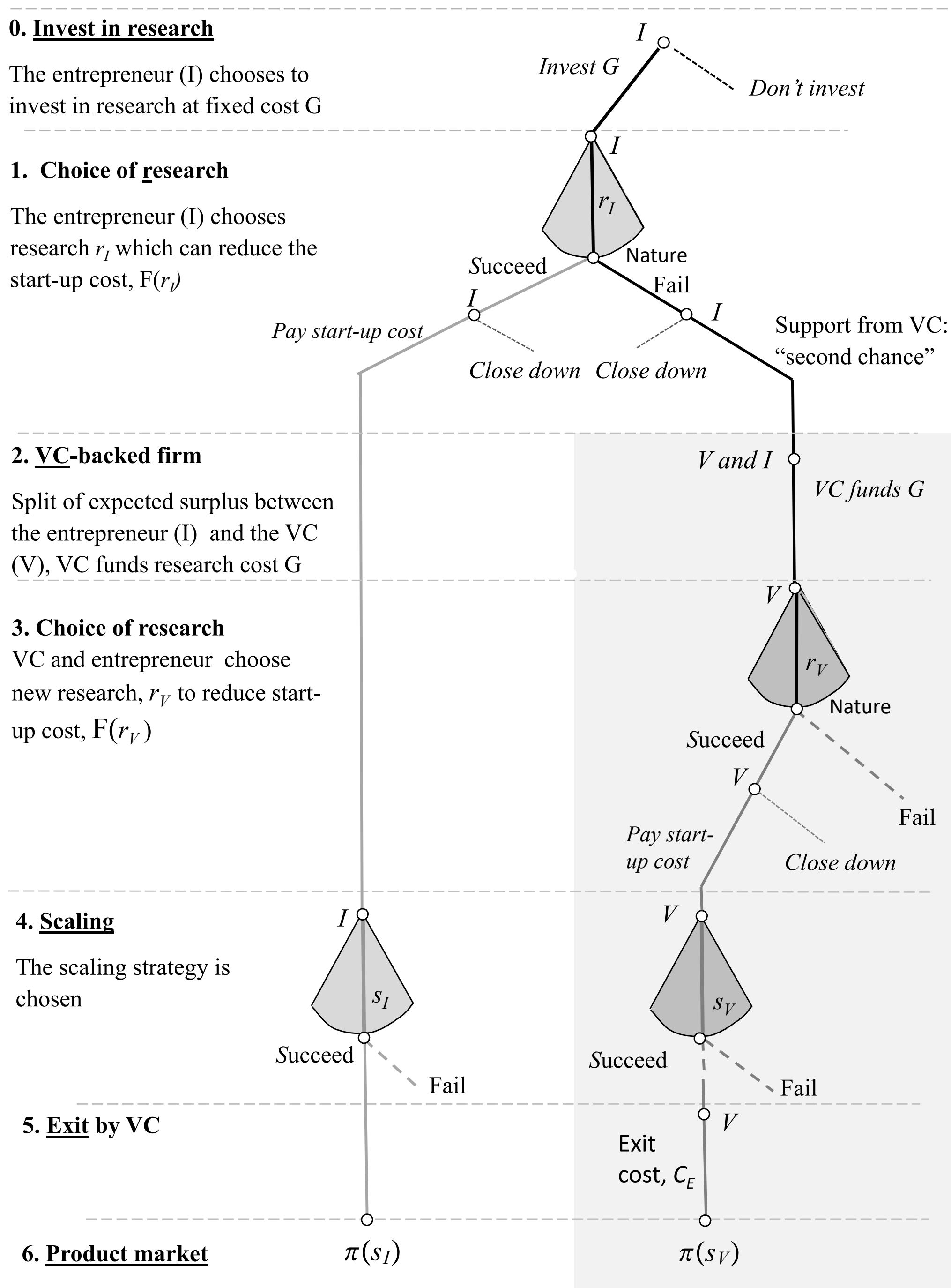

Figure 1: Model structure.

tivities, conducting product market trials, or other necessary endeavors to evaluate the startup's feasibility. Upon incurring the research cost, the entrepreneur selects a research strategy, r_I, capable of substantially decreasing the venture's startup costs, $F(r)$. A successful strategy can notably lower these costs; however, a more ambitious approach increases the risk of failure alongside its potential for cost reduction.

We consider the venture's startup costs to encompass all expenses associated with equipment, marketing, sales, inputs, office space, and other necessities for initiating business scaling and expansion. It is important to note that, from a theoretical standpoint, modeling the reduction in startup costs as an enhancement in profitability—stemming from insights into viable market opportunities—would yield equivalent results, albeit at the expense of increased model complexity.

If the entrepreneur's initial research project is successful, she can launch the startup by covering the startup costs. The process then advances to Stage 4, where the independent startup decides on its scale of operation, represented by s_I. Scaling involves a risk-return trade-off: a successful, more ambitious scaling strategy can capture a broader consumer base and market share, thereby enhancing product market profits in Stage 6. However, an aggressive scaling approach also carries greater risk, with a higher probability of failure leading to bankruptcy and the forfeiture of profits.

Should the entrepreneur's initial research fail in Stage 1, a VC firm, recognizing the value-generation potential of the entrepreneur and her firm-specific asset, may step in. This VC firm assists the entrepreneur in selecting an alternative research strategy, potentially introducing new ideas to pivot the startup. The venture, now supported by the VC, adopts a revised research strategy, r_V. Success in this phase, leading to a viable business concept, prompts investment and the covering of startup costs, $F(r)$. The VC-backed startup then advances to the scaling decision in Stage 4. Successful scaling allows the VC firm to divest its stake by either selling the startup to another entity or initiating a public offering (IPO) at an exit cost, C_E. Profits are ultimately realized in Stage 6. In Section 5.2, we account for the compensation structures prevalent within the VC industry, outlining the determinants of the VC firm's returns.

3.2 The exit cost

The exit cost, C_E, plays a crucial role in our analysis, featuring in our baseline model exclusively in scenarios where the firm is VC-backed.[1] We model VC-backed startups as incurring exit costs for two main reasons: the temporary nature of VC ownership and the presence of specific compensation structures, which often

[1] We relax this assumption in Section 5.2, in which exit costs apply to both independent startups and VC-backed startups.

incorporate hurdle rates and catch-up provisions.

First, VC funds, characterized as limited partnerships with a predetermined contractual lifespan, are inherently temporary asset owners. This transitory ownership entails accounting for transaction costs associated with the acquisition and subsequent resale of shares in supported startups. The direct exit cost encapsulates expenses linked to enlisting VCs for scaling decisions and the eventual firm sale. Such costs cover the opportunity losses VCs incur by not scaling other ventures and the expenses related to divesting investments, including those from orchestrating trade-sales or the direct and indirect costs incurred during the IPO process, which can be significant. Ritter (1987) suggests these could represent 21-31% of the firm's market value, while Chaplinsky, Hanley and Moon (2017) estimate total direct costs at approximately 9-10% of firm value. Additionally, the phenomenon of IPO underpricing implies that exit costs could increase further.

Second, VC firms procure capital from institutional investors to create VC funds, distributing proceeds from the exits of portfolio companies between the VC firm and the fund's investors based on a conventional "2/20" model. This entails a 2% management fee on the fund's committed capital and a 20% share of the returns that surpass an 8% "hurdle rate". Additionally, "catch-up provisions" are employed, allowing the VC firm to receive up to 100% of returns immediately after reaching the 8% threshold, effectively leading to an 80/20 split of the returns between investors and the VC firm. As will be detailed in Section 5.2, such compensation schemes create exit costs akin to those from temporary ownership. For analytical simplicity, our subsequent discussion assumes a straightforward fixed exit cost, C_E, rather than formalizing the full compensation contract inherent in VC-backed firms. Later, in Section 5.2, we explore how to extend the model to incorporate these nuances.

In our analysis, we adopt several simplifying assumptions for clarity and tractability. One key assumption is that commercialization cost remains constant, regardless of the scaling level. Although this assumption simplifies the exposition, as demonstrated in Section 6.1, it does not impact our findings.

Assumption 1. *The exit cost C_E is fixed and independent of the level of scaling, s.*

3.3 The second-chance through pivoting

A crucial aspect of our analysis is the role of VC firms in providing entrepreneurs, who were initially unsuccessful in their research efforts, with a second opportunity to develop a viable and scalable business idea. Pivoting is a common practice among startups, as underscored by research findings. Bandera and Thomas (2019) observed that slightly more than a fifth of all U.S. startups in the Kauffman Firm Survey underwent at least one pivot. This is echoed by Slávik et al. (2021), who found that a quarter of Slovakian startups significantly altered or developed their business concepts, indicating a propensity among startups to pivot in pursuit of success.

VC firms bring a distinctive advantage by recognizing the value-creation potential of the entrepreneur and her firm-specific asset. Their ability to *understand* the reasons behind the initial research effort's failure and identify salvageable elements is crucial (Gompers, Gornall, Kaplan and Strebulaev, 2020). This understanding is fundamental because, in many cases, failure could be misinterpreted as a negative reflection on the entrepreneur's quality. Without the VC's insight into the causes of the research setback, even in a scenario with asymmetric (or complete) information, they might be hesitant to offer a second-chance.[2]

VC firms are inclined to support entrepreneurs with prior founding experience, recognizing the significant impact of such experience on future entrepreneurial success (Hsu, 2007). Nahata (2019) demonstrates that serial entrepreneurs receiving VC backing experience less equity dilution, maintain more substantial board control, and more frequently continue as CEOs. This pattern persists even for those who have previously failed, compared to first-time entrepreneurs. This suggests that VCs value experience, viewing it as a critical asset even in the face of prior setbacks.

Finally, evidence suggests that the top management team is key in startups. Gompers et al. (2021) find that VCs believe both "the jockey" (the founding management team) and "the horse" (the business plans) are necessary but ultimately deem the founding management team more critical. If the talent of the founding management team is a *scarce resource* and the VC has little evidence to suggest that the failed business that emerged after the research stage was due to a bad management team, salvaging the firms assets and giving the team a second-chance appears to be an attractive option. This could involve continuing with the old firm or setting up a new firm, the exact organizational structure does not matter for our results.

To summarize:

Assumption 2. *Failing with a venture does not signal low entrepreneurial skills: rather it signals useful experience of running a new venture.*

[2]It's also worth noting that pivoting may involve significant experimentation and learning, aspects not fully addressed in our current framework (Agrawal, Gans and Stern, 2021).

3.4 The research and scaling choices

The entrepreneur, either independently or in collaboration with the VC firm, makes two decisions that embody a risk-reward trade-off: the first pertains to the research strategy, denoted by r; the second concerns the extent of scaling in the product market, denoted by s (sub-indices are omitted for clarity).

3.4.1 Research

We interpret the research stage as encompassing not just the generation of inventions through research efforts, but also product development, product market trials, initial beta versions, marketing, and sales efforts to gauge the business idea's market traction. To encapsulate this comprehensive notion of research, a more assertive research strategy, upon success, contributes to diminishing the startup costs of the venture. This framework reflects, for example, the significance of minimizing fixed costs for startups in the digital era. In this context, numerous new startups incur minimal variable costs within their business models, with a predominant portion of their expenses being fixed. For such companies, the marginal cost of accommodating an additional customer is negligible. However, substantial fixed costs are involved in research activities, such as the development of competitive algorithms, which are crucial for maintaining a competitive edge in the market.

Formally, a successful research strategy, represented as $r \in [0,1]$, results in a startup cost $F(r) = F - f(r)$. Here, $f(r)$ is a strictly increasing and strictly concave function that signifies the reduction in startup costs attributable to successful research, satisfying $f(0) = 0$, $f'(r) > 0$, and $f''(r) < 0$. The function $F(r)$ is depicted in Figure 2(i). To account for the increased risk associated with more aggressive research, we posit that the probability of a research project's success, r, is given by $1-r$. Consequently, a project with a higher value of r—indicating a more aggressive research approach—is more likely to fail.

Assuming that a failed research project does not reduce costs, the expected startup cost is modeled as $F - (1-r) \cdot f(r)$. For the research decision-making process be well-behaved, the expected decrease in startup costs, denoted as $(1-r) \cdot f(r)$, must exhibit strict concavity. This condition is guaranteed by the strict concavity of $f(r)$. Illustrated in Figure 2(ii), this results in a singular optimal research intensity, $\hat{r}$, that maximizes the expected reduction in startup costs, defined as $\hat{r} = \arg\max\,[(1-r) \cdot f(r)]$. Additionally, as depicted in Figure 2(iii), this optimal project $\hat{r}$ concurrently minimizes the expected startup costs, hence $\hat{r} = \arg\min\,[F - (1-r) \cdot f(r)]$. To summarize:

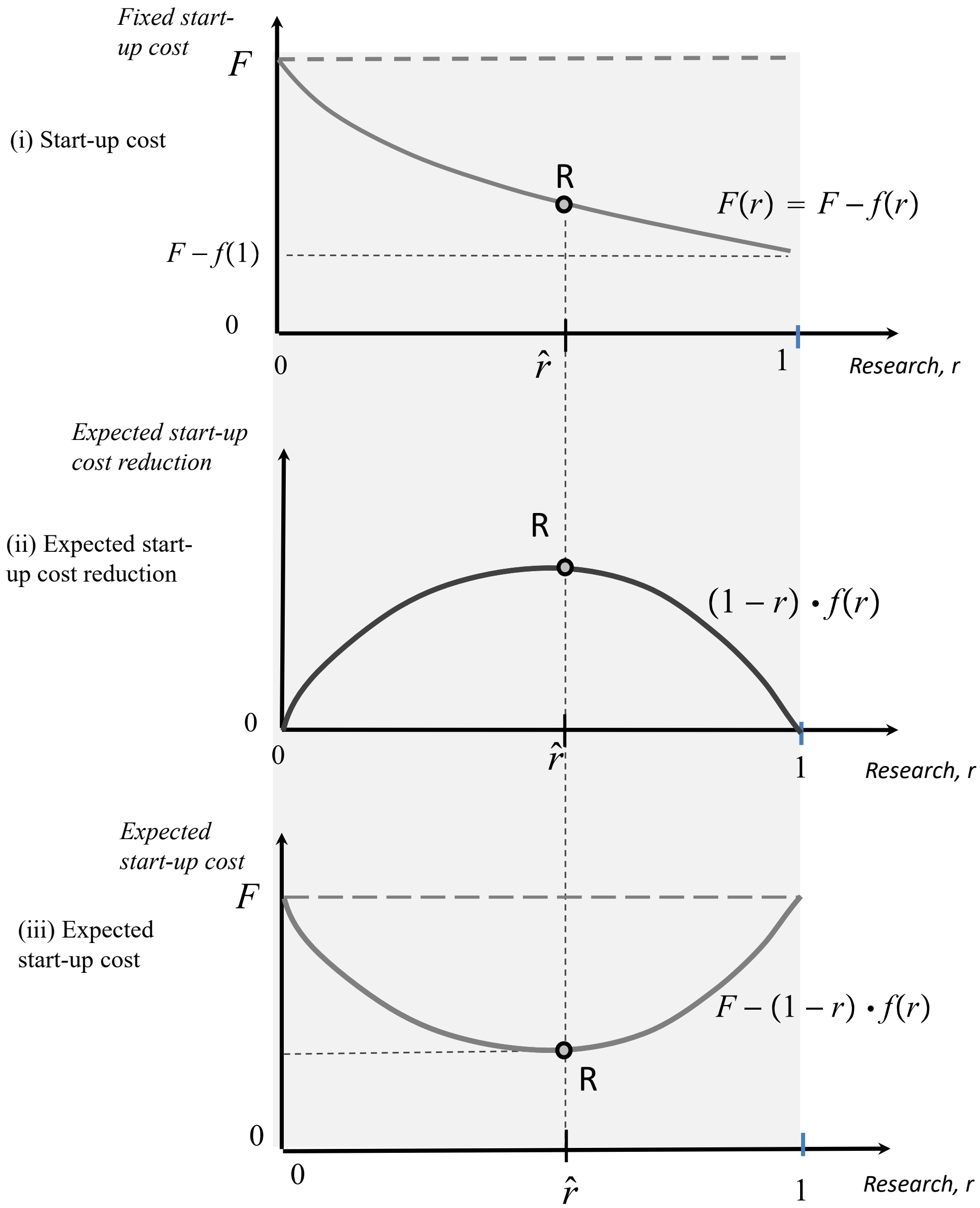

Figure 2: Research projects and startup costs.

Assumption 3. *Let $F - f(r)$ represent the startup cost, where $f(r)$ denotes the reduction in the startup cost attributed to a research project $r \in [0,1]$. We assume the following conditions:*

(i) $f'(r) > 0$,

(ii) $f(0) = 0$, *and*

(iii) $(1-r) \cdot f(r)$ *is strictly concave in r.*

3.4.2 Scaling

The distinction between scaling a startup and simply growing one is fundamentally rooted in the relationship between revenue growth and cost increase. Coad, Bornhäll, Daunfeldt and McKelvie (2024) identifies scale-ups as a distinct group within high-growth firms, characterized by a particular growth style that necessitates increased production of a new product or service. Unlike typical growth, which involves a proportional increase in both revenues and costs, scaling is marked by revenues rising significantly faster than costs. This shift alters a firm's structure by increasing fixed costs, reducing marginal costs, and intensifying capital use. Often, this scale-up phase is accompanied by an intensive marketing campaign to manage the surge in supply aimed at meeting strong market demand. The key difference lies in the underlying economic dynamics: scaling aims for exponential progress through enhanced economic leverage, contrasting with the linear increases seen in ordinary growth.

In a stylized example, consider a firm that manufactures bicycles at a production cost of 300 euros each and sells them for 500 euros. Growth for this firm implies selling more bicycles, which also means incurring higher expenses in marketing, materials, labor, etc., to facilitate these additional sales. As a result, while the firm's revenues increase with growth, its costs rise correspondingly, leaving the profit margin unchanged. Contrastingly, when a firm scales, such as in the case of a firm like Spotify that offers streaming music content, the dynamics differ significantly. For such a business, the marginal cost of delivering additional streamed content to new customers is exceptionally low. This difference in cost structure means that as the firm scales, its revenues can increase much more rapidly than its costs. Therefore, scaling a firm, as opposed to merely growing it, involves expanding revenue at a substantially faster rate than expenses, thereby enhancing the firm's profitability and efficiency in serving a larger customer base.[3]

[3]The investment by the Swedish PE/VC firm EQT in Epidemic Sound in 2015 exemplifies a venture capital investment that was grounded in a thorough due diligence process followed by an ambitious scaling strategy. Epidemic Sound operates a marketplace for

Scaling a startup indeed comes with significant challenges, including the substantial risk of failure. While setting the goal of scaling a product or an organization is one aspect, achieving exponential growth without correspondingly increasing complexity is an entirely different endeavor. As highlighted by Jules, Kshirsagar and Lloyd-George (2022), ”It’s worth remembering that the primary challenge here for founder CEOs is no longer just about securing resources—it’s about moving as fast as their products or organizations can evolve.”Empirical evidence suggests that the journey of scaling is fraught with challenges. According to a study cited in Jules et al. (2022), approximately 80 percent of startups that successfully launch and develop a product fail to achieve full scale-up. This high failure rate highlights the inherent difficulties in scaling, where the expansion of a startup’s operations and market reach does not guarantee success. Further, the research by Lee and Kim (2024) offers an empirical approach to measuring the onset of scaling activities within startups, focusing on the hiring of managers and sales personnel as indicative milestones. Their findings reveal a sobering reality: many startups that attempt to scale prematurely face increased failure rates without any discernible advantage in terms of achieving a successful exit.

Thus, the fundamental distinction between scaling and growing a startup lies in the potential outcomes and inherent risks associated with each approach. Scaling offers the opportunity for exponential revenue growth at comparatively lower incremental costs, yet it is accompanied by a heightened risk of failure. This contrast underscores a critical strategic decision for startups: whether to pursue a path of steady growth, with costs rising in tandem with revenues, or to aim for scaling, where revenues potentially increase at a faster pace than costs, albeit with greater uncertainty and operational challenges. In what follows, we will define the strategy of scaling a startup as follows:

Assumption 4. *Scaling a startup is a strategy that increases the possibility of a substantial increase in net revenues, but at a substantially increased risk of failure.*

Our model incorporates scaling as follows: if the research strategy proves successful, the entrepreneur proceeds with an independent startup and opts for a scaling strategy. A more ambitious scaling strategy, if

sourcing background music for videos and other streamed content, including podcasts. By 2021, the platform boasted an impressive library of approximately 32,000 music tracks and 60,000 sound effects. Following this expansion, Epidemic Sound announced a new financing round with plans to further develop its technology platform. This development aimed to offer enhanced tools for creators to match music with media more effectively, expand its catalogue, grow its customer base, and internationalize the service with more localized offerings. Consequently, the Stockholm-based startup secured $450 million from Blackstone Group and EQT Growth in an equity round, valuing Epidemic Sound at $1.4 billion. This strategic move highlighted the potential of scaling a digital platform to achieve rapid growth and substantial market valuation, demonstrating the effective execution of scaling strategies in the venture capital ecosystem. (Epidemic Sound raises $450M at a $1.4B valuation to ‘soundtrack the internet’, Ingrid Lunden, TechCrunch, March 11, 2021) successful, is expected to yield higher gross profits by reaching a broader consumer base. However, such a strategy also carries an increased risk of failure. We formalize this trade-off using $s \in [0,1]$ to represent the degree of scaling, where s is linked to a profit function $\pi(s)$ that is strictly increasing and strictly concave when scaling is successful—that is, $\pi(0) = 0$, $\pi'(s) > 0$, and $\pi''(s) < 0$. The probability of a successful scaling strategy decreases with its extent, modeled as $1-s$. The function $\pi(s)$ is visualized in Figure 3(i), while Figure 3(ii) illustrates the expected gross profit $(1-s)\cdot\pi(s)$, which is strictly concave and possesses a unique optimal scaling level $s^* = \arg\max[(1-s)\cdot\pi(s)]$. Thus, the startup must recognize that while increasing scaling s has the potential to amplify profits $\pi(s)$ upon success, it simultaneously elevates risk as the success probability $(1-s)$ decreases.

Assumption 5. *Let $\pi(s)$ for $s \in [0,1]$ denote the product market profit attained under the scaling strategy s. Then, the following is assumed to hold:*

(i) $\pi'(s) > 0$,

(ii) $\pi(0) = 0$,

(iii) $(1-s)\cdot\pi(s)$ *is strictly concave in s.*

It's important to clarify that our framework accommodates a scenario where $\pi(s) > 0$ is not only strictly increasing but also convex. The critical requirement is satisfying Assumption 5(iii), which asserts that the expected profit $(1-s)\pi(s)$ maintains strict concavity with respect to s. This necessitates that the second-order condition for $(1-s)\pi(s)$ is met. While this condition is naturally satisfied when $\pi(s)$ exhibits strict concavity, it can also be met when $\pi(s)$ is strictly convex, provided it is not too convex.

To emphasize the inherent risks associated with scaling, we posit that the initial startup costs are irrecoverable if the preliminary research does not yield success. Consequently, it is only upon the successful completion of the research phase in Stage 1 that the independent startup proceeds to scale up in Stage 4. Formally:

Assumption 6. *Scaling is never profitable if initial research fails: $\pi(s) < F$.*

This assumption will be partially relaxed in Section 5.1, where we explore the impact of the emergence of a venture capital market on incumbent firms.

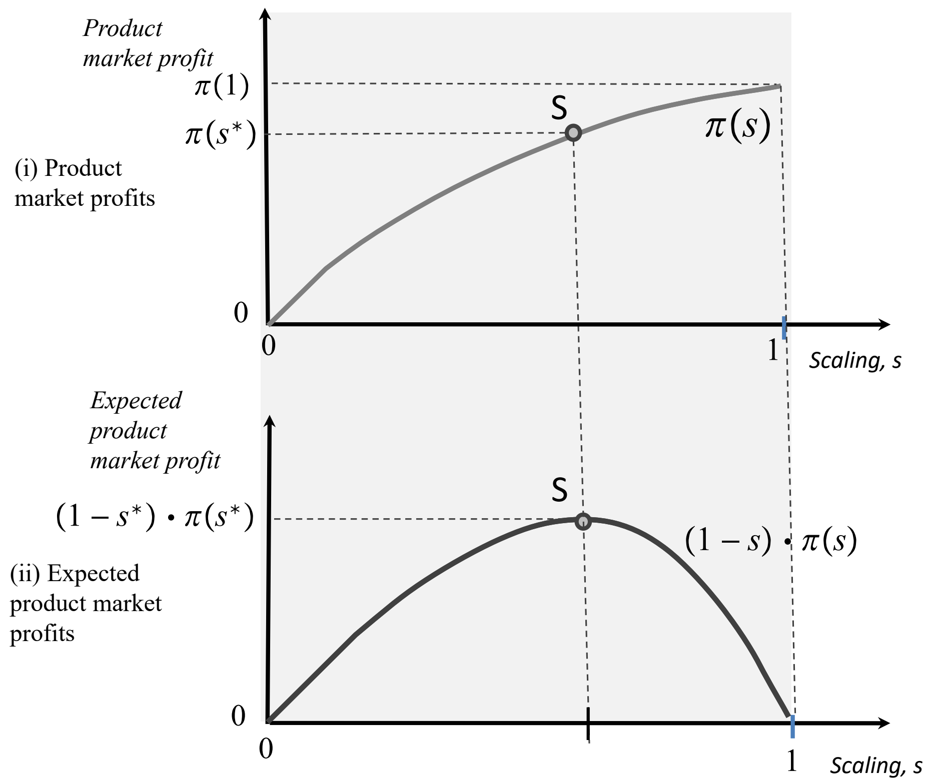

Figure 3: Scaling and product market profits.

4 Analysis

In Section 4.1, we establish the equilibrium research and scaling strategies for the independent startup, serving as a benchmark case absent of VC backing. Subsequently, in Section 4.2, we examine the equilibrium strategies for research and scaling in the context of a VC-backed startup. Lastly, Section 4.3 dedicates to quantifying the overall impact of an active VC market on the risk-taking behaviors of startups in both research and scaling activities.

4.1 Benchmark: The independent startup

For our benchmark analysis, we examine the research and scaling ambitions of the independent startup without VC backing. In this scenario, only Stages 1, 4, and 6, as illustrated in Figure 1, are relevant. Based on Assumptions 3 and 5, and acknowledging that the fixed research cost G becomes a sunk cost at Stage 1, we formulate the expected profit in Stage 1 as follows:

$$\begin{aligned}\Pi(s,r) \quad = \quad & \underbrace{(1-r)\cdot\left\{\overbrace{(1-s)\cdot[\pi(s)-(F-f(r))]}^{\text{Scaling succeeds}}-\overbrace{s\cdot(F-f(r))}^{\text{Scaling fails}}\right\}}_{\text{Research succeeds}} \\ & +\underbrace{r\cdot\left\{\overbrace{(1-s)\cdot[\pi(s)-F]}^{\text{Scaling succeeds}}-\overbrace{s\cdot F}^{\text{Scaling fails}}\right\}}_{\text{Research fails}} \end{aligned} \tag{1}$$

where we have for brevity left out the subscripts. From Assumption 6 , the expected profit in (1) then simplifies to:

$$\Pi(s,r) = (1-r)\cdot\{(1-s)\cdot\pi(s)-(F-f(r))\} \tag{2}$$

We proceed to resolve the problem faced by the independent startup through backward induction.

4.1.1 Scaling (Stage 4)

Assuming the independent startup has successfully navigated the initial research in Stage 1 and subsequently undertaken the startup cost, it is important to note that the cost, denoted as $F-f(r)$, is considered sunk by the time decision-making on scaling occurs in Stage 4. At this juncture, the entrepreneur, holding decision-making authority, aims to maximize expected profit, articulated as

$$\Pi(s) = (1-s)\cdot\pi(s), \tag{3}$$

within this framework, understanding that success will yield a product market profit $\pi(s)$ in Stage 6.

The first-order condition, $\frac{\partial\Pi(s)}{\partial s} = 0$, is

$$\underbrace{(1-s^*)\cdot\pi'(s^*)}_{MB(s^*)} = \underbrace{\pi(s^*)}_{MC(s^*)}. \tag{4}$$

The left-hand side (LHS) of Equation (4) represents the incremental expected profits derived from a marginal increase in scaling, which follows from that $\pi'(s^*) > 0$. This term symbolizes the *marginal benefit* of adopting a more aggressive scaling strategy, denoted as $MB(s) = (1-s)\cdot\pi'(s)$. The marginal benefit is illustrated in Figure 4's top-left panel as a downward-sloping marginal benefit locus. Conversely, the right-hand side (RHS) of Equation (4) encapsulates the *marginal cost* associated with choosing a more aggressive scaling strategy. A more intensive scaling approach s enhances the probability of failure, thereby elevating the risk of forfeiting the entire profit $\pi(s^*)$. The upward-sloping locus $MC(s) = \pi(s)$, depicted in the same panel of Figure 4, reflects the anticipated loss from opting for a more aggressive scaling strategy.

The equilibrium scaling strategy, denoted as s^*, is determined by the intersection of the marginal benefit locus, $MB(s)$, and the marginal cost locus, $MC(s)$, at point B in Panel (i) of Figure 4. This equilibrium point s^* is unique and stable, in accordance with Assumption 5.

4.1.2 Research (Stage 1)

Shifting focus to the research strategy, denoted by r, and incorporating the optimal scaling strategy, s^*, derived from inserting Equation (4) into the expected profit function (3), we can reformulate the objective function presented in (2) as follows:

$$\Pi(r) = (1-r)\cdot\{(1-s^*)\cdot\pi(s^*) - (F - f(r)\}. \tag{5}$$

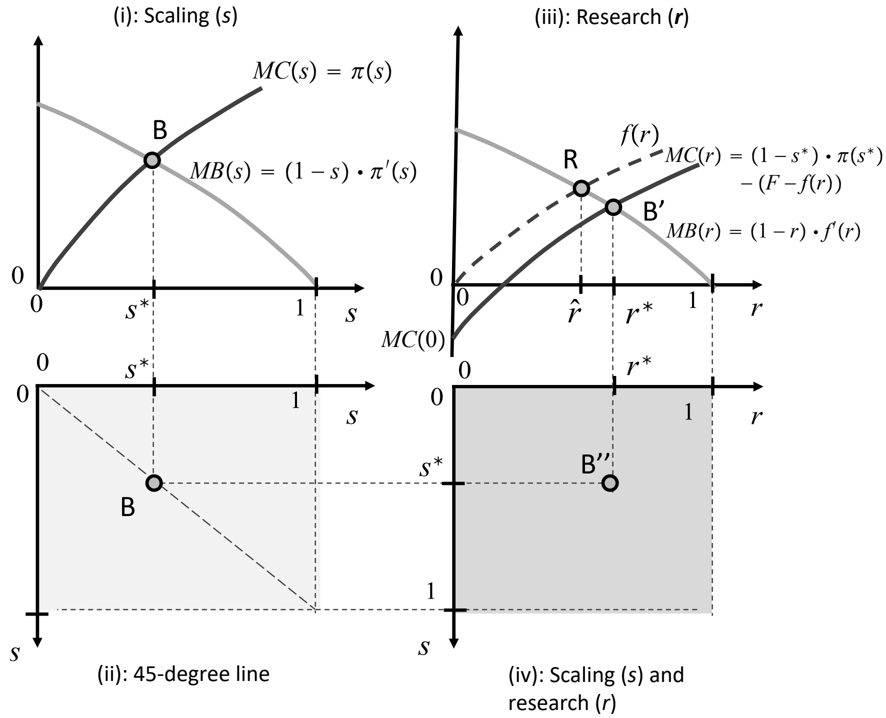

Figure 4: The benchmark without VC.

The first-order condition, $\frac{\partial \Pi}{\partial r} = 0$, is

$$\underbrace{(1-r^*)\cdot f'(r^*)}_{MB(r^*)} = \underbrace{(1-s^*)\cdot \pi(s^*) - (F - f(r^*))}_{MC(r^*)}. \tag{6}$$

The LHS of Equation (6) represents the marginal benefit of adopting a more aggressive research strategy, r, given by $MB(r) = (1-r)\cdot f'(r)$. This expression captures the expected decrease in startup costs and is illustrated as a downward-sloping curve in Panel (iii) of Figure 4. Conversely, the RHS of Equation (4) delineates the marginal cost associated with a more intensive research approach, $MC(r)$. A heightened research intensity elevates the probability of project failure, represented by the upward-sloping curve $MC(r) = (1-s^*)\cdot\pi(s^*) - (F - f(r))$ in Panel (iii). This curve signifies the anticipated net profit loss from opting for a riskier research venture, essentially the foregone net profit had the research not succeeded. Importantly, when $MC(0) = (1-s^*)\cdot\pi(s^*) - F < 0$, as posited under Assumption 6, the scenario where the research initiative yields no reduction in startup costs results in a negative net profit.

The optimal research strategy, r^*, is determined at the intersection of the marginal benefit curve, $MB(r)$, and the marginal cost curve, $MC(r)$, identified as point B' in Panel (iii) of Figure 4. Assumption 3 ensures that r^* is both unique and stable. This optimal strategy, r^*, entails a higher level of risk compared to the strategy that merely aims to minimize expected startup costs, denoted as $r^* > \hat{r}$. By employing the 45-degree line depicted in Panel (ii), the equilibrium scaling strategy, s^*, and the equilibrium research strategy, s^*, can be connected within Panel (iv). Consequently, point B" in Panel (iv) establishes the benchmark equilibrium for an independent startup. The subsequent analysis will explore how the presence of a VC market influences the risk-taking behavior of startups.

4.2 Introducing venture capital

Upon introducing VC into the industry, as depicted in Figure 1, entrepreneurs gain an alternative pathway following an initial research setback at Stage 1. Specifically, they can seek support from a VC firm. With the VC firm's assistance, the entrepreneur is able to pivot, selecting a new research endeavor aimed at reducing startup costs and ensuring the profitability of the new product or service. If this VC-supported research proves successful, the startup then proceeds to make strategic decisions regarding market scaling.

4.2.1 The VC-backed startup

To analyze the influence of VC on startup behavior, we contrast the research and scaling decisions of VC-backed startups with those made by independent startups lacking VC access. This comparison shows how VC involvement alters the strategic landscape, potentially shifting the risk tolerance and decision-making calculus of startups regarding their research intensity and market scaling approaches.

Consider the scenario where, after the entrepreneur has invested in research at Stage 0 by incurring a fixed cost G, her research projects do not succeed at Stage 1. At Stage 2, she encounters a VC firm. They decide to proceed as a VC-supported startup, agreeing to a division of proceeds from a successful exit at Stage 5.

To examine the incentives within the VC-backed startup, it is instructive to begin at Stage 3, from which we can derive the expected joint surplus generated by the VC-backed startup:

$$V(s,r) = (1-r) \cdot \{(1-s) \cdot [\pi(s) - C_E] - (F - f(r))\}. \tag{7}$$

Note that the joint surplus $V(s,r)$ in (7) and the expected profit $\Pi(s,r)$ in the benchmark (2) are almost identical. The primary distinction lies in the fact that the VC-backed startup opts for an exit through a trade sale or IPO in Stage 5, thereby incurring the exit cost, C_E.

Scaling (Stage 4) Suppose that the VC-backed startup succeeds with its research project in Stage 3. Given that the startup cost, $F - f(r)$, becomes sunk upon scaling in Stage 4, the objective function can be expressed as:

$$V(s) = (1-s) \cdot [\pi(s) - C_E]. \tag{8}$$

If successful with scaling, the owners of the startup will encounter a net profit $\pi(s) - C_E$ upon exiting in Stage 5, where $\pi(s)$ represents the profits of the new owners in Stage 6, and C_E denotes the exit cost.

The first-order condition, $\frac{\partial V}{\partial s} = 0$, is

$$\underbrace{(1-s_V^*) \cdot \pi'(s_V^*)}_{MB(s_V^*)} = \underbrace{\pi(s_V^*) - C_E}_{MC_V(s_V^*)}. \tag{9}$$

The LHS of equation (9) represents the marginal benefit ($MB(s)$) of increased scaling, mirroring the benchmark established in equation (4). This term highlights the expected rise in gross profits due to expanded scaling efforts. In contrast, the RHS of Eqs. (4) and (9) reveals differences: specifically, entrepreneurs backed by VC face a lower perceived marginal cost ($MC_V(s) < MC(s)$) for more aggressive scaling, as the exit cost C_E is avoided in the event of failure. This suggests that VC-backed startups are likely to scale more aggressively compared to benchmarks without VC support, i.e., $s_V^* > s^*$. Panel (i) of Figure 5 visually demonstrates this, showing how the marginal cost curve $MC_V(s)$ is lowered relative to $MC(s)$ by the magnitude of the exit cost, C_E. Consequently, the point of intersection between the marginal benefit and marginal cost curves shifts to the right, from B to V. This shift intuitively underscores that the lower potential loss of profits in case of failure, due to the presence of exit costs C_E, encourages VC-backed startups to adopt a more aggressive and risk-oriented scaling strategy compared to their independent counterparts.

Research (Stage 3) Returning to Stage 3, we determine the VC-backed startup's selection of a research project. By incorporating the optimal scaling factor s_V^* from Equation (9) into the joint surplus (7), we derive the objective function:

$$V(r) = (1-r) \cdot \{(1-s_V^*) \cdot [\pi(s_V^*) - C_E] - (F - f(r))\}. \tag{10}$$

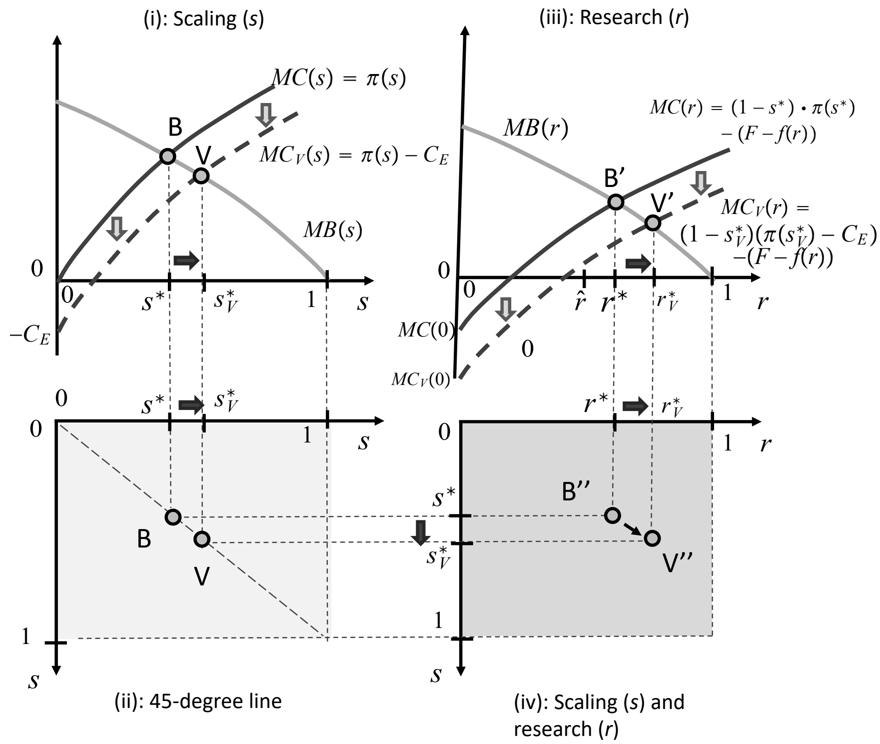

Figure 5: Scaling and research in the VC-backed startup.

The first-order condition, $\frac{\partial V}{\partial r} = 0$, is

$$\underbrace{(1-r_V^*)\cdot f'(r_V^*)}_{MB(r_V^*)} = \underbrace{(1-s_V^*)\cdot\left(\pi(s_V^*) - \overbrace{C_E}^{\text{Exit cost}}\right) - (F - f(r_V^*))}_{MC_V(r_V^*)}. \tag{11}$$

The LHS of Equation (11) represents the marginal benefit associated with opting for a more aggressive and risky research strategy, while the RHS denotes the marginal cost of such a strategy. Similar to the benchmark scenario, the marginal benefit reflects the expected decrease in startup costs, defined as $MB(r) = (1-r)\cdot f'(r)$. A closer examination of Equations (6) and (11) indicates that the presence of the exit cost, C_E, results in a lower marginal cost for the VC-backed startup compared to an independent startup, i.e., $MC_V(r) < MC(r)$. This difference is attributed to the direct influence of the exit cost, C_E, which mitigates the loss in net profit from a failed research project. Additionally, the reduced marginal cost for the VC-backed startup also arises from over-investment in scaling, $s_V^* > s^* = \arg\max[(1-s)\cdot\pi(s)]$, leading to $(1-s_V^*)\cdot\pi(s_V^*) < (1-s^*)\cdot\pi(s^*)$. Consequently, the VC-backed firm's over-investment in scaling also encourages more aggressive research to secure higher net profits through reduced startup costs, resulting in $r_V^* > r^*$ and $f(r_V^*) > f(r^*)$. This is depicted in Figure 5(ii), with point V' positioned to the right of benchmark B'. In summary:

Lemma 1. *The following holds:*

1. *If the exit cost for a VC-backed startup is strictly positive ($C_E > 0$), the startup, benefiting from venture capital support, will opt for a more aggressive and riskier scaling strategy, as well as a more aggressive and riskier research strategy, compared to an independent startup without access to VC funding: $s_V^* > s^*$ and $r_V^* > r^*$.*

2. *If the exit cost for a VC-backed startup is zero ($C_E = 0$), then the startup, despite being supported by venture capital, will adopt scaling and research strategies that are identical to those of an independent startup without VC funding: $s_V^* = s^*$ and $r_V^* = r^*$.*

4.2.2 The independent startup

Our findings suggest that entrepreneurs, when directly supported by VC, tend to adopt scaling and research strategies that are riskier than those chosen in the absence of VC backing. If these insights were applied to empirical data, we would anticipate that VC-backed startups would scale to larger sizes and engage in more radical research compared to startups without VC support.

The possibility of accessing VC can influence a startup's behavior, even if the entrepreneur ultimately decides against seeking VC backing. To examine this indirect channel, we now analyze the complete game as depicted in Figure 1. Here, the entrepreneur considers the option of pivoting with VC assistance in Stage 2 if she is unable to establish a viable business in Stage 1.

The potential support from VC is valuable to the entrepreneur particularly because it offers a safety net in the event of initial failure. Specifically, the entrepreneur stands to benefit from partnering with a VC firm in Stage 2 only if the research and scaling efforts succeed in the VC-backed scenario. Assuming that the entrepreneur retains a share $\theta \in (0,1)$ of the proceeds, the expected value to the entrepreneur of collaborating with the VC firm in Stage 2 can be written as:

$$v(s_V^*, r_V^*) = \underbrace{\theta}_{\text{Entrepreneur's share}} \cdot \underbrace{(1 - r_V^*)}_{\text{Prob. that pivot succeeds}} \cdot \left\{ \underbrace{(1 - s_V^*) \cdot (\pi(s_V^*) - C_E) - (F - f(r_V^*)) - G}_{\text{Expected net surplus from scaling of startup}} \right\}, \tag{12}$$

where we have taken into account that the VC firm also needs to be reimbursed for the fixed research cost, G.

We can now derive the expected profit for the entrepreneur (after paying the fixed research cost in Stage 0), as

$$\Pi_I(s, r) = (1 - r) \cdot \{(1 - s) \cdot \pi(s) - (F - f(r))\} + r \cdot v(s_V^*, r_V^*). \tag{13}$$

The net expected profit is captured by the first term, where $(1 - r)$ represents the probability of the entrepreneur's success in her initial research during Stage 1. This component aligns with the profit calculation in the benchmark scenario (equation (2)). The second term can be viewed as an insurance mechanism, which we'll refer to as *the option value of a second-chance*. Here, r indicates the probability of failing in the initial research phase in Stage 1, and $v(s_V^*, r_V^*)$ represents the anticipated value to the entrepreneur from collaborating with the VC firm following an initial setback.

Scaling (Stage 4) As depicted in Figure 1, if the entrepreneur successfully completes her research project in Stage 1, she possesses the capability to scale the startup and enter the market independently. Consequently, she progresses directly to Stage 4, where she will decide on the extent of scaling. At this juncture, with the initial startup costs considered sunk, her objective shifts to maximizing her expected profit

$$\Pi(s) = (1 - s) \cdot \pi(s). \tag{14}$$

The first-order condition, $\frac{\partial \Pi}{\partial s} = 0$, is

$$\underbrace{(1 - s_I^*) \cdot \pi'(s_I^*)}_{MB(s^*)} = \underbrace{\pi(s_I^*)}_{MC(s^*)}. \tag{15}$$

The equation (15) is identical to equation (4). Intuitively, this implies that if the entrepreneur successfully completes her research project and proceeds without VC support, she will opt for the same level of risk in scaling as established in the benchmark scenario, that is, $s_I^* = s^*$. This outcome is illustrated in Panel (i) of Figure 6.

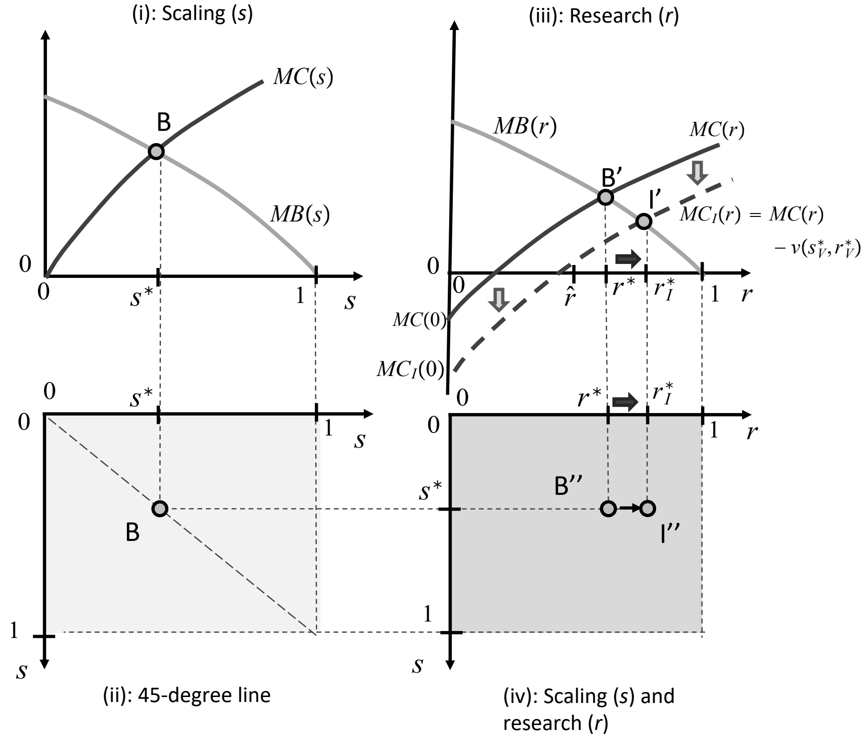

Figure 6: The entrepreneur's incentives when VC is present.

Research (Stage 1) Returning to the entrepreneur's research decision in Stage 1, by substituting the optimal scaling choice $s_I^* = s^*$ from equation (15) into the expected profit equation (13), we obtain

$$\Pi_I(r) = (1-r)\cdot\{(1-s_I^*)\cdot\pi(s_I^*) - (F - f(r))\} + r\cdot v(s_V^*, r_V^*). \tag{16}$$

The optimal research taken by the entrepreneur is then given from the first-order condition, $\frac{\partial \Pi_I}{\partial r} = 0$, or

$$\underbrace{(1-r_I^*)\cdot f'(r_I^*)}_{MB(r_I^*)} = \underbrace{(1-s_I^*)\cdot\pi(s_I^*) - (F - f(r_I^*)) - \overbrace{v(s_V^*, r_V^*)}^{\text{Second-chance effect}}}_{MC_I(r_I^*)}. \tag{17}$$

In equation (17), the LHS once more delineates the marginal benefit, $MB(r)$, signifying the reduction in marginal cost attributable to opting for more aggressive research. This component is identical to the benchmark presented in equation (6), as depicted in Panel (iii) of Figure 6. However, a comparison between the RHS of Eqs. (17) and (6) indicates that the entrepreneur perceives a diminished marginal cost for engaging in more aggressive research when VC is accessible within the industry, expressed as $MC_I(r) =$

$MC(r) - v(s_V^*, r_V^*) < MC(r)$. This reduction is highlighted by the final term in the RHS of equation (17), illustrating a *second-chance effect*: by choosing a riskier research strategy, the entrepreneur is aware that failure allows for the possibility of turning to VC, thereby securing an expected profit of $v(s_V^*, r_V^*)$.

Assuming that $v(s_V^*, r_V^*) > 0$, the second-chance effect acts to mitigate the expected loss associated with an unsuccessful initial research project. As illustrated in Panel (iii) of Figure 6, this effect encourages the entrepreneur to pursue a more aggressive—and inherently riskier—research strategy in the presence of VC, leading to $r_I^* > r^*$. The difference in strategic choices is evident when comparing points B' and I' in the figure.

The presence of the second-chance effect, attributed to VC, does not compel the independent startup to increase its scaling efforts beyond what is observed in the absence of VC, maintaining $s_I^* = s^*$. However, this effect does prompt the entrepreneur to opt for a riskier and more aggressive research project, denoted by $r_I^* > r^*$. This is visualized in Panel (iv). To summarize:

Lemma 2. *When the entrepreneur is aware of the possibility to secure VC backing after a potential failure in her Stage 1 research efforts, the scenario impacts her strategic decisions as follows:*

1. *The entrepreneur will to pursue a strictly more aggressive research strategy,* $r_V^* > r^*$.
2. *If the entrepreneur achieves success in the initial research phase, she will opt for the same level of scaling as she would in a benchmark scenario where VC is not present in the industry, denoted as* $s_V^* = s^*$.

4.3 Summing up: how the VC market affect startups

We now summarize our findings on the impact of an active VC market on startup risk-taking behavior. Our analysis considers two primary effects: the *direct effect*, which influences a startup upon becoming VC-backed, and the *indirect effect*, which stems from altered entrepreneurial incentives in anticipation of potential VC access. This indirect effect accounts for the option value associated with the opportunity for a second-chance provided by VC.

4.3.1 Startups take on more risk in scaling when VC-backed

We begin by examining the scaling decisions of startups, contrasting scenarios within industries that have access to VC against those that do not. We have the following proposition:

Proposition 1. *Startups opt for a more aggressive and riskier scaling strategy in the presence of VC and when exit costs, denoted by C_E, are strictly positive, such that $s_V^* > s_I^* = s^*$.*

If a startup's initial research in Stage 1 does not yield the desired outcomes, the VC firm offers an opportunity for a strategic pivot in Stage 2. Lemma 1 demonstrates that if the exit costs for a VC-backed startup in Stage 5 are strictly positive, denoted as $C_E > 0$, the entrepreneur is incentivized to pursue a higher level of scaling when supported by VC, compared to a non-VC-backed scenario, where $s_V^* > s^*$. Conversely, if the entrepreneur's initial research is successful, she will continue with an independent startup, bypassing further VC involvement. As indicated in Lemma 2, the scaling level chosen in this scenario aligns with what would have been selected in the absence of VC, i.e., $s_I^* = s^*$. Proposition 1 further suggests that startups receiving VC backing are likely to achieve higher gross profits, $\pi(s_V^*) > \pi(s_I^*) = \pi(s^*)$. This observation is in line with the findings of Gompers et al. (2021), who note that VC firms prioritize investments with the potential for significant returns. The underlying rationale for this preference towards large-scale, high-risk ventures is attributed to the substantial exit costs, $C_E > 0$, faced by VC-backed startups, compelling them to adopt more ambitious and risky scaling strategies.

4.3.2 Startups take on more risk in research when VC is available

Next, we turn to the research decision. We can state the following proposition:

Proposition 2. *Research within startups becomes more aggressive and risk-prone when VC is active in an industry: $r_l^* > r^*$ for $l = I, V$.*

This proposition is derived from Lemma 1 and Lemma 2. When a startup secures VC backing, the anticipated exit costs, denoted by $C_E > 0$, both directly and indirectly, result in a reduced net profit loss if initial research efforts fail. Consequently, this incentivizes the VC-backed startup to embrace higher risks as a strategy to decrease startup costs, thereby establishing that $r_V^* > r^*$.

We also discovered that even in the absence of VC support, entrepreneurs are inclined to assume higher risks to reduce startup costs. This effect is attributed to the *second-chance effect*, a phenomenon where the entrepreneur recognizes the opportunity to seek VC support if initial research fails, albeit at the cost of sharing venture proceeds. This realization motivates the entrepreneur to pursue riskier research avenues, resulting in $r_I^* > r^*$.

Thus, whether VC exerts a direct influence on the entrepreneur (via the exit cost effect) or an indirect one (via the second-chance effect), the entrepreneur tends to pursue riskier research in the presence of VC. Consequently, the presence of VC consistently results in more research and lower startup costs: $F - f(r_l^*) < F - f(r^*)$ for $l = I, V$.

An intriguing question arises regarding the optimal timing of venture capital's influence on technology choice. Does it exert the most significant impact merely by its presence (i.e., the indirect effect), or does direct involvement in the startup (the direct effect) hold greater sway? Therefore, let us now compare r_V^* and r_I^*. We derive the following corollary:

Corollary 1. *The indirect effect of VC, through the second-chance mechanism, can incentivize the entrepreneur to opt for a riskier research project than she would undertake when backed by VC.*

1. *If the exit cost is sufficiently small, $C_E \approx 0$, then $r_I^* > r_V^* \approx r^*$.*

2. *If the research cost G is sufficiently high so that $v(s_V^*, r_V^*) \approx 0$, then $r_V^* > r_I^* \approx r^*$.*

A direct comparison of the first-order conditions (11) and (17) reveals that if the exit cost of the VC-backed firm, C_E, is sufficiently small (i.e., if $C_E \approx 0$), the second-chance effect, $v(s_V^*, r_V^*)$, in (17) supersedes the exit cost effect, and $r_I^* > r_V^*$. The indirect effect of VC leads to a larger technological leap, as measured by lower startup costs, $F - f(r_I^*) < F - f(r_V^*)$.

However, a comparison of the first-order conditions (11) and (17) also reveals that if the research cost G is sufficiently high to limit the second-chance effect, then $r_I^* < r_V^*$, and consequently, $F - f(r_V^*) < F - f(r_I^*)$. The second-chance effect is similarly constrained when the entrepreneur is allocated a smaller share of the net surplus generated by the exit of the venture-backed firm (θ small). In this scenario as well, $r_I^* < r_V^*$.

4.3.3 The second-chance effect: VC and pivots

A pivot in our model is the occurrence where the entrepreneur initially encounters failure with her initial research project in Stage 1, followed by assistance from VC to select a new research project in Stage 3. This pivot holds significant real-economic implications. We have demonstrated how VC, whether through direct or indirect means, provides startups with incentives to undertake substantial risks. Should the initial research and consumer scaling prove successful, VC can yield substantial societal advantages by reducing startup costs and introducing new services to broader consumer bases and markets. Conversely, the heightened risks inherent in ambitious projects also entail a greater number of failed startups.

We conclude this section by assessing the expected impact of VC on startups. We begin by examining the overall probability of startup success.

To this end, let ϕ^{NVC} denote the probability of a startup reaching consumers in the product market in the benchmark scenario without VC presence in the industry. As derived from (6), ϕ^{NVC} is the product

$$\phi^{NVC} = \underbrace{(1-r^*)\cdot(1-s^*)}_{\text{Probability to reach market}} . \tag{18}$$

where $(1-r^*)$ represents the probability of an independent entrepreneur succeeding with her initial research, and $(1-s^*)$ signifies the probability of her success in scaling.

Let ϕ^{VC} denote the probability of a startup reaching consumers in the product market with VC presence in the industry. Utilizing (9) and (11), along with (15) and (17), and Proposition 1, ϕ^{VC} is the sum

$$\phi^{VC} = \underbrace{(1-r_I^*)\cdot(1-s^*)}_{\text{Direct probability to reach market}} + \underbrace{r_I^*(1-r_V^*)\cdot(1-s_V^*)}_{\text{Probability to reach market through pivoting}}. \tag{19}$$

The first term in (19) mirrors (18): it represents the probability that the entrepreneur introduces the product or service to the market without VC funding. The second term denotes the probability of a pivot, i.e., the probability that the entrepreneur receives a second-chance, where r_I^* signifies the probability of the entrepreneur failing with her initial research and subsequently seeking assistance from VC.

Define $\Delta\phi = \phi^{VC} - \phi^{NVC}$ as the difference in probability for the startup to succeed in reaching the market between the industry with and without VC. Utilizing Proposition 1, we have

$$\Delta\phi = \phi^{VC} - \phi^{NVC} = \underbrace{r_I^*\cdot(1-r_V^*)\cdot(1-s_V^*)}_{\text{Probability to reach market through pivoting}} - \underbrace{(r_I^*-r^*)\cdot(1-s^*)}_{\text{Reduction in direct probability}} . \tag{20}$$

The first term represents the probability that a pivot with VC succeeds. The second term indicates that the entrepreneur, fueled by the second-chance afforded by the availability of VC, selects a research project that is riskier and more prone to failure compared to the benchmark scenario. Consequently, the second term reflects the increased probability of failure by the entrepreneur when she operates independently. The question of which term dominates hinges on the relative magnitudes of these probabilities.

If we apply Lemma 1, we understand that when the research cost G becomes sufficiently high, the second-chance effect will be constrained, and r_I^* will approach r^*. As the research cost G does not influence the risk-taking behavior in the VC-backed startup (since G is sunk when the research and scaling decisions are made), r_V^* and s_V^* remain unaffected. Consequently, pivoting with VC enhances the probability that the startup successfully enters the market, yielding $\Delta\phi \approx r^*(1-r_V^*)\cdot(1-s_V^*) > 0$.

Conversely, a sufficiently high exit cost C_E will prompt the VC-backed firm to assume more risk in scaling, such that s_V^* approaches unity, and $\Delta\phi = -(r_I^* - r^*)\cdot(1-s^*) < 0$. This illustrates situations where the probability of a startup reaching the market may decrease if VC becomes available, yet the opposite outcome can also occur.

We can derive similar results for the expected gross profit. Note that

$$\Delta\pi = \pi^{VC} - \pi^{NVC} = \underbrace{r_I^*\cdot(1-r_V^*)\cdot(1-s_V^*)}_{\text{Probability to reach market through pivot}}\cdot\pi(s_V^*) - \underbrace{(r_I^*-r^*)\cdot(1-s^*)}_{\text{Reduction in direct probability}}\cdot\pi(s^*). \tag{21}$$

where π^{VC} is the expected gross profit when VC is present, and π^{NVC} is the expected gross profit when VC is absent. Thus, from (20) and (21), it follows that whenever the availability of VC increases the probability of startup success, $\Delta\phi > 0$. Additionally, the presence of VC will also elevate the expected gross profits from scaling, $\Delta\pi > 0$. The latter holds more generally since $\pi(s_V^*) > \pi(s^*)$.[4]

We conclude with the following proposition that summarized key empirical predictions from our model:

Proposition 3. *Suppose VC becomes available to startups in an industry that previously lacked access to it. Then:*

1. *Startups will opt for riskier research and scaling strategies.*
2. *If successful, VC-backed startups will achieve greater technological advancements and will scale products to reach more consumers and markets.*
3. *Due to the second-chance effect (pivoting with VC support), an equilibrium emerges where startups are more likely to succeed, achieve higher expected gross profits, incur lower startup costs, and undertake greater risks in both research and scaling endeavors.*

[4] To see this, note that the expected gross-profit when VC is not available to the industry is $\pi^{NVC} = (1-r^*)\cdot(1-s^*)\cdot\pi(s^*)$ and the expected gross-profit when VC is available to the industry is

$$\pi^{VC} = \underbrace{(1-r_I^*)\cdot(1-s_I^*)}_{\text{Direct probability to reach market}}\cdot\pi(s_I^*) + \underbrace{r_I^*(1-r_V^*)\cdot(1-s_V^*)}_{\text{Probability to reach market through pivoting}}\cdot\pi(s_V^*) .$$

5 Extensions

5.1 Can a VC market spur risk-taking and productivity in the whole innovation market?

Our analysis demonstrates that the advent of a VC market may heighten risk-taking not only in startups actively seeking VC funding but also in entrepreneurial firms outside this pursuit. This raises the question: How does the emergence of a VC market affect risk-taking across different types of firms, especially considering its impact on incumbent firms' research activities?

To address this, we examine a scenario involving a competitive dynamic between an incumbent and a startup, both engaged in research. Building on the setup above, we simplify the analysis by concentrating on the research decisions of firms. Initially, the incumbent enjoys a monopoly but risks losing this status to the startup. Should the incumbent maintain its monopoly, it secures a profit denoted by π^M; conversely, if the entrant successfully enters the market, both entities earn a duopoly profit, π^D. The incumbent holds several advantages in the innovation landscape: it retains monopoly status even if both entities achieve research success, given its superior resources for winning patent disputes; furthermore, unlike the startup, who must succeed in her research to profit, the incumbent can afford research failures yet remain in the market, as part of the startup cost b is already paid. Thus, we posit $\pi^D - (F - b) > 0 > \pi^D - F$, underscoring our assumption that the incumbent has already invested in market entry. We also posit that a failed startup may seek a second opportunity through VC funding, in line with Assumption 2, which acknowledges VCs' appreciation for experience gleaned from failure. Leveraging their expertise, VCs guide the startup towards less contested markets, potentially securing a monopoly profit, π^M, and sidestepping direct competition in innovation.´

5.1.1 Research (Stage 1)

Since our focus excludes scaling considerations, we directly proceed to the research decisions. Initially, we analyze the research decision from the startup's perspective, followed by an examination of the incumbent's strategy.

Startup Let's first examine the research decision in the benchmark scenario, where the VC market is absent. In this context, entry by the startup is only profitable if the incumbent's research project fails and the startup's own project succeeds. Consequently, the startup's expected profit is derived under these specific

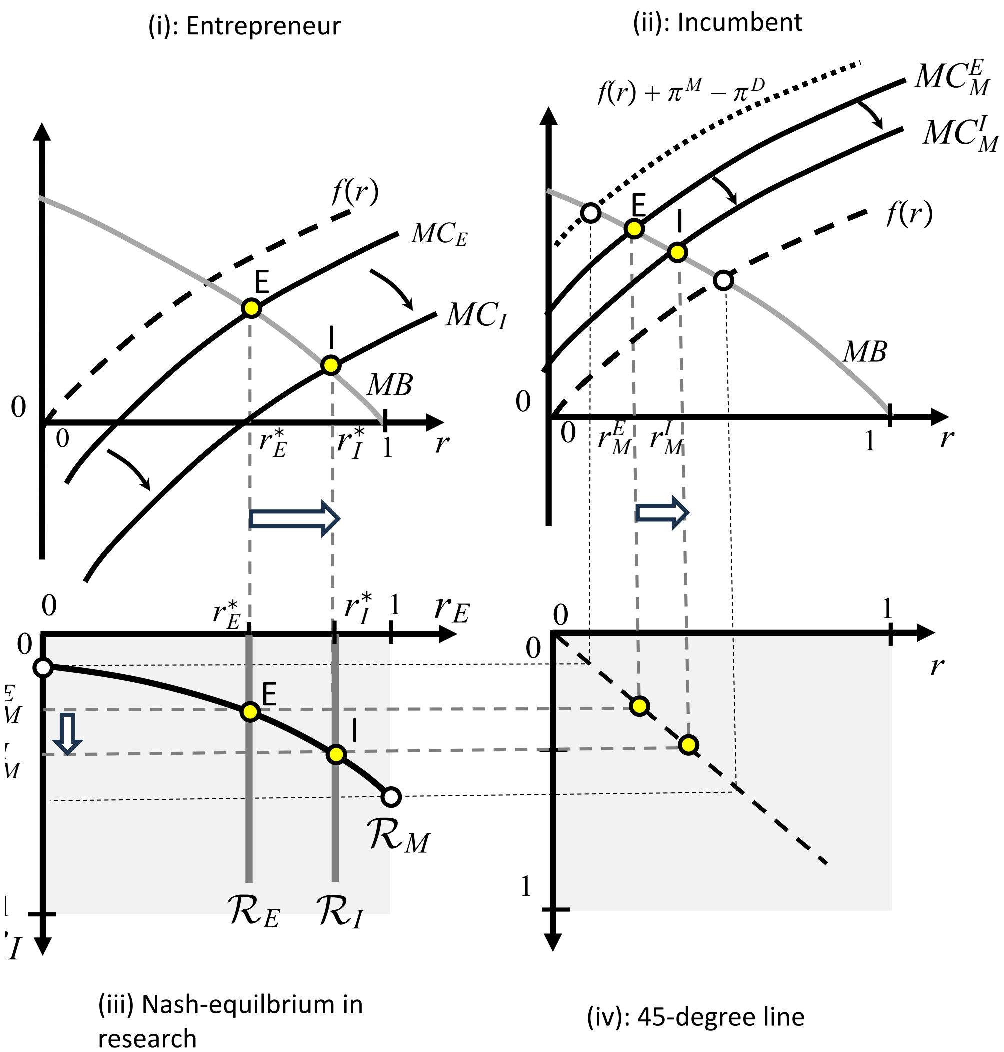

Figure 7: Interaction in research between the startup and the incumbent.

conditions.

$$\Pi_E = \max_{\{r_E\}} \; r_M \cdot (1-r_E) \cdot \left\{\pi^D - (F - f(r_E))\right\}, \tag{22}$$

where r_M is the risk level chosen by the incumbent and r_E the risk level chosen by the startup.

The associated first-order condition in the benchmark is

$$\underbrace{(1-r_B^*)f'(r_B^*)}_{MB_B} = \underbrace{\pi^D - (F - f(r_B^*))}_{MC_B}. \tag{23}$$

where we use the subindex B to denote the benchmark case. The startup decides to enter the market only if the incumbent fails in her research endeavor. Therefore, the startup's selection of a research project is not influenced by the incumbent's project choice. The LHS of equation (23) represents the marginal benefit, $MB(r_E)$, of adopting a more aggressive research strategy. This benefit is essentially the anticipated reduction in fixed costs and is illustrated as a downward-sloping curve in Panel (i) of Figure 7. Conversely, the RHS of equation (23) captures the marginal cost, $MB(r_E)$, associated with a more aggressive research approach. This cost, indicative of the potential loss from choosing a riskier strategy, is shown as an upward-sloping curve $MB(r_E)$ in the same panel. It is important to note that $MC(0) = \pi^D - F < 0$, which underscores our assumption that initiating a startup is not profitable without research success.

When a VC market is available, the independent startup's objective function is

$$\Pi_E = \max_{\{r_E\}} r_M \cdot \left[(1 - r_E) \cdot \left\{\pi^D - (F - f(r_E))\right\} + r_E \cdot v(r_V^*)\right]. \tag{24}$$

Direct market entry proves profitable solely under the condition where the incumbent's research effort fails while the startup's succeeds. The second term within the bracketed expression introduces a pivotal aspect: the presence of VC support grants the startup a "second-chance" should the initial research endeavor fail. Since the VCs induce the startup to target a different market where the VC-backed firm will become a monopolist if the research project succeeds, the optimal project in a second-chance is defined as

$$r_V^* = \arg\max_{\{r_E\}} \left[(1 - r_E) \cdot \left\{\pi^M - C_E - (F - f(r_E)) - G\right\}\right], \tag{25}$$

with the associated expected value, $v(r_V^*) \equiv \theta(1 - r_V^*) \cdot \left\{\pi^M - C_E - (F - f(r_V^*)) - G\right\}$, in symmetry with (12).

The associated first-order condition for the independent startup, when a second-chance is available from the presence of a VC-market, is therefore

$$\underbrace{(1 - r_I^*) f'(r_I^*)}_{MB_I} = \underbrace{\pi^D - (F - f(r_I^*)) - v(r_V^*)}_{MC_I}, \tag{26}$$

where we use the subindex I to denote the independent startup. When comparing equations (23) and (26), we observe that the marginal benefits align with those in the benchmark scenario. Panel (i) illustrates that an independent startup, aware of the existence of a VC market, perceives a reduced marginal cost of failure.

This perception stems from the opportunity for a second-chance, denoted as $MC_I < MC_B$. Consequently, the presence of VC financing incentivizes the startup to opt for a riskier strategy, reflected in the relationship $r_I^* > r_B^*$.

Incumbent Let's examine the impact of the emergence of a venture capital market on the incumbent's research strategy. The incumbent seeks to optimize the following objective function:

$$\max_{\{r_M\}} \Pi_M = (1-r_M)\cdot\left\{\pi^M - (F - f(r_M) - b)\right\} + r_M \cdot \left\{(1-r_E)\left(\pi^D - F - b\right) + r_E(\pi^M - (F-b))\right\}. \quad (27)$$

The first component of equation (27) reflects the incumbent's competitive edge in the innovation landscape. Should both entities achieve research breakthroughs, the incumbent, bolstered by its substantial resources, is more likely to emerge victorious in any patent litigation. The subsequent component of (27) outlines the incumbent's expected net gains when its research endeavors fail. In scenarios where the startup is successful, occurring with probability $1-r_E$, the incumbent, having already invested a portion of the start-up costs, denoted by b, remains viable in the market with a net profit of $\pi^D - (F-b) > 0$. Conversely, should the startup not succeed, with probability r_E, the incumbent stands to gain a profit of $\pi^M - (F-b) > 0$. This outcome is assuredly positive as the profits derived from monopolistic dominance exceed those from a duopoly setting, signified by $\pi^M > \pi^D$.

The associated first-order condition is

$$\underbrace{(1-r_M)f'(r_M)}_{MB_M} = \underbrace{f(r_M) + (1-r_E)\left(\pi^M - \pi^D\right)}_{MC_M}. \quad (28)$$

The LHS of equation (28) matches that of the startup in equations (23) and (26), illustrating the marginal benefits of adopting a more aggressive research strategy, denoted as $MB(r_M)$. This is represented by the declining curve in Panel (ii) of Figure 7. Conversely, the RHS of equation (4) quantifies the marginal cost of a more assertive research approach, $MC(r_M)$, depicted as the ascending curve in the same panel. A comparison between Panels (i) and (ii) highlights that the incumbent's marginal costs deviate from those of the startup due to the incumbent's market presence post-failure, either as a monopolist if the startup also fails, or as a participant in a duopoly if the startup succeeds. The initial term on the RHS of (28) indicates that failure results in a loss tied to the unrecovered portion of the start-up cost, $f(r_M)$, alongside an anticipated decline in market profits as monopoly profits give way to duopoly profits, occurring with probability $1 - r_E$.

This framework sets the stage to analyze how the advent of a VC market influences the incumbent's selection of research projects. Panel (i) in Figure 7 demonstrates that the potential for a second opportunity encourages startups to undertake more ambitious projects ($r_I^* > r_B^*$) compared to scenarios devoid of VC support. Consequently, the probability of the startup's project failing increases in the VC-enabled environment, since $1 - r_I^* < 1 - r_B^*$. This reduction in the anticipated cost of failure for the incumbent, as derived from equation (28), suggests that the incumbent will opt for a bolder and riskier research initiative, $r_M^I > r_M^B$. This shift is visualized in Panel (ii), where the marginal cost curve $MC(r_M)$ lowers, reflecting the diminished expected loss for the incumbent due to competitive entry.

The overarching effect of VC market emergence on the innovation landscape is depicted in Panel (iii), showcasing the reaction functions of both the incumbent, R_I, and the startup, R_E. The startup's reaction functions, both with and without VC market presence, are illustrated as vertical lines, indicating the independence of the startup's project choice from the incumbent's decisions, i.e., $R_I = r_I^* > R_B = r_B^*$. The incumbent's reaction function, $R_I(r_E)$, is the downward-sloping curve in Panel (iii), formulated by correlating the incumbent's optimal research choices from Panel (ii) with the diagonal line in Panel (iv). The slope of the incumbent's reaction function of the incumbent can be formally derived by differentiating the first-order condition (28) to get:

$$\frac{dr_M^*}{dr_E} = R_M'(r_E) = -\frac{\overbrace{\pi^M - \pi^D}^{>0}}{\underbrace{2f'(r_M^*) + (1 - r_M^*) \cdot f''(r_M^*)}_{<0}} > 0.$$

Thus, for the incumbent, the research strategies pursued by the two firms function as strategic complements. Specifically, if the incumbent anticipates that the startup will adopt a more aggressive research approach, it will respond by selecting a similarly aggressive strategy. This behavior is particularly pronounced when the presence of a VC market encourages the startup to embrace greater risk. In such scenarios, the incumbent's inclination towards risk-taking is heightened, as the threat of ceding its monopoly status to the startup diminishes.

We can summarize:

Proposition 4. *The presence of VC increases research risk among established incumbents, as their research efforts are strategic complements to the research risk choices of startups.*

Proposition 4 demonstrates that the introduction of VC into an industry can increase research risk levels, affecting not only VC-backed startups but also independent startups and incumbents. Consequently, the advent of the VC market can stimulate increased risk-taking and enhance productivity within the innovation sector.

5.2 Bank versus VC financing

To explore the impact of temporary ownership by VC firms on a VC-backed startup's research and scaling choices, we initially consider that the startup incurs a distinct exit cost, C_E. However, the intricacies of the VC model—including specific costs and the revenue sharing arrangement between investors and the VC firm—also influence these strategic decisions. A prevalent aspect of such contracts suggests that a substantial portion of the startup's exit value predominantly benefits the investors. These contractual dynamics introduce "exit costs" that further influence the startup's research and scaling activities.

In practical scenarios, an entrepreneur must also cover her startup's initial costs, often turning to bank financing for this capital. Consequently, our model must also account for bank financing. We propose that, similar to VC-backed startups, independently funded startups encounter an "exit cost" upon repayment of bank loans. Nevertheless, we will illustrate that the "exit cost" tends to be more burdensome for VC-backed startups than for their bank-financed counterparts.

Our analysis begins with the benchmark case of an independent startup, which relies on bank financing to meet its startup costs. We will investigate how this financial structure affects the startup's decisions regarding scaling and research. Subsequently, we will examine the influence of the VC-backed startup's contractual agreements with investors on its strategic choices in scaling and research.

5.2.1 Bank financing

Assuming the startup's research project r is successful in Stage 1, she must secure financing to cover the residual startup cost $F - f(r)$. If the bank stipulates a minimum equity investment A from the startup, and given that her wealth W exceeds A in Stage 1, she will seek a loan for the amount $F - f(r) - A$ at a predetermined interest rate ρ. Consequently, she will utilize this loan along with her own equity to meet the startup cost $F - f(r)$ by the end of Stage 1.

In order to concisely understand the implications of debt financing, we will simplify our model by removing the second-chance effect. Under this simplification, the independent startup's optimization problem can be represented as follows:

$$\max_{\{r,s\}} \Pi(s,r) = \begin{cases} 0, \text{ or } \varphi(s,r) < 1+\rho, \\ W-(1-r)A+(1-r)\cdot(1-s)\cdot\{\pi(s)-(1+\rho)\cdot(F-f(r)-A)\}, \text{ for } \varphi(s,r) \geq 1+\rho. \end{cases} \tag{29}$$

In (29), we have defined $\varphi(s,r)$ as the return for a successful project with a scaling strategy s and research strategy r that gives exactly a return equal to the bank lending rate, i.e.

$$\varphi(s,r) = \frac{\pi(s)-(F-f(r)-A)}{F-f(r)-A}. \tag{30}$$

The upper scenario in equation (29) illustrates the instance where, even if successful, the startup is unable to repay the loan along with the accrued interest. Consequently, our analysis will primarily concentrate on the latter scenario described in equation (29), wherein $\varphi(s,r) > 1+\rho$. This condition implies that the startup, upon achieving success, is capable of generating a net profit after covering all costs, including the repayment of the loan with interest. For this discussion, we will bypass the bank's lending incentives to the startup, instead assuming model parameters are set such that the bank deems it profitable to extend credit to the startup at the interest rate ρ, provided that the startup invests an initial equity amount A into the startup.

Scaling (Stage 4) In Stage 4, conditional on succeeding with her research in Stage 1, the independent startup will maximize the expected profit

$$\Pi(s,r) = W-A+(1-s)\cdot\{\pi(s)-(1+\rho)\cdot(F-f(r)-A)\}. \tag{31}$$

Debt financing significantly alters the incentives for the independent startup to scale its operations. In our benchmark scenario, it was assumed the startup finances the startup costs with her own resources at the end of Stage 1. According to equation (3), this means that in the benchmark case, the startup cost $F-f(r)$ is considered a sunk cost by the time decisions regarding scaling, denoted by s, are made. However, as equation (31) demonstrates, this assumption does not hold under debt financing.

Under debt financing, the startup is aware that she must repay the borrowed amount plus interest, calculated as $(1+\rho)\cdot(F-f(r)-A)$, at the conclusion of Stage 6. This introduces a crucial, endogenous relationship between the research and scaling decisions, as the costs associated with scaling now directly impact the financial obligations of the startup due to the debt arrangement. This shifts how the startup evaluates the cost-benefit analysis of scaling decisions, underscoring the intertwined nature of financing, research, and scaling within the startup's strategic considerations.

Maximizing (31), the first-order condition, $\frac{\partial \Pi(s,r)}{\partial s} = 0$, becomes

$$\underbrace{(1-s)\cdot\pi'(s)}_{MB_L(s=s_L^*(r))} = \underbrace{\pi(s)-(1+\rho)(F-f(r)-A)}_{MC_L(s=s_L^*(r))}. \tag{32}$$

When comparing the first-order condition for scaling under debt financing to the analogous condition in the benchmark scenario without debt (denoted by (4)), we find that the *marginal benefit* of a more aggressive scaling strategy, $MB_L(s)$, remains consistent with that in the own-financing benchmark case. However, the *marginal cost* associated with a more ambitious scaling approach under debt financing, $MC_L(s)$, diverges from the marginal cost encountered with own financing, $MC(s)$.

In both scenarios, adopting a more aggressive scaling strategy, s, heightens the probability of failure, thereby increasing the risk of forfeiting the product market profit, $\pi(s)$. Yet, under debt financing, the financial repercussions of failure are somewhat mitigated. This mitigation arises because the obligation to repay the loan, quantified as $(1+\rho)(F-f(r)-A)$, is contingent upon successful scaling. Therefore, when comparing the two first-order conditions—(4) and (32)—it becomes evident that the marginal cost of selecting a more aggressive scaling strategy under debt financing, $MC_L(s)$, is lower than that under own financing, $MC(s)$. This discrepancy can be expressed as $MC_L(s) = \pi(s)-(1+\rho)\cdot(F-f(r)-A) < MC(s) = \pi(s)$. Consequently, this lower marginal cost under debt financing naturally incentivizes the independent startup to pursue a more aggressive scaling strategy, hence $s_L^* > s_I^*$.

Thus we can state the following proposition:

Proposition 5. *When a startup selects bank financing to support her startup, this debt financing method encourages a more aggressive scaling strategy compared to cases where the startup is financed without debt, as demonstrated in the benchmark scenario. Consequently, it implies that $s_L^* > s^*$, suggesting that the leverage obtained through debt financing motivates startups to engage in more ambitious scaling initiatives.*

Referring to (32), it becomes clear that debt financing renders the optimal scaling decision s_L^* in Stage 4 contingent on the research project choice r made in Stage 1, represented as $s_L^*(r)$. Indeed, differentiating

(32), we obtain

$$\frac{ds_L^*}{dr} = \frac{(1+\rho)\overset{(+)}{f'(r)}}{-2\underset{(+)}{\pi'(s_L^*)} + (1-s)\cdot \underset{(-)}{\pi''(s_L^*)}} < 0.$$

An aggressive research strategy, symbolized by r, can lower the loan repayment when successful, as shown by $(1+\rho)f'(r) > 0$. This increase in the marginal cost of pursuing a more assertive scaling strategy is attributed to a heightened expected net loss in the event of failure. This encourages the startup to opt for a more conservative scaling strategy, thus $\frac{ds_L^*}{dr} < 0$.

Proposition 6. *If a startup utilizes debt from bank financing for her startup, she is likely to adopt a more aggressive scaling strategy, s_L^*, especially if she has previously succeeded with a more assertive research approach, as indicated by $\frac{ds_L^*}{dr} < 0$.*

Drawing from (32), it is inferred that under debt financing, the startup is inclined to adopt a more aggressive scaling strategy as the interest rate ρ increases and when utilizing less of her own wealth A.

Research (Stage 1) Turning our focus to the research strategy, r, Proposition 5 illustrates that debt financing prompts the startup to pursue a more ambitious scaling strategy compared to financing with their own resources, denoted as $s_L^*(r) > s^*$. However, this inclination does not necessarily extend to the selection of the research strategy, r. To understand this, we first insert the optimal scaling $s_L^*(r)$ from (32) at Stage 1 into the objective function presented in (2):

$$\Pi(r, s_L^*(r)) = W - (1-r)A + (1-r)\cdot(1-s_L^*(r))\cdot\{\pi(s_L^*(r)) - (1+\rho)\cdot[F - f(r) - A]\} \tag{33}$$

Applying the envelope theorem, the first-order condition, $\frac{\partial \Pi(r,\bar{s}^*(r))}{\partial r} = 0$, can be written as:[5]

$$\underbrace{(1+\rho)\cdot(1-r)\cdot f'(r) + \frac{A}{1-s_L^*(r)}}_{MB_L(r=r_L^*)} = \underbrace{\pi(s_L^*(r)) - (1+\rho)\cdot[F-f(r)-A]}_{MC_L(r=r_L^*)}. \tag{34}$$

Comparing the first-order condition for research under debt financing in (34) with that for research without debt financing in (6), the marginal benefit of adopting a more aggressive research strategy under debt financing, $MB_L(r)$, is highlighted. It includes the expected savings on startup costs, including financial expenses,

[5]To see this, note that $\frac{d\Pi(r,s_L^*(r))}{dr} = \frac{\partial\Pi(r,s_L^*(r))}{\partial r} + \frac{\partial\Pi(r,s_L^*(r))}{\partial s}\cdot\frac{ds_L^*}{dr} = \frac{\partial\Pi(r,s_L^*(r))}{\partial r}$ since $\frac{\partial\Pi}{\partial s} = 0$ from (32).

$(1+\rho)\cdot(1-r)\cdot f'(r)$, and the benefits of a successful research outcome in terms of retaining own wealth invested in the business $\frac{A}{1-s_L^*(r)}$, adjusted by the success probability of scaling, $1-s_L^*(r)$. In comparison, the marginal benefit in the benchmark scenario, $MB(r)=(1-r)\cdot f'(r)$ as shown in (6), suggests debt financing significantly incentivizes riskier research, $MB_L(r) > MB(r)$.

However, assessing the marginal cost of a more aggressive research strategy under debt financing, $MC_L(r) = \pi(s_L^*(r)) - (1+\rho)\cdot[F-f(r)-A]$, against that under own financing, $MC(r) = (1-s^*)\pi(s^*) - [F-f(r)]$, as outlined in (6), doesn't yield a straightforward conclusion, denoted as $MC_L(r) - MC(r)$. The expected loss of profits for a failed riskier research project is higher under debt financing, $\pi(s_L^*(r)) > (1-s^*)\pi(s^*)$, because debt financing encourages a more aggressive scaling approach, $s_L^*(r) > s^*$, as per Proposition 5. This could potentially raise the marginal cost of riskier research under debt financing, suggesting less risk-taking in research. Nonetheless, the financial burden of startup costs under debt financing, $(1+\rho)\cdot[F-f(r)-A]$, could be lower than the total startup costs, $[F-f(r)]$, borne by the startup under own financing. Therefore, it remains ambiguous whether research projects will be more or less aggressive under debt financing: $r_L^* \lesseqgtr r^*$.

5.2.2 VC financing

Transitioning to VC financing, we observe that VC firms accumulate capital from institutional investors to establish VC funds, typically with a lifespan of about 10 years. These funds are then allocated across multiple startups. VC firms actively collaborate with these startups to facilitate their growth and scaling. Ultimately, the aim is to sell these investments at a profit. The proceeds from these sales are returned to the institutional investors, ideally yielding a significant return on their initial investment. The compensation contracts for VC firms, i.e. what they are maximizing, contain two central elements (Phalippou, 2009; Metrick and Yasuda, 2010):

1. An annual management fee of 2 percent of capital commitments.

2. Carried interest. This arrangement constitutes an incentive fee for managers, predicated on the fund's returns. Initially, all capital divested is directed to the investors until the cumulative distribution achieves an "internal rate of return" of 8% per annum. Subsequent to reaching this benchmark, all proceeds are allocated to the VC firm until it secures 20% of the excess over the total distributed amount and the aggregate of the two previously mentioned components. This mechanism is referred

to as a "catch-up provision". At this juncture, the distribution ratio stands at 80% for investors and 20% for the VC firm. Any returns exceeding this threshold are divided, with 80% allocated to investors and 20% to the VC firm.

A critical element of the contract between investors and the VC firm concerning VC-backed startups' research and scaling activities is the distribution of returns. Initially, investors are the residual claimants, receiving 100% of the capital divested by the fund until the cumulative distribution matches an "internal rate of return" of 8% per annum. Following this, the VC firm becomes the residual claimant until it acquires 20% of the surplus over the total distributed amount and the combined total of the previously mentioned components, referred to as the "catch-up provision". At this stage, investors have received 80% of the returns, and the VC firm 20%.

In simplifying the contractual dynamics between the VC firm and institutional investors, we focus exclusively on carried interest and the hurdle rate, denoted by h, under the premise that the VC firm's financial commitment is limited to covering the startup cost, $F - f(r)$. By disregarding the "second-chance effect" (i.e., $\theta \approx 0$), transactions between the startup and the VC firm upon the latter's investment can also be omitted. Although incorporating additional fees and payments to the startup is feasible, it introduces complexity. Furthermore, the model does not account for the VC firm's strategy of investing in multiple startups throughout the fund's lifespan.

To characterize the contract, it is useful to first make two definitions. Firstly, let us define $\varphi_V(s,r)$ as the return for a successful project with a scaling strategy s and research strategy r that gives exactly a (gross) return equal to the hurdle rate,

$$\varphi_V(s,r) = \frac{\pi(s) - (F - f(r)}{F - f(r)}, \tag{35}$$

where the VC firm gets $I = F - f(r)$ from investors.

Secondly, we introduce $\vartheta(s,r)$ to represent the relative return for a successful project, contingent upon the scaling strategy s and the research strategy r, within the context where the 20-80 rule applies. Specifically, $\frac{\pi(s)-(1+h)\cdot(F-f(r))}{\pi(s)-[F-f(r)]}$ calculates the portion of the return attributed to the VC firm, while $\frac{h\cdot(F-f(r))}{\pi(s)-[F-f(r)]}$ determines the investors' share of the return. Then, $\vartheta(s,r)$ is simply defined as

$$\vartheta(s,r) = \frac{\frac{\pi(s)-(1+h)\cdot(F-f(r)}{\pi(s)-[F-f(r)]}}{\frac{h\cdot(F-f(r)}{\pi(s)-[F-f(r)]}}. \tag{36}$$

Using (35) and (36), the objective function for the VC-firm can then be written

$$V(s,r) = \begin{cases} 0, \text{ if } \varphi_V(s,r) \leq 1+h, \\ (1-r)\cdot(1-s)\cdot\{\pi(s)-(1+h)\cdot[F-f(r)]\}, \text{ if } \varphi_V(s,r) > 1+h \text{ and } \vartheta(s,r) \in (0, 20/80], \\ 0.2\cdot(1-r)\cdot(1-s)\cdot\{\pi(s)-[F-f(r)]\}, \text{ if } \varphi_V(s,r) > 1+h \text{ and } \vartheta(s,r) > 20/80. \end{cases} \tag{37}$$

To assess VC financing, incorporating the 80-20 contract along with a hurdle rate, against bank financing, we enforce the concept of an interior solution. This approach involves examining projects with sufficiently high returns upon success, denoted by $\varphi_V(s,r) > 1+h$. From this premise, several observations can be made.

First, comparing the objective functions under VC and bank financing reveals distinct implications for financing costs. Specifically, the term $(1+h)\cdot[F-f(r)]$ from the VC financing equation (37) is greater than $(1+\rho)\cdot[F-f(r)-A]$ from the bank financing scenario (29), attributed to $h > \rho$ and $A > 0$. This inequality suggests that exit costs are inherently higher with VC financing compared to bank financing. The assumption of an exogenous exit cost, C_E, associated with VC funding previously hinted at VC financing encouraging more aggressive scaling. This is further supported by the higher funding costs tied to VC financing.

Second, examining high-return projects within the VC financing framework (37), it becomes evident that VC-backed startups will opt for projects mirroring those chosen by independent startups in the benchmark scenario, leading to $s_V^* = s^*$ and $r_V^* = r^*$ as seen in (4) and (6), respectively. Consequently, the focal point shifts to the scenario within (37) where the VC firm assumes full residual claimancy post-distribution of the hurdle rate to investors.

Scaling (Stage 4) From the second line in (37), the objective function for the VC firm in Stage 4 becomes

$$V(s,r) = (1-s)\cdot\{\pi(s)-(1+h)(F-f(r))\}. \tag{38}$$

The first-order condition, $\frac{\partial V(s,r)}{\partial s} = 0$, is

$$\underbrace{(1-s)\cdot\pi'(s)}_{MB_V(s=s_V^*(r))} = \underbrace{\pi(s)-(1+h)\cdot(F-f(r))\;)}_{MC_V(s=s_V^*(r))} \tag{39}$$

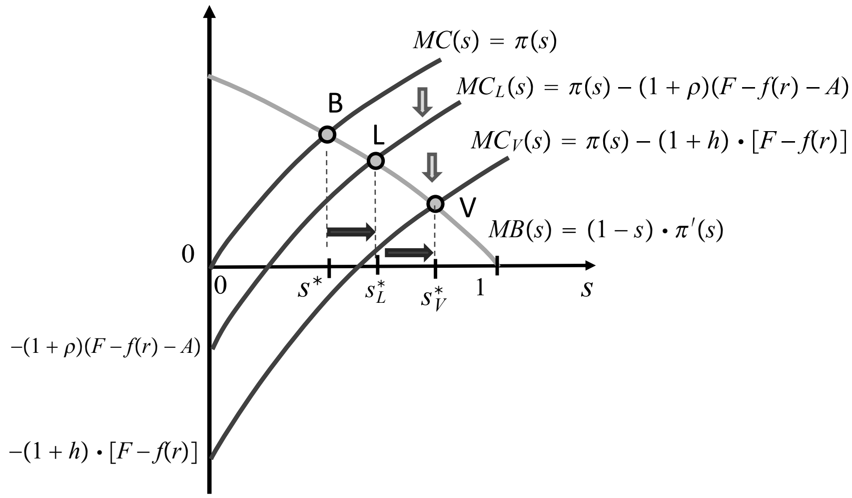

Figure 8: Scaling under different forms of financing.

The marginal benefit for a VC firm, denoted as $MB_V(s)$ in (39), matches the marginal benefit for startups financed by bank loans, also represented as $MB_V(s)$, in (32). However, due to the interest rate ρ on bank loans being lower than the hurdle rate ($\rho < h$), and the requirement for the startup to provide assets ($A > 0$) as collateral to secure a bank loan, the startup's marginal cost of scaling aggressively, $MC_L(s) = \pi(s) - (1 + \rho)(F - f(r) - A)$, is lower than that for a VC-backed startup, where $MC_V(s) = \pi(s) - (1+c)(F - f(r))$. Consequently, for a specific research project r, a VC-financed startup is inclined to scale more aggressively than one financed by bank loans, which in turn is more aggressive than a startup financed independently, indicated by $s_V^*(r) > s_L^*(r) > s^*$. This ordering is confirmed by Proposition 5 and illustrated in Figure 8, where the marginal benefit and cost loci for VC-backed startups intersect at point V, further to the right than the intersection point L for bank-financed startups, and even further than the point B for independently financed startups.

Thus we can state the following proposition:

Proposition 7. *For a specific research project r, a VC-backed startup is inclined to adopt a riskier scaling strategy compared to a bank-financed startup. This difference arises because the VC's hurdle rate, h, exceeds the interest rate, ρ, charged on bank loans. Additionally, bank financing necessitates that the entrepreneur contribute personal funds, denoted as A, towards the startup's financing.*

Research (Stage 3) Let us now turn to choice of the research strategy, r, in the VC-backed startup. Inserting the optimal scaling strategy, $s_V^*(r)$, from (4) into (37), we get the objective function

$$V(r) = (1-r)\cdot(1-s_V^*(r))\cdot[\pi(s_V^*(r)) - (1+h)\cdot(F - f(r)].$$

Applying the envelope theorem, the first-order condition, $\frac{\partial V}{\partial r} = 0$, becomes

$$\underbrace{(1+h)\cdot(1-r)\cdot f'(r)}_{MB_V(r=r_V^*)} = \underbrace{[\pi(s_V^*(r)) - (1+h)\cdot(F - f(r))]}_{MC_V(r=r_V^*)}. \tag{40}$$

The LHS of (40) represents the marginal benefit for a VC-backed startup from adopting a more aggressive research strategy, r, denoted as $MB_V(r) = (1+h)\cdot(1-r)\cdot f'(r)$. This benefit may be either smaller or larger than the corresponding marginal benefit for a bank-financed startup, which, according to (34), is given by $MB_L(r) = (1+\rho)\cdot(1-r)\cdot f'(r) + \frac{A}{1-s_L^*(r)}$. The relative magnitude of these benefits depends on the comparison between the hurdle rate and the bank lending rate ($h > \rho$), and the extent of personal investment ($A > 0$) banks require from the entrepreneur in a bank-financed arrangement. Moreover, when comparing the marginal cost of choosing a more risky research project in (40) under VC financing, and (34) under bank-financing, we get

$$MC_V(r) - MC_L(r) = \underbrace{\pi(s_V^*(r)) - \pi(s_L^*(r))}_{(+)} - (F - f(r))\cdot\underbrace{[h-\rho]}_{(+)} + (1+\rho)\cdot A \lesseqgtr 0$$

which we cannot either sign without making more assumptions.

To refine the model and accurately rank the research choices between startups with bank financing and those with VC financing, additional structure is required. Nonetheless, our analysis highlights that if the variance in research projects across different funding mechanisms is minimal, Proposition 7 indicates that VC-backed startups tend to opt for riskier projects compared to those financed by banks or entrepreneur's own funds.

In summary, the potential for a second-chance through VC backing may motivate startups to pursue riskier endeavors than would an opportunity based on employment post-failure. This is because a failure in a high-risk research strategy can enhance a startup's prospects for VC funding, whereas failure in a low-risk strategy might make employment for the entrepreneur more appealing.

Our findings demonstrate that for projects with exceptionally high returns, as seen in the third line of (37), VC-backed startups will make identical project choices to independent startups, as evidenced in both $s_V^* = s^*$ in (4) and $r_V^* = r^*$ in (6). This alignment also holds for highly successful VC funds that have recouped their investments from earlier deals. However, VC-backed startups, especially in a fund's initial deals, are incentivized to embrace greater risks in scaling to mitigate expected exit costs.

For a given research strategy, r, it is observed that startups backed by VC perceive a higher marginal cost for aggressive scaling, $MC_V(s,r) > MC(s,r)$, primarily because they can bypass financing repayment costs if the venture fails. This suggests that with the same research strategy, r, a startup will scale less aggressively under VC backing compared to bank financing, i.e., $s_V^*(r) < s^*(r)$. This opens up an intriguing research avenue into how the structure and performance of VC funds over time influence the risk behavior in scaling of their portfolio companies.

6 Robustness

In Section 6.1, we demonstrate that the core findings regarding scaling strategies, as outlined in Proposition 3, remain valid even when exit costs are not only increasing but also strictly convex with respect to scaling. Moving to Section 6.2, we challenge the initial assumption of independence between research and scaling within the product market profit function, previously denoted as $\frac{\partial^2 \pi(s,r)}{\partial s \partial r} = 0$. We adopt a more nuanced stance, assuming a positive relationship between research and scalability—expressed as $\frac{\partial^2 \pi(s,r)}{\partial s \partial r} > 0$. This implies that riskier research projects correlate with greater scaling opportunities. Under these conditions, if the increased exit costs associated with VC backing prompt the startup to pursue riskier research endeavors, and if the rewards for aligning research with scalability are significant, then a VC-backed startup is likely to scale more aggressively than an independent startup would.

In Section 6.3, we extend our analysis to consider the impact of an employment-based second-chance option for independent founders. We find that, even within this context, a VC-based second-chance option continues to incentivize more risky research strategies among these startups. This suggests that the potential for a VC-backed "safety net" influences independent founders to adopt riskier, potentially more rewarding strategies, reinforcing the critical role of funding structures in shaping startup behaviors.

6.1 VC-exit costs increasing in scaling

Proposition 3 shows that the availability of VC funding prompts startups to adopt riskier research and scaling strategies. As a result, successful ventures are likely to achieve more significant technological advancements and expand their market reach more extensively. A critical simplification in deriving this outcome was the assumption that the exit cost for a VC-backed firm, C_E, remained constant and unaffected by the scale of expansion. We now extend our analysis to embrace a more realistic assumption where the exit cost, C_E, varies with scaling, denoted as $C_E(s)$, and is characterized by a positive gradient, $C_E'(s) > 0$. This adjustment modifies the VC-backed firm's objective function in (8) to account for the dynamic nature of exit costs in relation to scaling intensity:

$$V(s) = (1-s) \cdot [\pi(s) - C_E(s)]. \tag{41}$$

The first-order condition, $\frac{\partial V}{\partial s} = 0$, is

$$\underbrace{(1-s_V^*) \cdot \pi'(s_V^*)}_{MB(s_V^*)} = \underbrace{\pi(s_V^*) - (C_E(s_V^*) - (1-s_V^*)C_E'(s_V^*))}_{MC_V(s_V^*)}. \tag{42}$$

The LHS of (9) shows the marginal benefit $MB(s)$ of more aggressive scaling. It is identical to the benchmark in (9) and shows the expected increase in gross profits from increased scaling. However, the RHS in (9) and (42) differ: a comparison with (4) reveals that the marginal exit cost is now $C_E(s_V^*) - (1-s_V^*)C_E'(s_V^*))$. However, note that $C(s_V^*) - (1-s_V^*)C'(s_V^*) > 0$ since

$$C(s_V^*) - (1-s_V^*)C'(s_V^*) = \int_0^{s_V^*} C'(s)ds - (1-s_V^*)C'(s_V^*) > 0 \tag{43}$$

since $(1-s_V^*) < 1$ and $C'(s) > 0$. Then, note that since the research- and scaling choices are independent, so (11) becomes

$$\underbrace{(1-r_V^*) \cdot f'(r_V^*)}_{MB(r_V^*)} = \underbrace{(1-s_V^*) \cdot \left(\pi(s_V^*) - \overbrace{C_E(s_V^*)}^{\text{Exit cost}}\right) - (F - f(r_V^*))}_{MC_V(r_V^*)} \tag{44}$$

Replacing (9) and (11) for (42 and (44) it is easily checked that our results as summarized in Proposition 3 also hold when exist costs are increasing and strictly convex in scaling.

6.2 Complementarities between research and scaling

To integrate this feature into our model, we consider the product market profit to be a function of both scaling and research, represented as $\pi(s,r)$, where both $\frac{\partial \pi(s,r)}{\partial s} > 0$ and $\frac{\partial \pi(s,r)}{\partial r} > 0$. This setup allows us to introduce the notion of a research-scalability reward—essentially, the synergy between successful research outcomes and effective scaling efforts.

Assumption 7. *Research-scalability reward:* $\frac{\partial^2 \pi(s,r)}{\partial s \partial r} > 0$.

We then apply this assumption in our model and as before, we use backward induction and start with the scaling decision in Stage 4.

6.2.1 Scaling (Stage 4)

Since only the reduced-form profits has changed compared to the base model, we can rewrite the objective functions in (2) and (7), as

$$\Pi(s,r) = (1-s) \cdot \pi(s,r) - (F - f(r)) \tag{45}$$

$$V(s,r) = (1-s) \cdot [\pi(s,r) - C_E] - (F - f(r)) \tag{46}$$

The first-order conditions for scaling for the independent startup and the VC-backed startup are then

$$\underbrace{(1-s^*) \cdot \frac{\partial \pi(s^*(r),r)}{\partial s}}_{MB(s^*(r))} = \underbrace{\pi(s^*(r),r)}_{MC(s^*(r))}, \tag{47}$$

$$\underbrace{(1-s_V^*) \cdot \frac{\partial \pi(s_V^*(r),r)}{\partial s}}_{MB_V(s_V^*(r))} = \underbrace{\pi(s_V^*(r),r) - C_E}_{MC_V(s_V^*(r))}. \tag{48}$$

The first-order conditions closely resemble those in (4) and (9) from the benchmark model. Nevertheless, the interplay between riskier research projects and scaling introduces a dependency of optimal scaling on the chosen research project r, denoted as $s^*(r)$ and $s_V^*(r)$. For any specific research strategy r, it becomes evident that the perceived marginal cost of scaling is lower for ventures supported by VC, symbolized as $MC_V(s,r) < MC(s,r)$. This is attributed to the fact that VC-backed startups avoid the exit cost C_E in failure scenarios, leading to a conclusion that, for a given r, startups will undertake more scaling under VC backing compared to scenarios without VC, indicated by $s_V^*(r) > s^*(r)$.

However, we cannot here sign how succeeding with more risky research affects the optimal choice of scaling. To see this, differentiate (47) and (48), to get

$$\frac{ds_I^*}{dr} = -\frac{(1-s_I^*)\cdot\frac{\partial^2\pi(s^*(r),r)}{\partial s\partial r} - \frac{\partial\pi(s^*(r),r)}{\partial r}}{\underbrace{SOC}_{(-)}} \gtreqless 0 \tag{49}$$

$$\frac{ds_V^*}{dr} = -\frac{(1-s_V^*)\cdot\frac{\partial^2\pi(s_V^*(r),r)}{\partial s\partial r} - \frac{\partial\pi(s_V^*(r),r)}{\partial r}}{\underbrace{SOC}_{(-)}} \gtreqless 0 \tag{50}$$

where the SOC denotes the second-order condition. Success in higher-risk research enhances the profitability of more aggressive scaling, as illustrated by $\frac{\partial^2\pi(s^*(r),r)}{\partial s\partial r} > 0$, repeated in both instances in (49). This reflects an increased marginal benefit of scaling in the first-order conditions shown in (47) and (48). Conversely, the achievement in riskier research endows the startup with superior products or services, thus higher profits, indicated by $\frac{\partial\pi(s^*(r),r)}{\partial r} > 0$ and $\frac{\partial\pi(s_V^*(r),r)}{\partial r} > 0$ in (49). These higher profits increase the marginal cost of failure, as reflected in the first-order conditions (47) and (48), moderating the incentive for aggressive scaling.

It follows that should the higher exit cost associated with VC-backed startups prompt them to pursue riskier research, and if the reward for research-scalability is significant, then VC-backed startups will opt for more aggressive scaling compared to their independent counterparts.

6.2.2 Research (Stages 1 and 3)

Let us move back to Stage 1 and Stage 3, respectively, and solve for the independent startup's and the VC-backed startup's choice of research. Inserting the optimal scaling $s^*(r)$ from (49) into (45) and s_V^* from (48) into (46), we obtain the objective functions

$$\Pi(r) = (1-r)\cdot\{(1-s^*(r))\cdot\pi(s^*(r),r) - (F-f(r))\} \tag{51}$$

$$V(r) = (1-r)\cdot\{(1-s_V^*(r))\cdot[\pi(s_V^*(r),r) - C_E] - (F-f(r))\}. \tag{52}$$

Using the envelope theorem, the first-order conditions become

$$\underbrace{(1-r)\cdot f'(r)+(1-r)\cdot((1-s^*(r))\cdot\frac{\partial\pi(s^*(r),r)}{\partial r}}_{MB(r=r^*)} = \underbrace{(1-s^*(r))\cdot\pi(s^*(r),r)-(F-f(r))}_{MC(r=r^*)}. \tag{53}$$

$$\underbrace{(1-r)\cdot f'(r)+(1-r)\cdot((1-s_V^*(r))\cdot\frac{\partial\pi(s_V^*(r),r)}{\partial r}}_{MB(r=r_V^*)} = \underbrace{(1-s_V^*(r))\cdot\left(\pi(s_V^*(r),r)-\overbrace{C_E}^{\text{Exit cost}}\right)-(F-f(r))}_{MC_V(r=r_V^*)} \tag{54}$$

We can then state the following lemma:

Lemma If the direct effect $\frac{\partial\pi(s,r)}{\partial r}>0$ is limited in size, then $r_V^*>r^*$.

The proof of the lemma is immediate noting that if $\frac{\partial\pi(s,r)}{\partial r}$ is small, (53) and (54) approximate to (6) and (11) in our previous analysis.

6.3 Pivoting and leaving for wage work

The VC market's provision of an option value encourages startups to embrace greater risks, given the lessened consequences of failure when a second-chance is at hand. However, startups may have alternatives to pivoting with VC support in the event of failure. This prompts an inquiry into whether VC-provided second-chances are uniquely advantageous.

This section examines a specific distinction: the choice between pursuing a second-chance through VC backing versus engaging in wage employment as an alternative route. Imagine a startup faces a choice between pivoting with VC support or accepting a salaried position, earning a wage w, which we term the *employee-based second-chance option*.

Under this framework, an increasing wage w as an alternative option correlates with heightened risk-taking by the startup during the research phase. To see this, note that the startup's objective function in this case becomes:

$$\Pi(s,r)=(1-r)\cdot\{(1-s)\cdot\pi(s)-(F-f(r))\}+r\cdot w. \tag{55}$$

Solving the model with backward induction, we may first note that, in Stage 4, the entrepreneur choose scaling to maximize $\Pi(s)=\{(1-s)\cdot\pi(s)-(F-f(r))\}$, with the optimal scaling strategy s^* given from

(4). In Stage 1, entrepreneur will then choose research strategy to maximize expected profit:

$$\Pi(r) = (1-r)\cdot\{(1-s^*)\cdot\pi(s^*) - (F - f(r))\} + r\cdot w \tag{56}$$

The optimal research strategy is given from the first-order condition

$$\underbrace{(1-r^*)\cdot f'(r^*)}_{MB(r=r_w^*)} = \underbrace{(1-s^*)\cdot\pi(s^*) - (F - f(r^*)) - \overbrace{w}^{\text{Second-chance effect}}}_{MC_I(r=r_w^*)}. \tag{57}$$

The RHS in (57) shows that we have a second-chance effect also when the outside opportunity is in the form of becoming an employee. The higher the wage, the more risk the entrepreneur will take. This effect is the *employment-based second-chance effect*.

A key distinction between VCs and wage employment as fallback options may lie in the learning outcomes of the research stage. When an entrepreneur initially opts for a low-risk project, it often involves reliance on proven techniques and methods, akin to a process innovation. The expertise acquired in such projects may have limited applicability in future startups focusing on groundbreaking technologies and business models but could be highly valuable in established companies offering wage employment. Conversely, the *VC-based second-chance effect* potentially encourages startups to select riskier initial research projects. Such projects are more likely to result in novel insights, like product innovations, which are invaluable for developing new ventures potentially supported by VCs during a pivot. These innovations are less likely to be of use in traditional, incumbent firms.

We can capture this in our model through the following Assumption:

Assumption 8. *The accumulated skill for being an employee in an established firm decreases with the risk level in the research strategy, i.e* $\frac{\partial w(r)}{\partial r} < 0$.

Incorporating this assumption, the first-order condition in (57) now becomes:

$$\underbrace{(1-r_w^*)\cdot f'(r_w^*)}_{MB(r_w^*)} = \underbrace{(1-s^*)\cdot\pi(s^*) - (F - f(r_w^*)) - \overbrace{(w + r_w^*\cdot\overset{(-)}{\frac{\partial w}{\partial r}})}^{\text{Employment-based second-chance effect}}}_{MC_I(r=r_w^*)}. \tag{58}$$

Compare the employment-based second-chance effect's first-order conditions in (58) with the VC-based second-chance effect's condition in (17). In the latter, a riskier research strategy diminishes the outside option, i.e., $w + r_w^* \cdot \frac{\partial w}{\partial r} < w$. This outcome does not occur under the VC-based second-chance effect because $v(s_V^*, r_V^*)$, as outlined in (17), remains unaffected by the startup's chosen research strategy, r_I.

7 Conclusions

Summary In this paper, we investigated how an active VC market influences the establishment and growth of startups. We developed a model capturing three key aspects: (i) independent startups have the option to either bootstrap or seek VC backing for creation and scaling, (ii) the startup development process is inherently risky, and (iii) independent startups aim to maximize future profit streams, whereas VC-backed startups focus on maximizing exit values (via IPOs or trade sales), taking into account exit costs that may be direct or indirect (stemming from VC compensation structures). Under plausible assumptions regarding how profits depend on chosen risk levels in the research and scaling processes, our findings reveal that VC-backed startups are more inclined towards strategies that are high-risk but potentially high-reward compared to their independent counterparts. The reason is that the compensation structures and exit costs of VC-backed startups imply that only big (risky) exits pay off.

Additionally, we demonstrate that an active VC market encourages independent startups to adopt riskier research strategies, offering them a lifeline to pivot in the event of initial failures—essentially, the VC market introduces an option value for startups to recalibrate their strategy following early setbacks. Expanding our analysis to include incumbent firms engaging in research, we further show that the advent of VC in an industry prompts incumbent firms to increase their research risk levels, as incumbents' research strategies are strategic complements with startups' research choices. Consequently, the rise of the VC market acts as a catalyst for heightened risk-taking and enhanced productivity across the entire innovation ecosystem, making it more appealing for both independent startups and incumbent firms to take greater risks to find truly innovative and scalable products.

Policy conclusions Our framework and findings offer significant insights for academics, industry practitioners, and policymakers. By integrating risk as a fundamental aspect of firm scaling, our research suggests a paradigm shift in how theoretical and empirical studies should approach the growth and scaling of businesses. We argue that conventional growth metrics, such as employment growth or sales revenue changes, fail to encapsulate the full essence of scaling, as they overlook the critical dimension of risk. Our analysis enriches the existing metrics for assessing growth by incorporating risk considerations, highlighting the pivotal role of ownership type in fostering high firm growth (Demir, Wennberg and McKelvie, 2017). Specifically, we note that owners focused on developing startups for sale, such as VC firms, possess a heightened incentive to embrace risk during the scaling phase. This inclination results in a dichotomy where such firms are more susceptible to failure but also stand to grow more rapidly upon success. Additionally, the presence of VC firms incentivizes independent startups to pursue riskier ventures initially, as a failed high-risk project could potentially lead to more favorable terms in subsequent ventures backed by VC financing.

For policymakers, our study underscores the importance of fostering ecosystems that accommodate diverse ownership models, thereby nurturing a culture of scaling-driven creative destruction. This diversity is crucial for stimulating innovation and supporting startups through various growth trajectories. Furthermore, the advent of venture capital in an industry encourages incumbent firms to increase their levels of research risk, as taking on risk is complementary within the ecosystem. For practitioners, the research illuminates the reality that ambitious scaling efforts are inherently linked with a significant risk of failure. Business owners aiming for aggressive expansion need to be prepared for the high stakes involved, recognizing that while the path may be fraught with challenges, the rewards of successful scaling can be substantial.

Our analysis highlights the pivotal role of the local VC market in fostering the development of scalable business plans and the pursuit of aggressive scaling strategies. Beyond the traditionally recognized contributions of providing capital, networks, and expertise, VC firms introduce a distinct value proposition by incentivizing scaling through the dynamics of buying and selling businesses. This aspect of VC involvement diverges from the roles commonly emphasized in academic literature, underscoring a unique mechanism through which VC firms catalyze growth (Rin, Hellmann and Puri, 2013).

The implications of our findings extend into the realm of policy, suggesting that VC firms are instrumental in encouraging the development and expansion of scale-ups. Therefore, policymakers aiming to stimulate local scale-up activity should prioritize the support and enhancement of the local VC ecosystem. Existing literature outlines various strategies to achieve this, including government-led VC programs and the establishment of conducive institutional frameworks (Lerner and Tåg, 2013; Bradley, Duruflé, Hellmann and Wilson, 2019; Hellmann and Thiele, 2019). By fostering a robust local VC market, policymakers can create an environment that nurtures ambitious scaling efforts and facilitates the successful growth of scale-ups, contributing to the broader economic development and innovation landscape.

Limitations Our model, while providing valuable insights, is subject to certain limitations that merit consideration. One significant limitation pertains to the inference that the introduction of VC induces a propensity for riskier research behavior among startups due to the prospect of a second-chance. This assumption might not hold if a failure in the first venture is interpreted as an indicator of low entrepreneurial skill rather than misfortune. In contexts where capital markets are less developed, venture capitalists might find it challenging to differentiate between low entrepreneurial skills and bad luck. Consequently, if we relax Assumption 2, a startup who anticipates potential VC support may opt for a more conservative strategy than they might have in a more forgiving market context.

Furthermore, the conclusion that the advent of VC leads to increased risk-taking among incumbents also faces potential challenges. Specifically, this may not apply in scenarios where incumbent firms are in competition and rely on acquiring innovations from their local ecosystems. To protect against the possibility of competitors' ecosystems yielding successful innovations, incumbents within a local ecosystem—defined by either technological fields or geographical proximity—may find it strategically advantageous to pursue less risky research strategies when startups in their vicinity assume higher risks. This suggests a nuanced interplay between the behavior of new entrants and established firms, influenced by the structure and maturity of the local VC market and the competitive landscape.

Future research Identifying future research directions, our study opens the door to intriguing questions, particularly around asymmetric information issues within VC-backed startup scaling decisions. The possibility that novel scaling strategies may be hampered by significant asymmetric information problems could potentially limit the choices available to VC-backed startups. Conversely, succeeding with a particularly innovative scaling approach could enhance a startup's appeal in future financing rounds, suggesting a complex interplay between scaling decisions and financing constraints stemming from asymmetric information.

An avenue ripe for exploration is how asymmetric information affects the financing of scaling decisions. Given that a venture capitalist closely monitoring a startup is likely in a better position to discern the reasons behind its failure, this insider knowledge offers a competitive advantage over external investors. This suggests that the original venture capitalist may be more inclined to provide further investment for a pivot, in contrast to less informed external investors. Incorporating asymmetric information dynamics into the model could proceed as follows: (i) Startups come in varying qualities, with only the high-quality ones poised for success. (ii) To sidestep screening and signaling dilemmas, assume the startup's quality remains concealed until the initial investment phase. (iii) Through the first round of investment, the venture capitalist uncovers the startup's true quality. (iv) In cases of initial failure but high-quality entrepreneurship, the original VC is more likely to reinvest, though such failure casts a shadow on the startup's reputation among external investors, thus reducing their willingness to invest.

The premise of a second-chance remains compelling in this context, as high-quality founders understand that their true potential is apparent to their initial VC, even in failure. However, the efficacy of this second-chance effect may be diluted due to the decreased probability of investment from external VCs following a failure. Studying how competition among VCs with varying degrees of information influences investment strategies presents a fascinating and worthwhile area for future research, promising to shed light on decision-making processes within the venture capital ecosystem.

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