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Risky Business: Venture Capital, Pivoting and Scaling

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ABSTRACT

The creation and scaling of startups are associated with risk-taking and different types of owners treat these risks differently. We show how an active venture capital (VC) market affects risk-taking in research and scaling decisions of startups. VC-backed startups will choose more high-risk, high-reward research and scaling strategies than independent startups. The reason is temporary ownership and the compensation structures used in the VC industry. These create "exit costs" for VC-backed startups that imply that riskier strategies pay off. We also show that the presence of an active VC market may induce startups to take more risks initially since VC firms can help startups pivot in case of failure.

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

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1 Introduction

The scale-up of promising startups has become a key ingredient in today's digitized global market. An efficient venture capital (VC) market is crucial in this system. In recent years, a large part of VC activities has been focused on identifying scalable startups. As described by EQT Ventures: ”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, little is known about how an active VC market affects startup research behaviour and scaling strategies (Coviello, 2019; Shepherd and Patzelt, 2020). The purpose of this paper is to address these issues.

Our approach is to construct a theoretical framework inspired by recent work on innovation in the industrial organization literature. This work highlights risk as a central component of the research behaviour of different types of firms. We incorporate scaling and a VC market into this model. We argue that a VC market brings in three elements that affect risk-taking: temporary ownership, incentive structures for VC firms, and opportunities for startups to pivot.

Our model works as follows. A startup owned by an entrepreneur undertakes a research project to create a novel product or service. We view the research stage as involving not only R&D efforts in terms of coming up with inventions, but also product development, product market trials, marketing efforts, sales efforts, and initial beta versions to assess traction of the business idea. There are different types of research strategies to choose from, but all of them are described by a probability of discovery and a return accompanying that probability of discovery. An research strategy aimed at finding a more novel and profitable business idea has a lower chance of success and is thus riskier.

If the research project fails and VCs are present, the entrepreneur may seek support from a VC fund to pivot in a new direction. Research shows that pivoting is common among startups. Bandera and Thomas (2019) document that a bit over a fifth of all US startups in the Kauffman Firm Survey pivoted at least once, similar to Slávik, Bednár and Mišúnová Hudáková (2021) who document that a quarter of all Slovakian startups pivoted by changing or developing their business concept substantially. The specific contribution that VC bring to the table here is that they knows the value-creating potential possessed by the entrepreneur and *can understand* why the first research effort failed and what can be salvaged. Moreover, evidence suggests that the top management team is key in startups. Gompers, Gornall, Kaplan and Strebulaev (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.

A central issue for startups of today is also the scaling decision. The pace of scaling is inherently a trade-off between high returns and high risk, or low returns and low risk. If successful, scaling gives a high payoff, but if not, the company might go bankrupt. If the independent startup is successful with its research project, it will scale up the business and the produce in the product market. If the startup is VC-backed, however, the VC firm sets the scaling strategy and then exits the investment through an IPO or a trade sale. Thus, we argue that scaling relative to growth is more about taking a decision on how aggressively to scale and that faster scaling comes with a lower probability of success instead of simply taking a decision on how much to grow without necessarily any consequences for success probabilities.

A first insight from our analysis is that VC-backed startups are more prone to implementing riskier scaling strategies than are independent startups. The reason is that VC-backed startups have a different objective function than independent startups due to two reasons: temporary ownership and specific compensation structures that include hurdle rates and catch-up provisions.

First, VC firms are temporary owners of assets because they invest in startups through VC funds that have a preset contractual life (usually 10 years). Temporary ownership means that they account for transaction costs in buying and reselling the shares in the startups they back. There are thus exit costs associated with reselling assets relating to initial public offerings (IPOs) or mergers and acquisitions in case the startups are successful.

Second, VC firms raise money from institutional investors for investing in startups. They are compensated for this through standard compensation contracts. The returns from the proceeds exiting startups are split between the VC firm and the investors in the VC fund according to a standard ”2/20” model. That is, the VC firm charges a 2% management fee on committed capital to the fund and then obtains 20% of the returns exceeding an ”hurdle rate” of 8%. So called ”catch up provisions” are also used, meaning that the VC firm obtains up to 100% of returns directly after the 8% hurdle rate has been hit. This results in an overall 80/20 split of the returns between investors and the VC firm. As we formally show, these compensation contracts generate similar exit costs as temporary ownership does.

When the exits costs arising due to temporary ownership and compensation structures are large, it will induce the VC-backed startup to use a riskier scaling strategy with higher potential returns than an independent startup. The reason for this is that the increase in risk level reduces the expected exit costs. Consider the following simple illustration of this mechanism: Two different scaling strategies are available. Scaling aggressively, labelled A, has an associated payoff of 100, with probability 0.5 and of 0 with probability 0.5. Scaling safe, labelled S, has an associated payoff of 50 with probability 1. An entrepreneur retaining the startup under her own control avoids the exit cost: thus, she will be indifferent between scaling strategies A and S. In contrast, consider the VC-backed startup facing an exit cost of 10. The VC-backed startup will prefer the aggressive (high potential-high risk) scaling strategy A over the safe scaling strategy S. This follows since $(100-10)\times 0.5+0\times 0.5>50-10$. By going riskier, the expected exit cost drops from 10 to 5 (since the exit cost is only paid if scaling succeeds).

A second insight from our model is that the exit cost also affects incentives when choosing an research strategy. We show that the VC-backed startup will choose an research strategy with a higher potential and lower probability of success compared to the strategy chosen by the independent startup if VCs would be absent from the industry. We refer to this effect as the *VC big-exit effect*. That VC:s focus on ”big exits” is documented in Gompers et al. (2021), who noted 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.”

A third insight from our model is on how the emergence of an active VC market can affect the pivoting behaviour of startups. There are several prominent examples of startups that pivoted before making their success: Groupon initially started as a social network; Twitter emerged from a failed podcasting platform, and Slack initially developed an online game. Our analysis identifies a strategic effect showing that a vivid VC market can induce startups to go riskier in their initial research strategies—even if these startups in the end do not receive VC funding. The reason is that the prospect of future VC support acts as a second chance for the independent startup if the research project fails. This option value in the form of a second chance induces the independent startup to choose a more risky research strategy—as compared to a situation where VC is absent—since the cost of failure declines. We label effect of this option value on the risk taking behaviour the *VC second-chance effect*. We also in an extension show when this option to pivot creates greater incentives to take risk compared to exiting to wage work. The reason is that failing in a high-risk research strategy tends to improve the entrepreneur’s probability to get VC-funding, whereas failing in a low-risk research strategy increases the value for the entrepreneur if switching to wage work.

A fourth insight from our model is that the form of financing matters for risk-taking in research and scaling decisions. We show how debt-financing changes the startup's incentives to scale up. This happens because in the benchmark case without external capital providers, the startup cost is sunk when the decision on scaling is taken. But with bank-financing, repayments of loans happen after scaling is successful and product market profits are realized. The entrepreneur then realizes that loan payments with interest are only paid in case of success, which gives the entrepreneur incentives to scale more aggressively. Scaling under debt financing is more aggressive when the interest rate is higher and when less own equity is used. Comparing VC-backing with bank funding, we then show that if the difference in research projects is limited between the different forms of funding, a VC-backed startup will take on more risk than startups funded by either bank-financing or internal funds. Thus, external capital provision introduces a novel link between research and scaling decisions.

The model shows that access to VC in an industry changes risk-taking in startups in a direct way (through affecting the scaling strategy) as well as in an indirect way (through the potential to help pivot startups). Both effects increase startups appetite for risk-taking. This has several noteworthy consequences. Suppose that VC becomes available to startups in an industry that previously did not have access to VC. Then (i) startups will choose more risky research and scaling strategies, (ii) successful VC-backed startups will make greater technological leaps and will scale products to more consumers and markets, and (iii) due to pivoting with VC support (second-chance), there exist an equilibrium where startups become more likely to succeed, achieve higher expected gross profits, have lower expected startups costs, and take higher risks in research and scaling.

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. We highlight that these three streams of literature are highly complementary.

2.1 Management and entrepreneurship literature on 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.

This literature, however, is short on formal work on exactly what scaling means and what role a VC market plays in affecting startups incentives to pivot and scale. Our contribution to this literature is to develop a formal model highlighting risk as a key component of scaling and that emphasizes the role VC funds play in affecting incentives to create and scale startups. This contribution is important because our paper provides a novel formal unified framework to analyze risk-taking, scaling and pivoting in the presence of VC firms. This framework is useful for future theory work, for forming the basis of empirical analyses of scaling, pivoting, and VC, and for developing models aimed at evaluating policy initiatives to help firms scale.

2.2 Industrial organization literature on innovation and ownership

With regards to the industrial organization literature, our model borrows elements from the theoretical literature on firm development, economic of scale and market structure (Gilbert, 2006). To our knowledge, however, only a few papers have considered asymmetries between firms in such a context and there is no work on scaling. On asymmetries, Cabral (2003) shows that small firms may have an incentive to choose the risky development strategy due to strategic output effects in the product market; i.e., small firms do not take on low risk-return projects since they cannot exploit the improvements over large output. The difference in development behavior between small and large firms stems from the difference in post-development outputs in the product market. Färnstrand Damsgaard, Hjertstrand, Norbäck, Persson and Vasconcelos (2017) consider the choice of the probability of success by an entrant and an independent firm. They show that if the entrant incurs a higher cost of commercializing than the independent firm, this then induces the entrant to pursue a more radical development projects. Haufler, Norbäck and Persson (2014) incorporates taxation into this framework. Henkel, Rønde and Wagner (2015) examine a setup with entrants innovating for sale in competition with independent firms and show that entrants tend to choose more radical research approaches and are more likely to generate the highest-value innovation. Thus, the need of entrants to be acquired yields a new explanation for why radical innovations tend to come from entrants. 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.

As with the management and entrepreneurship literature on scaling, this literature as not examined how the presence of VC firms affect risk-taking behavior of startups in their research and scaling decision. It has also not yet explored asymmetries between firms that stem from that some owners are long run owners and some owners are temporary aiming at reselling firms, that stem from compensation contracts between different type of stake holders (in our case VC firms and outside investors), and that stem from that some actors can provide value through providing a pivoting opportunity. Thus, the temporary nature of VC ownership of firms—also emphasized by Norbäck and Persson (2009), Norbäck, Persson and Tåg (2018), and Baziki, Norbäck, Persson and Tåg (2017)—and the formal modeling of the compensation contracts in the VC industry is novel in our model and central to the results we derive on risk, pivoting, and scaling. The importance of this contribution cannot be understated. VC firms are central players when it comes to high-potential startups and are commonly involved in scaling digital firms and helping them go global. A model of innovation and risk-taking that omits such firms is clearly incomplete.

2.3 Financial economics literature on VC

Finally, our paper is also related to the financial economics literature that examines the role played by VC in the innovation process. In a study on VC and innovation, Kortum and Lerner (2000) find increases in VC activity in an industry associated with significantly higher patenting rates. Moreover, Hellmann and Puri (2000) find that VC associated with a significant reduction in the time required for bringing a new product to the market. Hellmann (2002) shows that startups seek support from VC funds if products substitute for incumbents' products, while startups seek support from incumbents' if their products are complement.

Norbäck and Persson (2009) show that VC-backed startups have a stronger incentive to develop commercialized innovations than incumbent firms due to strategic product market effects on the sales price of the VC-backed startup. Ewens, Nanda and Rhodes-Kropf (2018) show how technological shocks can shift investment strategies of VC funds to favor more experimentation. Hellmann and Thiele (2019) study government policies that either support entrepreneurs or investors backing entrepreneurs.

Despite much work on the role VC firms play in the economy, this literature contains little work on how the presence of VC firms affect research and scaling decisions of firm. We contribute by showing that VC-backed startups will choose more high-risk, high-reward research and scaling strategies since only big (risky) exits pay off. Moreover, we show that an active VC market induces independent startups to take on more risky research strategies since VC support may give them a chance to pivot their startup in case of failure. These are all new findings, and point to an important role of VC firms in the scaling of startups.

3 Model

3.1 Overview

Consider an industry where there is an independent entrepreneur (I) with ownership of a firm–specific asset necessary to develop a new startup. There is a potential for creating a new product or service by using a research strategy. A research strategy involves coming up with ideas about how to combine new technologies, existing assets, startups skills and market knowledge to create a new business model, product or service. This includes investments in sales and marketing. The new business model, product or service can then be taken to the market using a scaling strategy.

The interaction is shown in Figure 1. In Stage 0, the entrepreneur can invest into a fixed research cost G which can be thought of as building a research lab, incurring costs to hire skilled labor to conduct the research, doing product market trials or other activities needed to assess the viability of a startup. After incurring the research cost, the entrepreneur chooses her research strategy, denoted r_I, which has the potential to significantly reduce the venture's startup costs, $F(r)$: If it succeeds, a more aggressive research strategy will significantly lower the startup cost—but a more aggressive research strategy is at the same time more risky with a higher risk of failure.

We take the ventures startup costs to involve all costs related to the cost for equipment, marketing, sales, inputs, office space etc., which is needed to start scaling and expanding the business. Notice, however, that

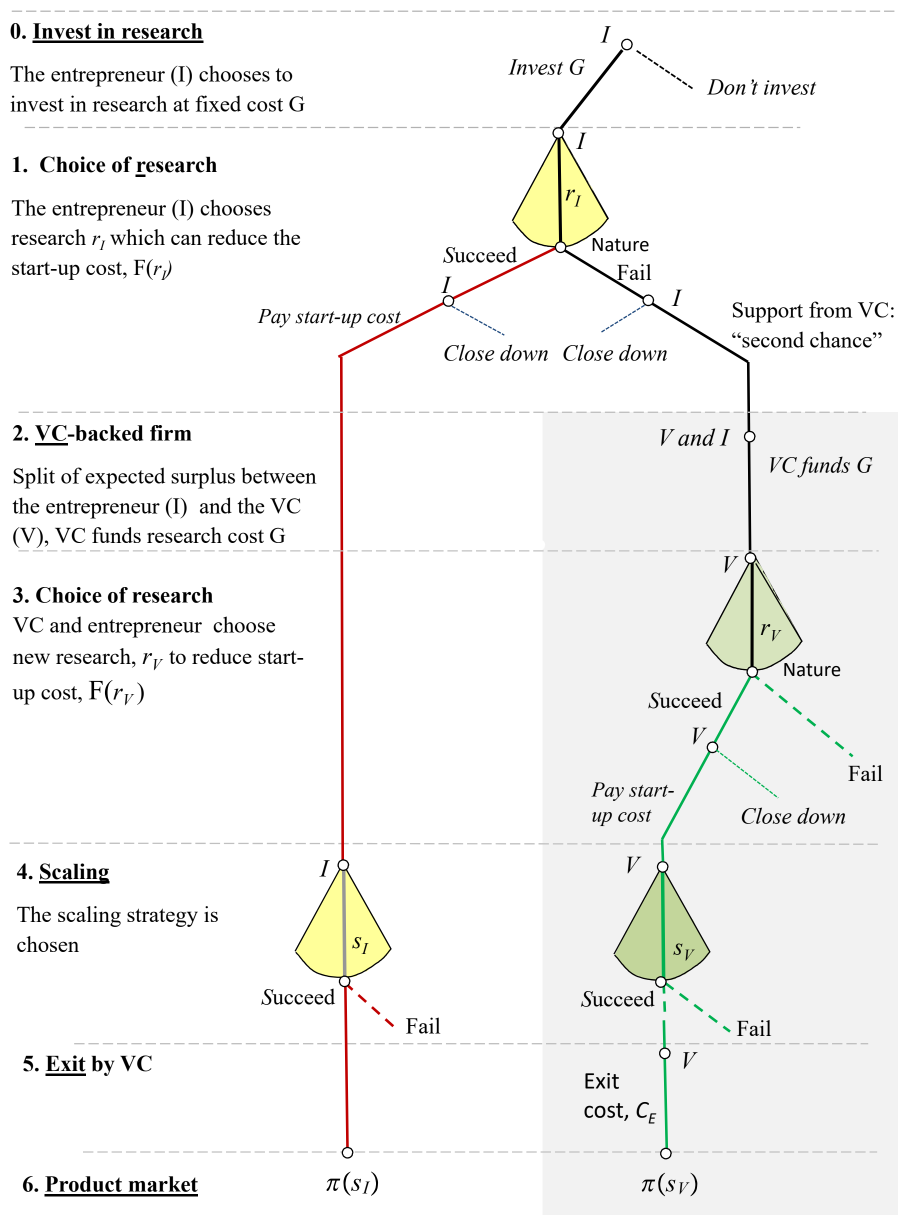

Figure 1: Model structure.

from a theoretical perspective we could as well have chosen to model the lower startup cost as an increase in profitability that comes from learning about viable market opportunities and our results would be remain the same (but at the cost of complicating the model).

If the entrepreneur succeeds with her initial research project, she can get the startup running by paying the startup cost. The interaction then moves directly to Stage 4, where the independent startup now chooses the scale of operation, denoted s_I. Scaling also contains a risk-return trade-off: If it succeeds, a more aggressive scaling strategy reach more consumers and markets and increases the product market profits in Stage 6. But a more aggressive scaling is also more risky and is more likely to fail leading to bankruptcy and zero profits.

If the entrepreneur fails with her initial research in Stage 1, there is a VC firm who knows the value-creating potential possessed by the entrepreneur and her firm-specific asset. The VC firm can then aid the entrepreneur in choosing a second-chance research strategy by bringing in new ideas that help the entrepreneur pivot the startup. The newly VC-backed startup chooses a new research strategy, denoted r_V. If the VC-backed startup succeeds with the research to come up with a viable business idea, it invests and pays the startup cost $F(r)$. The VC-backed startup will then proceed to the scaling decision in Stage 4. If scaling succeeds, the VC firm will exit its investment by selling the startup to another firm or publicly listing it on a stock exchange through an initial public offering (IPO) at exit-cost, C_E. Finally, profits are realized in Stage 6. In Section 7, we explicitly account for compensation structures in the VC industry that determine payoffs to the VC firm.

3.2 The exit costs

The exit cost C_E is a key component of our analysis and it is present in our baseline model when the firm is VC backed, but not otherwise. [1] There are two reasons for why model VC-backed startups as face exit costs: temporary ownership and specific compensation structures that include hurdle rates and catch-up provisions.

First, VC funds are temporary owners of assets because they are limited partnerships with a preset contractual life. Temporary ownership means that they account for transaction costs in buying and reselling the shares in the startups they back. The direct exit cost and captures costs associated with bringing in VCs that help with the scaling decision and the subsequent sale of the firm. These costs include the opportunity costs that VCs face in having to forgo scaling other firms and it includes the costs of exiting the investments such

[1] Exit costs are, however, present both for independent startups and VC-backed startups in Section 7.

as costs associated with arranging a trade-sale or direct and indirect costs arising during the IPO process. The latter costs can be substantial. (Ritter, 1987) estimates that these could overall be 21-31% of market value of the firm, while Chaplinsky, Hanley and Moon (2017) estimate the total direct costs to amount to 9-10% of firm value. Additionally, IPO underpricing means that the cost of the exit can be even greater. Ferretti and Meles (2011) report that for private equity-backed IPOs, underpricing amounted to about 41 over the 1998-2008 time period.

Second, VC firms raise money from institutional investors for VC funds. The returns from the proceeds from exiting portfolio companies are split between the VC firm and the investors in the VC fund according to a standard ”2/20” model. That is, the VC firm charges a 2% management fee on committed capital to the fund and then obtains 20% of the returns exceeding an ”hurdle rate” of 8%. So called ”catch up provisions” are also used, in which case the VC firm obtains up to 100% of returns directly after the 8% hurdle rate has been hit, resulting in an overall 80/20 split of the returns between investors and the VC firm. As we formally will show in Section 7, these compensation contracts generate similar exit costs as temporary ownership does. To keep the analysis tractable, we will in what follows work with a simple fixed exit cost C_E instead of modelling the complete compensation contract that is in place when the firm is VC-backed. Then, in Section 7, we show how the model can be generalized.

3.3 A second chance through pivoting

Another key component of our analysis is that VC firms can offer a second chance to entrepreneurs that where initially unsuccessful with their research efforts to come up with a viable and scaleable business idea. Research shows that pivoting is common among startups. Bandera and Thomas (2019) document that a bit over a fifth of all US startups in the Kauffman Firm Survey pivoted at least once, similar to Slávik et al. (2021) who document that a quarter of all Slovakian startups pivoted by changing or developing their business concept substantially.

The specific contribution that VC brings to the table here is that they knows the value-creating potential possessed by the entrepreneur and her firm-specific asset and *can understand* why the first research effort failed and what can be salvaged. The underlying assumption that the VC firm understands why failure happens is important because in many instances, failure can be a bad signal about the quality of the entrepreneur. If the VC firm would not understand the reasons for the failed research effort then in a world with asymmetric (or even full information) he or she might be quite reluctant to provide a second chance.[2]

VC firms may also be willing to back former entrepreneurs since researchers have found that prior founding experience matters for future entrepreneurship success (Hsu, 2007). Nahata (2019) finds that serial entrepreneurs backed by VCs suffer less dilution of equity, retain greater board control, and are also able to survive more often as CEOs. These findings also hold for previously unsuccessful serial entrepreneurs compared to novice entrepreneurs, consistent with that VCs view experience as valuable.

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.

3.4 Preliminaries

The entrepreneur—on her own, or in cooperation with the VC firm—takes two decisions with a risk-reward trade-off: the first involves the research strategy, r; the second involves the amount of scaling in the product market, s (skipping sub-indices).

3.4.1 Research

We view the research stage as involving not only RD efforts in terms of coming up with inventions, but also product development, product market trials, and initial beta versions, marketing efforts, and sales efforts to assess traction of the business idea.

A way to capture this broad concept of research is that more aggressive research strategy, if it succeeds, leads to a reduction in the startup cost of the venture. We believe that this set-up captures, for instance, the importance of reducing the fixed costs for startups in the digital age, where many of the new startups have very low variable costs in their business model and the main part of the firm’s costs are fixed. For these firms, the cost of serving one more customer is very low, but there are large fixed cost associated

[2] There may also be substantial experimentation and learning involved with pivoting that our current framework does not capture (Agrawal, Gans and Stern, 2021).

with research, such as developing competitive algorithm, which are necessary for being able to sustain a competitive advantage in the market.

Formally, a successful research strategy $r \in [0,1]$ gives rise to a startup cost $F(r) = F - f(r)$, where the strictly increasing and strictly concave function $f(r)$ captures the reduction in startup costs from successful research, with $f(0) = 0$, $f'(r) > 0$ and $f''(r) < 0$. The startup cost $F(r)$ is illustrated in Figure 2(i). To incorporate that more aggressive research carries more risk, we assume that the probability of succeeding with the research project r is $1 - r$, that is, a more aggressive research project (a project with a higher r) is more likely to fail.

Assuming that a failed research project gives no cost reduction, the expected startup cost is $F - (1 - r) \cdot f(r)$. To ensure well-behaved solutions for the research-decision, the expected reduction in startup costs $(1 - r) \cdot f(r)$ needs to be a strictly concave function, which is ensured by strict concavity of $f(r)$. As shown in Figure 2(ii), there is then a unique research intensity $\hat{r}$ that maximizes the reduction in expected startup costs, i.e. $\hat{r} = \arg\max\left[(1 - r) \cdot f(r)\right]$. Furthermore, as shown in Figure 2(iii), the project $\hat{r}$ must then minimize the expected startup cost, i.e. $\hat{r} = \arg\min\left[F - (1 - r) \cdot f(r)\right]$. To summarize:

Assumption 1. *Let $F - f(r)$ be the startup cost, where $f(r)$ is the reduction in the startup cost associated with a research project $r \in [0,1]$. Then, the following is assumed to hold:*

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

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

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

3.4.2 Scaling

If the research strategy succeeds, the entrepreneur goes ahead with an independent startup and will choose a scaling strategy. A more aggressive scaling strategy should deliver higher gross profits from selling to more consumers if successful. But a more aggressive scaling also has a higher chance of failing. We capture this trade-off as follows: Let $s \in [0,1]$ denote the amount of scaling $s \in [0,1]$ associated with a strictly increasing and strictly concave profit function $\pi(s)$ when scaling succeeds, i.e. $\pi(0) = 0$, $\pi'(s) > 0$ and $\pi''(s) < 0$. The probability of succeeding with the scaling strategy is $1 - s$. The profit function $\pi(s)$ is illustrated in Figure 3(i). Figure 3(ii) depicts the expected gross (product market) profit $(1 - s) \cdot \pi(s)$, which is strictly

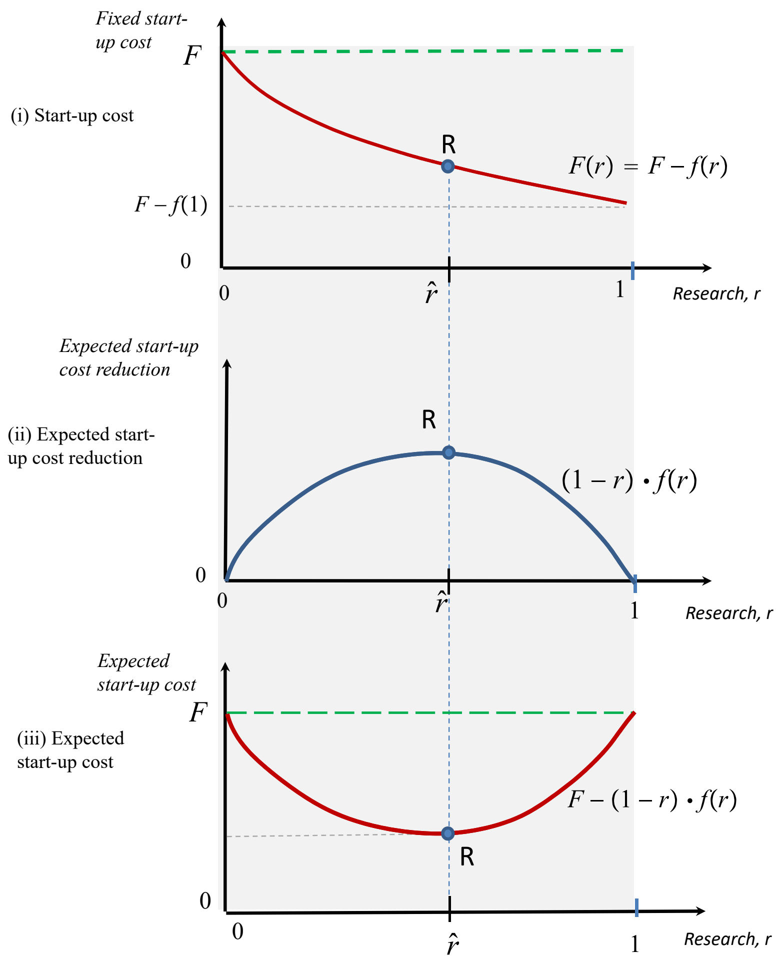

Figure 2: Research projects and startup costs.

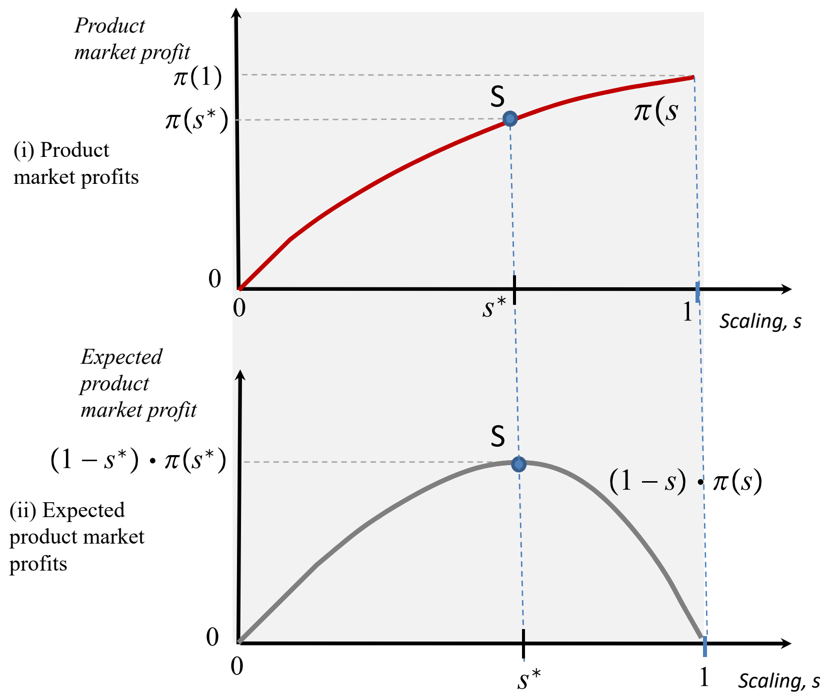

Figure 3: Scaling and product market profits.

concave with a unique optimal scaling strategy, $s^* = \arg\max\left[(1-s)\cdot\pi(s)\right]$. The independent startup will internalize that increased scaling s can produce a higher profit $\pi(s)$ if it succeeds, but is also more risky as the probability of success $(1-s)$ declines.

Assumption 2. *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.

Note, however, that we can allow $\pi(s) > 0$ to be strictly increasing and convex. What needs to hold is Assumption 2(iii), which tells us that the expected profit $(1-s)\pi(s)$ is strictly concave in s. This implies that the second order condition for $(1-s)\pi(s)$ needs to hold. The second order condition is always fulfilled if $\pi(s)$ is strictly concave, but it will also hold if $\pi(s)$ is strictly convex, given that it is not "too convex".

4 Benchmark: The independent startup

As a benchmark, we explore the research and scaling ambitions in the independent startup that is not VC-backed. Excluding VC, only Stages 1, 4 and 6 in Figure 1 are operational. Using Assumptions 1 and 2, and noting that the fixed research cost G is sunk in Stage 1, we can then write the expected profit in Stage 1 as:

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

where we have for brevity left out the subscripts.

For ease of exposition, let us assume that the startup cost cannot be recovered if the initial research fails. Thus, it is only when the research project in Stage 1 succeeds that the independent startup will scale up in Stage 4. Formally:

Assumption 3. *Scaling is never profitable if initial research fails:* $\pi(s) < F$.

From Assumption 3 , the expected profit in (1) then simplifies to:

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

We will now solve the independent startup's problem using backward induction.

4.1 Scaling (Stage 4)

Suppose the independent startup has succeeded with the initial research in Stage 1 and then invested in the startup cost. As the startup cost, $F-f(r)$, is sunk when the decision on scaling is taken in Stage 4, the entrepreneur in control will then maximize the expected profit

$$\Pi(s) = (1-s)\cdot\pi(s), \qquad (3)$$

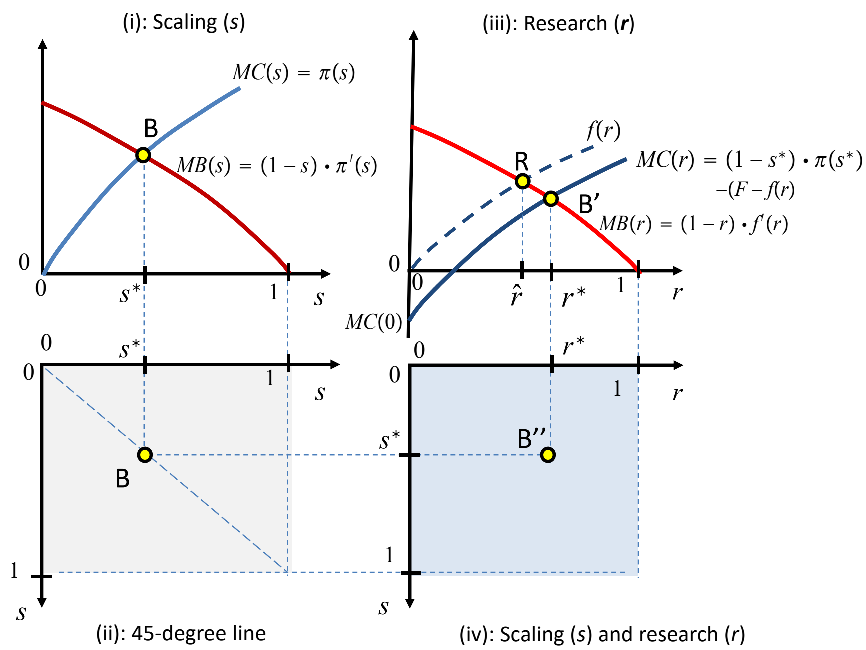

Figure 4: The benchmark without VC.

where the she knows that she will get the product market profit $\pi(s)$ in Stage 6 if she succeeds.

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 (4) is the increase in expected profits from a marginal increase in scaling, which follows from that $\pi'(s^*) > 0$. This term is thus the *marginal benefit* of more aggressive scaling strategy, $MB(s)$. The marginal benefit is depicted in the top-left Panel in Figure 4 as the downward-sloping marginal benefit-locus, $MB(s) = (1-s) \cdot \pi'(s)$. The right-hand-side (RHS) of (4) is the *marginal cost* of choosing a more aggressive scaling strategy, $MC(s)$. A more aggressive scaling strategy s increases the probability of failure and, hence, the independent startup increases the risk to loose the whole profit $\pi(s^*)$. Accordingly, the upward-sloping locus $MC(s) = \pi(s)$ in top-left Panel in Figure 4, shows the expected loss from choosing a more aggressive scaling strategy.

The equilibrium scaling strategy, s^*, is then given from 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. Note that s^* is a unique and stable equilibrium from Assumption 2.

4.2 Research (Stage 1)

Let us now turn to the research strategy, r. Inserting the optimal scaling strategy, s^*, from (4) into (3), we can write the objective function in (2), as

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

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 (6) is the marginal benefit from choosing a more aggressive research strategy r: $MB(r) = (1-r)\cdot f'(r)$ shows the expected reduction in startup costs and is depicted as the down-sloping locus in Panel (iii) in Figure 4. The RHS of (4) is the marginal cost of choosing a more aggressive research strategy, $MC(r)$. Since a more aggressive research strategy increases the probability of failure, the upward-sloping locus $MC(r) = (1-s^*)\cdot\pi(s^*) - (F - f(r))$ in Panel (iii) reflects the expected loss from choosing a more risky research strategy. This is simply the expected loss of net profit that would have occurred if the research effort did not fail. Note that $MC(0) = (1-s^*)\cdot\pi(s^*) - F < 0$ from Assumption 3: if the research project does not deliver a reduction in the startup cost, the net profit is negative, and failing prevents an economic loss.

The optimal research strategy r^* is given from the intersection of the marginal benefit locus $MB(r)$ and the marginal cost locus $MC(r)$, at point B' in Panel (iii) in Figure 4. From Assumption 1, r^* is unique and stable. The optimal research strategy r^* is also more risky than simply minimizing the expected startup cost, $r^* > \hat{r}$. Using the 45-degree line in Panel (ii), we can connect the equilibrium scaling strategy s^* and the equilibrium research strategy s^* in the Panel (iv). Point B" in Panel (iv) thus gives us the benchmark equilibrium for the independent startup. Let us now investigate the impact of a VC market on the startups risk-taking behavior.

5 Venture capital

Now assume that the industry gets access to VC. As shown in Figure 1, the entrepreneur can then turn to the VC firm if she fails with her initial research in Stage 1. With help from the VC firm, entrepreneur pivots and decides on a new research project in order to bring down startup costs and make the new product or service profitable to sell. If successful, the VC-backed startup then takes its decision on scaling to the market.

5.1 The VC-backed startup

To infer the impact of VC, let us first explore how the VC-backed startup firm's decisions on research and scaling differs from the corresponding decisions taken by the independent startup (without access to VC).

Consider the situation where the entrepreneur invested in research in Stage 0 (paying the fixed cost G), but failed with her research projects in Stage 1. In Stage 2, she meets the VC firm and agrees to continue operations as a VC-backed startup, and where they agree to split of the proceeds from a successful exit in Stage 5.

To explore the incentives in the VC-backed startup, it is useful to start in Stage 3, and derive the expected joint surplus generated the 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 difference is that the VC-backed startup will exit through a trade sale or IPO in Stage 5 and hence incurs the exit cost, C_E.

5.1.1 Scaling (Stage 4)

Suppose that the VC-backed startup succeeds with its research project in Stage 3. Since the startup cost, $F-f(r)$, is sunk when scaling takes place in Stage 4 the objective function can be written as:

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

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

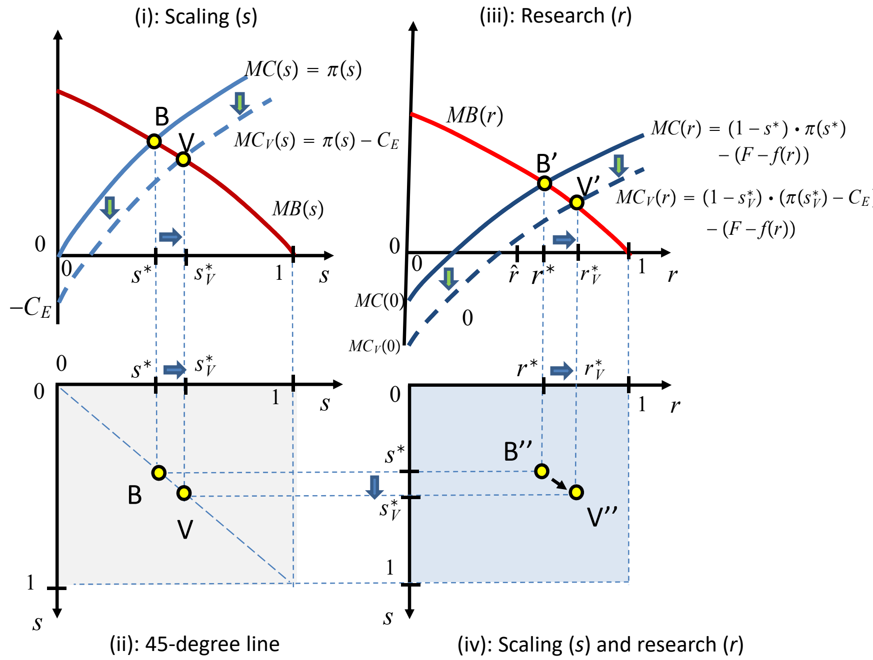

Figure 5: Scaling and research in the VC-backed startup.

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 (9) shows the marginal benefit $MB(s)$ of more aggressive scaling. It is identical to the benchmark in (4) and shows the expected increase in gross profits from increased scaling. However, the RHS in (4) and (9) differ: A comparison reveals that the entrepreneur perceives a lower marginal cost from more aggressive scaling when backed by VC, i.e. $MC_V(s) < MC(s)$, since the exit cost C_E is avoided in case of a failure for the VC-backed startup. This, implies that the startup will scale up more when backed by VC than in the benchmark without VC, i.e. $s_V^* > s^*$. This is illustrated in Panel (i) in Figure 5, where the marginal cost locus $MC_V(s)$ shifts down from $MC(s)$ with the size of the exit cost, C_E: the intersection of the marginal benefit-locus and the marginal cost-locus now intersect at V located to the right of the benchmark B. Intuitively, since the VC-backed startup perceives a lower loss of profits in case of failure due to presence of the exit cost C_E, this induces the VC-backed startup to choose a more aggressive and risky scaling strategy than the independent startup.

5.1.2 Research (Stage 3)

Let us move back to Stage 3 and solve for the VC-backed startup's choice of research project. Inserting the optimal scaling s_V^* from (9) into the joint surplus (7), we obtain the objective function

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

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

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

We can again interpret the LHS of (11) as the marginal benefit of choosing a more aggressive and risky research strategy, while the RHS captures the marginal cost of choosing a more risky research strategy. As in the benchmark, the marginal benefit is the expected reduction in the startup cost, $MB(r) = (1-r) \cdot f'(r)$. However, inspecting (6) and (11) more closely reveals that the hurdle from the exit cost C_E implies a lower marginal cost for the VC-backed startup than for independent startup, $MC_V(r) < MC(r)$. This is explained by the direct impact of the exit cost, C_E, which reduces the loss in net profit from failing with the research project. But, in addition, the lower marginal cost for the VC-backed startup also stems from the over-investment in scaling, $s_V^* > s^* = \arg\max[(1-s) \cdot \pi(s)]$, which implies that $(1-s_V^*) \cdot \pi(s_V^*) < (1-s^*) \cdot \pi(s^*)$. The fact that the VC-backed firm over-invests in scaling to the market also leads to more aggressive research in order to obtain a higher net profits through lower startup costs, i.e. $r_V^* > r^*$ and $f(r_V^*) > f(r^*)$. This is illustrated in Figure 5(ii) noting that point V' being located to the right of the benchmark B'. We can summarize:

Lemma 1. *The following holds:*

1. *Suppose that the exit cost of the VC-backed startup is strictly positive, $C_E > 0$. A VC-backed startup then chooses a more aggressive and more risky scaling strategy—as well as a more aggressive and risky research strategy—compared to an independent startup (without access to VC): $s_V^* > s^*$ an $r_V^* > r^*$.*

2. *Suppose that the exit cost of the VC-backed startup is is zero, $C_E = 0$. The VC-backed startup will*

then choose identical scaling and research strategies as the independent startup, $s_V^* = s^*$ *and* $r_V^* = r^*$.

5.2 The independent startup

Our results so far indicate that the entrepreneur, when *directly* backed by VC, will choose scaling and research strategies which are more risky than she would do in absence of VC-backing. Taking this prediction to the data, we would expect that VC-backed startups would scale to larger sizes and pursue more radical research than startups without VC-backing.

However, potential access to VC can also change the startup's behavior— even if the entrepreneur in the end does not seek VC-backing. To explore the latter *indirect* channel, we now consider the full game in Figure 1, where the entrepreneur takes into account that she can pivot with the help of the VC firm in Stage 2, if she fails to create a viable business in Stage 1.

How much is the potential support worth for the entrepreneur? Note that it is only in the event that research and scaling succeeds in the VC-backed startup that the entrepreneur will gain from turning to the VC firm upon failing in Stage 1. Assuming that a share $\theta \in (0,1)$ of the proceeds accrues to the entrepreneur, her expected value of teaming up with the VC firm in Stage 2 is:

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

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 first term is the net expected profit, where $(1-r)$ is the probability that the entrepreneur succeeds with her initial research in Stage 1. This term is identical to the corresponding profit in the benchmark (2). We can think of the second term as an insurance term which we will label *the option value of a second-chance*, where r is the the probability that the entrepreneur fails in the initial research in Stage 1, and $v(s_V^*, r_V^*)$ is the value she then expects from teaming up with the VC firm.

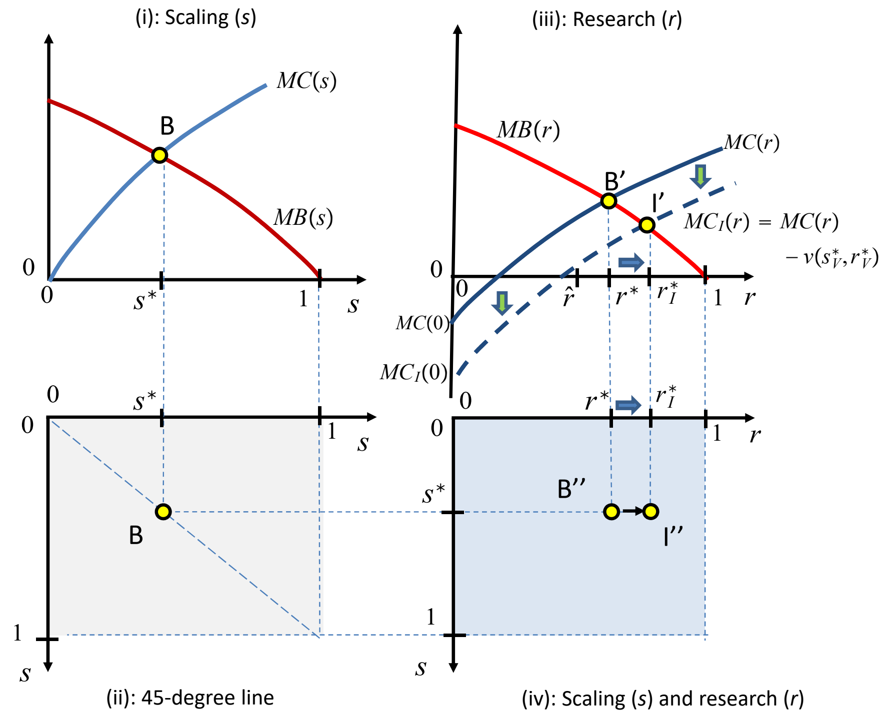

Figure 6: The entrepreneur's incentives when VC is present.

5.2.1 Scaling (Stage 4)

As illustrated in Figure 1, if the entrepreneur succeeds with her research project in Stage 1 she can manage to scale and bring the startup to the market on her own. She will then move directly to Stage 4 in order to choose her level of scaling. With the startup cost yet again sunk, she will maximize her expected profit

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

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

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

Note that (15) is identical to the benchmark in (4). Intuitively, if the entrepreneur succeeds with her research project and then goes alone without VC support, she will choose the same level of risk in scaling as in the benchmark, i.e. $s_I^* = s^*$. This is shown in Panel (i) of Figure 6.

5.2.2 Research (Stage 1)

Let us, then move back to the entrepreneur's research in Stage 1. Inserting the optimal scaling $s_I^* = s^*$ from (15) into the expected profit (13), we have

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

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

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

The LHS in (17), yet again, represents the marginal benefit in terms the reduction in marginal cost from choosing more aggressive research, $MB(r)$. This term is identical to the benchmark in (6), as illustrated in Panel (iii) of Figure 6. However, the RHS comparison of (17) and (6) reveals that the entrepreneur perceives a lower marginal cost of pursuing more aggressive research when VC is available in the industry, $MC_I(r_I) = MC(r) - v(s_V^*, r_V^*) < MC(r)$. This can be seen from the last term in the RHS of (17) which represents a *second-chance effect*: when choosing a more aggressive—and, hence, a more risky—research strategy, the entrepreneur knows that if she fails she can turn to VC giving her an expected profit of $v(s_V^*, r_V^*)$.

Assuming that $v(s_V^*, r_V^*) > 0$, the second-chance effect will limit the expected loss from failing with the initial research project. As shown in Panel (iii) of Figure 6, the second-chance effect induces the entrepreneur to choose a more aggressive—and more risky—research strategy when VC is present, $r_I^* > r^*$. This can be seen by comparing points B' and I'.

While the second-chance effect of VC does not induce the independent startup to scale up more than in absence of VC, $s_I^* = s^*$, it will make the entrepreneur to choose a more risky and aggressive research project, $r_I^* > r^*$. This is shown in Panel (iv). To summarize:

Lemma 2. *Suppose that the entrepreneur knows that she has a chance to get VC-backing if she fails with her research in Stage 1. Then, the following holds:*

1. *The entrepreneur will to pursue a strictly more aggressive research strategy, $r_V^* > r^*$.*

2. *If the entrepreneur succeeds with the initial research, she will choose the same level of scaling as she would in the benchmark where VC is absent from the industry: $s_V^* = s^*$.*

6 How the VC market affect startups

Let us now summarize our findings of how an active VC market affects startup's risk-taking behavior. We then need to take into account both *the direct effect of VC* (which operates when a startup becomes VC-backed) and *the indirect effect of VC* (which operates through changed incentives for the entrepreneur when she knows that she can get access to VC, i.e. accounting for the option value that the second chance chance from VC brings).

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

Starting with the startups' scaling decision. Comparing an industry with and without access to VC, we have the following proposition:

Proposition 1. *Startups choose more aggressive and risky scaling when VC is present and exit costs C_E are strictly positive: $s_V^* > s_I^* = s^*$.*

If the startup fails with its research in Stage 1, the VC firm provides a chance to pivot in Stage 2. Lemma 1 then showed that if the exit costs of the VC-backed startup in Stage 5 are strictly positive, $C_E > 0$, the entrepreneur will choose a higher level of scaling when backed by VC, as compared to the benchmark, $s_V^* > s^*$. If on the other hand, the entrepreneur succeeds with her initial research, she will proceed on her own with an independent startup. As shown in Lemma 2, the amount of scaling is then identical to her choice in a benchmark without VC, $s_I^* = s^*$. Proposition 1 implies that gross profits will be higher in startups which is backed by VC, $\pi(s_V^*) > \pi(s_I^*) = \pi(s^*)$. This finding is consistent with the findings in Gompers et al. (2021) who report that VC look for big exits. Our explanation for this venture big exit incentive is that VC-backed startups face significant exit costs, $C_E > 0$, and this makes them prefer more ambitious and risky scaling strategies.

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

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

Proposition 2. *Research in startups becomes more aggressive and risky with VC is present in an industry: $r_l^* > r^*$ for $l = I, V$.*

This proposition follows from Lemma 1 and Lemma 2. When the startup receives VC-backing, the expected exit cost, $C_E > 0$—directly as well as indirectly—leads to a lower loss in net profit, when failing with the initial research. This induces the VC-backed startup to take on more risk to reduce the startup cost, i.e. $r_V^* > r^*$.

But we also found that even without support from VC, the entrepreneur would take on more risk to bring down the startup cost. This was due to the *second-chance effect*, which arises as the entrepreneur internalizes that if she fails in her initial research she can seek support from the VC firm (at the cost of sharing the proceeds of the venture), inducing her to go for more risky in research, $r_I^* > r^*$.

Thus, regardless if VC influences the entrepreneur directly (through exit cost effect) or indirectly (through the second-chance effect), the entrepreneur would go for more risky research when VC is present. This implies that presence of VC always leads to stronger technological development in terms of lower startup cost, $F - f(r_l^*) < F - f(r^*)$ for $l = I, V$.

An interesting question is then when VC has the greatest influence on the technology choice. Is it through its mere presence (i.e. the indirect effect), or is through a direct involvement in the startup (the direct effect)? Thus, let us now compare r_V^* and r_I^*. We have the following corollary:

Corollary 1. *The indirect effect of VC through the second-chance effect can induce the entrepreneur to choose a more risky research project than she would do when VC-backed:*

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) dominates the exit cost effect, and $r_I^* > r_V^*$. The indirect effect of VC leads to larger technology leap as measured by low startups 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 so that the the second-chance effect is limited then $r_I^* < r_V^*$ and, hence, $F - f(r_V^*) < F - f(r_I^*)$. The second-chance effect is also limited when the entrepreneur is given a lower share of the net surplus generated by the exit of the venture-backed firm (θ small), and also in this case $r_I^* < r_V^*$.

6.3 VC and pivots: The second-chance effect

A pivot in our model is the event where the entrepreneur first fails with her initial research project in Stage 1 and then receives help by VC to choose a new research project in Stage 3. Pivoting has important real-economic effects. We have shown how VC—directly or indirectly—give startups incentives to take on large risks. If initial research and scaling to consumers succeeds, VC can bring significant societal benefits in terms of lower startup costs and bringing new services to more consumers and markets. On the downside, with the larger risks associated with bolder projects, comes more failed startups.

We therefore close this section by evaluating the impact of VC on startups in expected terms. Let us start by looking at the overall probability that the startup succeeds.

To this end, let ϕ^{NVC} be the probability that a startup reaches the consumers in the product market in the benchmark without VC present in the industry. From (6), ϕ^{NVC} is the product

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

where $(1-r^*)$ is the probability that independent entrepreneur succeeds with her initial research and $(1-s^*)$ is the probability that she succeeds with scaling.

Let ϕ^{VC} denote probability that a startup reaches the consumers in the product market with VC present in the industry. Using (9) and (11), and (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) is symmetric to (18): it shows that probability that the entrepreneur take the product or service to the market when not funded by VC. The second terms is the probability of a pivot, i.e. the probability that the entrepreneur will get a second chance where r_I^* is the probability that the entrepreneur fails with her initial research and then approaches VC.

Define $\Delta\phi = \phi^{VC} - \phi^{NVC}$ as the difference probability for the startup to succeed to reach the market between the industry with- and without VC. Using 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 is the probability that a pivot with VC succeeds. The second term reflects that the entrepreneur—ignited by the second-chance emerging from the availability of VC—chooses a research project that is more risky and more likely to fail as compared to the benchmark. The second term thus reflects the higher probability of failure by the entrepreneur when she goes on her own. Which term dominates?

If we apply Lemma 1, we know that if the research cost G becomes sufficiently high, the second-chance effect will be limited and r_I^* will approach r^*. Since the research cost G does not affect the risk-taking behaviour in the VC-backed startup (G is sunk when the research and scaling decision are taken), r_V^* and s_V^* are not affected. Hence, pivoting with VC increases the likelihood that the startup makes into the market, $\Delta\phi \approx r^*(1-r_V^*)\cdot(1-s_V^*) > 0$. On the other hand, an sufficiently high exit cost C_E will induce the VC-backed firm to take more risk in scaling, i.e. so that s_V^* approaches unity, and $\Delta\phi = -(r_I^* - r^*)\cdot(1-s^*) < 0$.This shows that there is situations where the likelihood of a startup reaching the market can decline if VC becomes available, the opposite can also occur.

We can derive similar results for the expected gross profit. In the Appendix we show 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 availability of VC make startups more likely to succeed, $\Delta\phi > 0$, presence of VC will also make expected gross profits from scaling higher, $\Delta\pi > 0$. The latter will hold more generally since $\pi(s_V^*) > \pi(s^*)$. In the Appendix, we derive a similar result for expected startup costs. We conclude with the following proposition that summarized key empirical predictions from our model:

Proposition 3. *Suppose that VC becomes available to startups in an industry that previously did not have access to VC. Then:*

1. *Startups will choose more risky research and more risky scaling strategies.*

2. *If successful, VC-backed startups will make greater technological leaps and will scale products to more consumers and markets.*

3. *Due to pivoting with VC support (second-chance), there exist an equilibrium where startups become more likely to succeed, achieve higher expected gross profits, have lower expected startups costs, and take higher risks in research and scaling.*

7 Bank versus VC financing

To examine how temporary ownership by VC firms affected a VC-backed startup's research and scaling decisions, we assumed that the VC-backed startup faced a specific fixed exit cost, C_E. However, the VC-model's specific characteristics, and its specific costs and division of revenues between the investors and the VC firm, can also affect the research and scaling decisions. We argue below that a general feature of these contracts between the VC firm and the investors imply that the large initial part of the exit value of the startup is going to the investors. These contracting features also creates ”exit costs” that affect research and scaling decisions.

In practise, the entrepreneur will also need to finance her independent startup costs and will typically rely on bank-financing for these investments. We thus need to incorporate bank-financing into the model as well. We will below show that this implies that also the independent startup faces an ”exit cost” when the bank loan is to be paid back. We will, however, show mechanisms that support that the ”exit cost” is higher for the venture-backed startup than for the bank-financed startup.

We will start with the benchmark case with the independent startup in a situation where she has to finance her startup cost with bank financing and examine how this affects her scaling and research decisions. We will then turn to how the VC-backed startup's contract with investors affects its scaling and research decisions.

7.1 Bank financing

Suppose that the entrepreneur is successful with her research project r in Stage 1. She will now need to borrow to cover the startup cost $F - f(r)$ from a bank. Suppose that the bank requires the entrepreneur to at least put in own equity A in order to lend, and that the entrepreneur has wealth $W > A$ in Stage 1. The entrepreneur will then borrow $F - f(r) - A$ at an exogenous interest rate ρ, and then pay the startup cost $F - f(r)$ at the end of Stage 1.

To highlight the mechanisms in play from debt-financing, we shall simplify such that the second-chance-effect plays no major role here. We can then write the independent startup's maximization problem in the following way:

$$\max_{\{r,s\}} \Pi(s,r) = \begin{cases} 0, \text{ or } \varphi(s,r) < 1+\rho, \\ W-(1-r)A+(1-r)\cdot(1-s)\cdot\{\pi(s)-(1+\rho)\cdot(F-f(r)-A)\}, \text{ for } \varphi(s,r) \geq 1+\rho. \end{cases} \tag{22}$$

In (22), 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.

$$\varphi(s,r) = \frac{\pi(s)-(F-f(r)-A)}{F-f(r)-A} = 1+\rho. \tag{23}$$

The upper line in (22) thus shows the case where the startup—if successful—cannot pay back the loan with interest. It follows that we will focus on the lower line in (22), where $\varphi(s,r) > \rho$, that is, where the startup if successful can make a net profit.[3]

7.1.1 Scaling (Stage 4)

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

$$\Pi(s,r) = W-A+(1-s)\cdot\{\pi(s)-(1+\rho)\cdot(F-f(r)-A)\}. \tag{24}$$

Note how debt-financing changes the independent startup's incentives to scale up. In the benchmark case, we assumed that the entrepreneur uses own resources to finance the startup cost incurred at the end of Stage 1. As shown in (3), this implies that—in the benchmark case—the startup cost, $F-f(r)$, is sunk when the decision on scaling s is taken. As shown in (24), this is no longer true under debt financing. This is since the entrepreneur will internalize that she will pay back the loan with interest, $(1+\rho)\cdot(F-f(r)-A)$, at the end of Stage 6. This introduces a novel endogenous link between the research and scaling decisions.

Maximizing (24), the first-order condition, $\frac{\partial\Pi(s,r)}{\partial s} = 0$, becomes

[3]Note that we abstract from the incentives of the bank to lend to the entrepreneur and simply assume that the parameter values of the model are such that the bank finds it profitable to lend to the entrepreneur at the interest rate ρ given that the entrepreneur commits A to the startup.

$$\underbrace{(1-s)\cdot\pi'(s)}_{MB_L(s=s_L^*(r))} = \underbrace{\pi(s)-(1+\rho)(F-f(r)-A)}_{MC_L(s=s_L^*(r))}. \tag{25}$$

Let us compare the above first-order condition for scaling under debt-financing with corresponding first-order condition for scaling in the benchmark without debt financing in (4). The *marginal benefit* of more aggressive scaling strategy, $MB_L(s)$, is identical to the marginal benefit in the benchmark case of own financing. However, the *marginal cost* of choosing a more aggressive scaling strategy with debt financing, $MC_L(s)$ differs from the corresponding marginal cost with own financing, $MC(s)$. As in the benchmark case, a more aggressive scaling strategy s increases the probability of failure and, hence, the independent startup increase the risk to loose the product market profit $\pi(s)$. However, the net loss of failing under debt financing is lower, since—as we noted—the loan, $(1+\rho)(F-f(r)-A)$ needs to be repaid only if the scaling is successful. Comparing the two first-order conditions (4) and (25), it is then clear that marginal cost of choosing a more aggressive scaling strategy is lower under debt-financing, $MC_L(s)$, than under own financing, $MC(s)$, i.e. $MC_L(s) = \pi(s)-(1+\rho)\cdot(F-f(r)-A) < MC(s) = \pi(s)$. It then follows that debt-financing will make the independent entrepreneur more aggressive in scaling, i.e. $s_L^* > s_I^*$.

Thus we can state the following proposition:

Proposition 4. *If the entrepreneur finances her startup with debt from bank-financing, she will choose a more aggressive scaling strategy compared to the case when she finances her startup without debt (as in the benchmark case), $s_L^* > s^*$.*

From (25), it is also evident that debt-financing makes the optimal scaling decision s_L^* in Stage 4 dependent on the chosen research project r, given from Stage 1, $s_L^*(r)$. Indeed, differentiating (25), we obtain

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

A more aggressive research strategy r will, if it succeeds, lead to a reduction of the repayment of the loan with $(1+\rho)f'(r) > 0$. This, in turn, raises the marginal cost of choosing a more aggressive scaling strategy since the expected net of loss of failing increases, inducing the entrepreneur to choose a less aggressive scaling strategy, $\frac{ds_L^*}{dr} < 0$.

Proposition 5. *If the entrepreneur finances her startup with debt from bank-financing, she will choose a more aggressive scaling strategy, s_L^*, if she has succeeded with a more aggressive research strategy,* $\frac{ds_L^*}{dr} < 0$.

From (25), it also follows that the entrepreneur becomes more aggressive in scaling under debt financing when the interest rate ρ is higher and when less own wealth A is used.

7.1.2 Research (Stage 1)

Let us now turn to the research strategy, r. Proposition 4 showed that debt financing will induce the entrepreneur to choose a more aggressive scaling strategy than under own financing, $s_L^*(r) > s^*$. It turns out that this is not necessarily true for the choice of the research strategy, r. To see this, first use the optimal scaling $s_L^*(r)$ from (25) in Stage 1, to write the objective function in (2), as

$$\Pi(r, s_L^*(r)) = W - (1-r)A + (1-r)\cdot(1-s_L^*(r))\cdot\{\pi(s_L^*(r)) - (1+\rho)\cdot[F - f(r) - A]\} \tag{26}$$

Applying the envelope theorem, the first-order condition, $\frac{\partial\Pi(r,\bar{s}^*(r))}{\partial r} = 0$, can be written as[4]

$$\underbrace{(1+\rho)\cdot(1-r)\cdot f'(r) + \frac{A}{1-s_L^*(r)}}_{MB_L(r=r_L^*)} = \underbrace{\pi(s_L^*(r)) - (1+\rho)\cdot[F - f(r) - A]}_{MC_L(r=r_L^*)}. \tag{27}$$

Let us now compare the first-order condition for research under debt-financing in (27) with corresponding first-order condition for research without debt financing in (6). The left-hand side of (27) shows the marginal benefit of choosing a more aggressive research strategy, $MB_L(r)$, and consists of the sum of the expected savings of the startup costs including financial costs, $(1+\rho)\cdot(1-r)\cdot f'(r)$, and the gain from succeeding with the research project from retaining the own wealth invested in the business $\frac{A}{1-s_L^*(r)}$ (adjusted by the probability of succeeding with scaling, $1-s_L^*(r)$). If we compare with the marginal benefit of a more aggressive research strategy in the benchmark, $MB(r) = (1-r)\cdot f'(r)$ in (6), it follows directly that debt financing creates a stronger incentive for the entrepreneur to choose a more risky research, $MB_L(r) > MB(r)$. However, when comparing the marginal cost of a more aggressive research project under debt-financing in (27), $MC_L(r) = \pi(s_L^*(r)) - (1+\rho)\cdot[F - f(r) - A]$, and own financing $MC(r) = (1-s^*)\pi(s^*) - [F - f(r)]$ in (6), we cannot sign $MC_L(r) - MC(r)$. A more risky research project that fails, incurs a larger expected loss of profits under debt financing, $\pi(s_L^*(r)) > (1-s^*)\pi(s^*)$ since debt-financing induces the independent startup

[4]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 (25).

to scale more aggressively, $s_L^*(r) > s^*$ from Proposition 4. This will tend to make the marginal cost of more risky research higher under under debt financing and induce less risk-taking in research under debt-financing. However, since the financial cost of the startup cost under debt financing, $(1+\rho)\cdot[F-f(r)-A]$, may be lower be than the startup cost, $[F-f(r)]$, which is fully paid by the entrepreneur under own financing, we cannot tell if research projects will be more or less aggressive under debt financing, i.e. $r_L^* \lesseqgtr r^*$.

7.2 VC financing

Let us now turn to VC financing. VC firms raise money from institutional investors for VC funds with a predetermined lifespan of around 10 years. The VC firm then invests the money in the fund in several startups, works with the startups to grow and scale them, and then they resell them. The proceeds they earn are then returned to the institutional investors (ideally generating a return for them). 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 is an incentive fee for managers based on the returns earned by the fund. Of capital divested, everything goes to the investors until the cumulative distribution to investors equals an "internal rate of return" of 8% per year. After this, everything goes to the VC firm until it has received 20% of the difference between the total amount distributed and the sum of the two components just mentioned. This is called a "catch up provision". At that point, 80% have gone to investors and 20% to the VC firm. Any additional returns above this are split such that 80% goes to investors and 20% to the VC firm.

A key aspect of these features of the contract between investors and the VC firm for the VC-backed startups research and scaling behavior is that the investor is the residual claimants up to that out of the capital divested by the fund, 100% goes to the investors until the cumulative distribution to investors equals an "internal rate of return" of 8% per year. Thereafter the VC firm will be the residual claimant until it has received 20% of the difference between the total amount distributed and the sum of the two components just mentioned (the "catch up provision"). At that point, 80% of returns have gone to investors and 20% to the VC firm.

We now introduce the contractual features of the interaction between the VC firm and the institutional investors in a simple way. We will abstract from all fees except carried interest and the hurdle rate, which we label h and assume that the VC firm only needs to finance the startup cost, $F - f(r)$. Since we are abstracting from the second chance effect (i.e. $\theta \approx 0$), we can also ignore any transaction between the entrepreneur and the VC firm when the VC firm makes it's investment. It is tedious, but straightforward, to introduce other fees and any payments to the entrepreneur. We will also ignore that VC firms typically invest in several startups over the lifetime of a fund.

To characterize the contract, it is useful to first make two definitions: First, 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,

$$\varphi_V(s,r) = \frac{\pi(s) - (F - f(r)}{F - f(r)} = 1 + h, \tag{28}$$

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

Second, we define $\vartheta(s,r)$ as the relative return for a successful project with a scaling strategy s and research strategy r where the 20-80 rule is binding. That is, let $\frac{\pi(s)-(1+h)\cdot(F-f(r)}{\pi(s)-[F-f(r)]}$ be the share of the return going to the VC firm and let $\frac{h\cdot(F-f(r)}{\pi(s)-[F-f(r)]}$ be the share going to the investors. Then, $\vartheta(s,r)$ is simply defined as

$$\vartheta(s,r) = \frac{\frac{\pi(s)-(1+h)\cdot(F-f(r)}{\pi(s)-[F-f(r)]}}{\frac{h\cdot(F-f(r)}{\pi(s)-[F-f(r)]}} = \frac{0.2}{0.8} = 1/4. \tag{29}$$

Using (28) and (29), the objective function for the VC-firm can then be written

$$V(s,r) = \begin{cases} 0, \text{ if } \varphi_V(s,r) \leq 1+h, \\ (1-r)\cdot(1-s)\cdot\{\pi(s) - (1+h)\cdot[F - f(r)]\}, \text{ if } \varphi_V(s,r) > 1+h \text{ and } \vartheta(s,r) \in (0, 1/4], \\ 0.2\cdot(1-r)\cdot(1-s)\cdot\{\pi(s) - [F - f(r)]\}, \text{ if } \varphi_V(s,r) > 1+h \text{ and } \vartheta(s,r) > 1/4. \end{cases} \tag{30}$$

To compare VC financing (with the 80-20 contract combined with a hurdle rate) to bank financing, we shall again impose an interior solution, that is, we shall consider projects that have a sufficiently high return if successful, $\varphi_V(s,r) > 1+h$. Several things can then be noted.

First, if we compare the second line in the objective function under VC financing (30) with the second line under bank financing in (22), we note that $(1+h)\cdot[F-f(r)] > (1+\rho)\cdot[F-f(r)-A]$, since $h>\rho$ and $A>0$. This inequality can be interpreted as the "exits cost" is higher under VC financing than under bank financing. We previously showed that VC financing induced a more aggressive scaling driven by assuming an exogenous exit cost associated with VC funding, C_E. Below, we will see that the same result emerges from VC financing being associated with higher funding costs.

Second, for projects with a very high return in the third line of (30), it follows that the VC-backed startup will choose exactly the same project as the independent startup in the benchmark case, i.e. $s_V^* = s^*$ in (4) and $r_V^* = r^*$in (6). We shall therefore focus on the middle line in (30), where the VC firm is the full residual claimant after paying the investors a return equal to the hurdle rate.

7.2.1 Scaling (Stage 4)

From the second line in (30), the objective function for the VC firm in Stage 4 becomes

$$V(s,r) = (1-s)\cdot\{\pi(s)-(1+h)(F-f(r))\}. \tag{31}$$

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

$$\underbrace{(1-s)\cdot\pi'(s)}_{MB_V(s=s_V^*(r))} = \underbrace{\pi(s)-(1+h)\cdot(F-f(r))\,)}_{MC_V(s=s_V^*(r))} \tag{32}$$

The marginal benefit for the VC firm in (32), $MB_V(s)$, is identical to marginal benefit of the startup financed by bank loans, $MB_V(s)$, in (25). However, since the interest rate on the bank loan ρ is lower than the hurdle rate, $\rho < h$, and, since the entrepreneur needs to provide asset in place $A>0$ to be able to borrow from the bank, the entrepreneur's marginal cost of a more aggressive scaling $MC_L(s) = \pi(s)-(1+\rho)(F-f(r)-A)$ is lower than the marginal cost for VC-backed startup which is $MC_V(s) = \pi(s)-(1+c)(F-f(r))$. For a given research project r, it then follows that a startup with VC financing will choose a more aggressive scaling than a startup financed by bank loans which in turn will choose more aggressive scaling than a startup with own financing, $s_V^*(r) > s_L^*(r) > s^*$, where the latter inequality stems from Proposition 4. This transitivity in scaling is shown in Figure 7, where the marginal benefit-locus and the marginal cost-locus for VC-backed startup intersect at point V, which is located to the right of the startup with bank finance at point

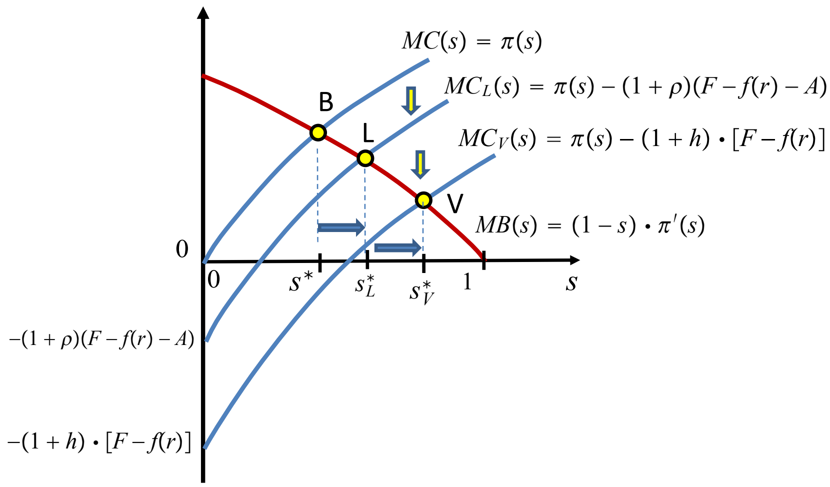

Figure 7: Scaling under different forms of financing.

L, which, in turn, is located to the right of the startup with own financing at point B.

Thus we can state the following proposition:

Proposition 6. *For a given research project, r, the VC-backed startup will choose more risky scaling strategy than will a bank-financed startup, since the hurdle rate h is higher than interest on bank financing ρ and bank financing requires that the entrepreneur herself finances the startup with A.*

7.2.2 Research (Stage 3)

Let us finally turn to choice of the research strategy, r, in the VC-backed startup. Inserting the optimal scaling strategy, $s_V^*(r)$, from (4) into (30), 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

$$\underbrace{(1+h)\cdot(1-r)\cdot f'(r)}_{MB_V(r=r_V^*)} = \underbrace{[\pi(s_V^*(r)) - (1+h)\cdot(F - f(r))]}_{MC_V(r=r_V^*)}. \tag{33}$$

The left-hand-side (LHS) of (33) is the marginal benefit for the VC-backed startup from choosing a more aggressive research strategy r, $MB_V(r) = (1+h)\cdot(1-r)\cdot f'(r)$. This can be smaller or larger than the corresponding marginal benefit the bank-financed startup since from (27), $MB_L(r) = (1+\rho)\cdot(1-r)\cdot f'(r) + \frac{A}{1-s_L^*(r)}$, depending relative size of the hurdle rate and the bank-lending rate ($h > \rho$) and how much own wealth banks requires the entrepreneur invests in the startup under bank-financing ($A > 0$). Moreover, when comparing the marginal cost of choosing a more risky research project in (33) under VC financing, and (27) 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.

While we need to put more structure to the model to rank research choices in startups with bank-financing and VC financing, the analysis in this section nevertheless reveals that if the difference in research projects is limited between the different forms of funding, Proposition 6 suggests that a VC-backed startup will choose more risky projects than startups funded by either bank-financing or funds from provided by the entrepreneur.

8 The difference between pivoting and leave for wage work

The option value that a VC market bring to startups induces them to take on more risk as failure is not as costly when a second chance is available. In reality, however, entrepreneurs may have different other options in case of failure aside from pivoting with the help of VCs. This raises the question of if there is something special about the second chance offered by VCs?

In this section, we explore one difference between taking second chances from VCs and going for wage work as an outside option. Formally, consider the situation where the entrepreneur has a second chance in the form of becoming an employee earning an wage w instead of pivoting with the help of a VC. We can refer to this as an *employee-based second chance option*.

In this situation, it then follows that as the outside option in the form of the wage w increases, the entrepreneur takes on more risk in the research stage. To see this note that the entrepreneur's objective function in this case becomes:

$$\Pi(s,r) = (1-r)\cdot\{(1-s)\cdot\pi(s) - (F - f(r))\} + r\cdot w. \tag{34}$$

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:

$$\Pi(r) = (1-r)\cdot\{(1-s^*)\cdot\pi(s^*) - (F - f(r))\} + r\cdot w \tag{35}$$

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

$$\underbrace{(1-r^*)\cdot f'(r^*)}_{MB(r=r_w^*)} = \underbrace{(1-s^*)\cdot\pi(s^*) - (F - f(r^*)) - \overbrace{w}^{\text{Second-chance effect}}}_{MC_I(r=r_w^*)}. \tag{36}$$

The RHS in (36) 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*.

One potential difference between VCs and wage work as outside options relates to what is learned during the research stage. If the entrepreneur in its initial attempt chooses a low risk project, such a project will perhaps rely to a larger extent on established techniques and methods (such as a process innovation). The knowledge gained working on such a project could then perhaps be of lower value to future startups with novel technologies and business ideas but of higher value in wage work in established incumbents. On the other hand, the *VC-based second chance effect* should perhaps increase in risk the entrepreneur takes in its initial research project since she then learns something novel (such as a product innovation) that will be of use in creating other new ventures that might be backed by VC firms in a pivot and that will have less use in incumbent firms.

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

Assumption 4. *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 (36) now becomes:

$$\underbrace{(1-r_w^*)\cdot f'(r_w^*)}_{MB(r_w^*)} = \underbrace{(1-s^*)\cdot\pi(s^*) - (F - f(r_w^*)) - \overbrace{(w + r_w^*\cdot\overset{(-)}{\frac{\partial w}{\partial r}})}^{\text{Employment-based second-chance effect}}}_{MC_I(r=r_w^*)}. \tag{37}$$

Compare the first-order conditions under the employment-based second chance effect in (37) to the first-order condition under the VC-based second chance effect in (17). Note that in the latter a more risky research strategy reduced the size of the outside option, $w + r_w^* \cdot \frac{\partial w}{\partial r} < w$. This is not the case under the VC-based second chance effect, since the VC-based second chance effect in (17), $v(s_V^*, r_V^*)$, is not affected by the the research strategy chosen by the entrepreneur, r_I.

Summing up, the existence of VC-backed second chance option may create incentives for entrepreneurs to take more risk in the startup than an employee-based second chance option would. The reason is that failing in a high-risk research strategy tends to improve the entrepreneur's probability to get VC-funding, whereas failing in a low-risk research strategy increases the value for the entrepreneur if switching to wage work.

9 Complementarities between research and scaling

To simplify the analysis we assumed in the baseline analysis that the relationship between research decision and the scaling decision was very simple. Section 7 that introduced external financiers implemented a link between the research and scaling decision since the startup cost now directly affected scaling risk.

In practice, there may be additional reasons for why the two decisions are linked. The link may depend on technology, market conditions and institutional features. It is outside the scope of this paper to fully address this issue but we here highlight a mechanism that we believe are of relevance. If a startup takes on riskier research and is successful it will possess a more unique product. In some industries this will increase scalability a lot (e.g. digital network industries), whereas in other industries this will be of less value for scaling up (e.g. mining).

To capture this in our model, we let the reduced product market profit be $\pi(s,r)$ with $\frac{\partial \pi(s,r)}{\partial s} > 0$ and $\frac{\partial \pi(s,r)}{\partial r} > 0$. We then define the concept research-scalability reward—or the complementarity between successful research and successful scaling—as follows:

Assumption 5. *Research-scalability reward:* $\frac{\partial^2 \pi(s,r)}{\partial s \partial r} > 0$.

To illustrate how assuming a complementarity between successful research and scaling affects our results, we make use of the benchmark model.

9.1 Scaling (Stage 4)

As before, we use backward induction and start with the scaling decision in Stage 4. Since only the reduced-form profits has changed compared to the benchmark model, we can rewrite the objective functions in (2) and (7), as

$$\begin{aligned} \Pi(s,r) &= (1-s)\cdot\pi(s,r)-(F-f(r)) && (38) \\ V(s,r) &= (1-s)\cdot[\pi(s,r)-C_E]-(F-f(r)) && (39) \end{aligned}$$

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

$$\underbrace{(1-s^*)\cdot\frac{\partial\pi(s^*(r),r)}{\partial s}}_{MB(s^*(r))}=\underbrace{\pi(s^*(r),r)}_{MC(s^*(r))}, \tag{40}$$

$$\underbrace{(1-s_V^*)\cdot\frac{\partial\pi(s_V^*(r),r)}{\partial s}}_{MB_V(s_V^*(r))}=\underbrace{\pi(s_V^*(r),r)-C_E}_{MC_V(s_V^*(r))}. \tag{41}$$

These first-order conditions are almost identical to (4) and (9) in the benchmark model. However, due to the complementarity in profits between more risky research projects and scaling, the optimal amount of scaling will depend on the choice research project r, i.e. $s^*(r)$ and $s_V^*(r)$. For a given research strategy, r, a comparison reveals that the entrepreneur perceives a lower marginal cost from more aggressive scaling when backed by VC, i.e. $MC_V(s,r) < MC(s,r)$, since the exit cost C_E is yet again avoided in case of a failure for the VC-backed startup. This, implies that for a given research strategy, r, the start-up will scale up more when backed by VC than in the benchmark without VC, i.e. $s_V^*(r) > s^*(r)$.

However, in contrast to our previous results under bank-financing and VC-funding—where riskiness of scaling and research were negatively related—we cannot here sign how succeeding with more risky research affects the optimal choice of scaling. To see this, differentiate (40) and (41), to get

$$\frac{ds_I^*}{dr} = -\frac{(1-s_I^*)\cdot\frac{\partial^2\pi(s^*(r),r)}{\partial s\partial r}-\frac{\partial\pi(s^*(r),r)}{\partial r}}{\underbrace{SOC}_{(-)}} \gtreqless 0 \tag{42}$$

$$\frac{ds_V^*}{dr} = -\frac{(1-s_V^*)\cdot\frac{\partial^2\pi(s_V^*(r),r)}{\partial s\partial r}-\frac{\partial\pi(s_V^*(r),r)}{\partial r}}{\underbrace{SOC}_{(-)}} \gtreqless 0 \tag{43}$$

where the SOC denotes the second-order condition. Note that having succeeded with more risky research makes it more profitable to scale more aggressively, as shown by the terms $\frac{\partial^2\pi(s^*(r),r)}{\partial s\partial r} > 0$ in (42) and $\frac{\partial^2\pi(s^*(r),r)}{\partial s\partial r}$ in (42). This corresponds to a higher marginal benefit of scaling in the first-order conditions (40) and (41). However, counteracting this effect is that when succeeding with more risky research, the start-up will have in its possession a better product or services which yields a higher profit, as shown by the terms $\frac{\partial\pi(s^*(r),r)}{\partial r} > 0$ in (42) and $\frac{\partial\pi(s_V^*(r),r)}{\partial r} > 0$ in (42). The higher profit increases the marginal cost of failure in the first-order condition (40) and (41), which dampens the incentive to choose a more aggressive scaling.

We can finally note that if the VC-backed startup's higher exit cost induces it to take more risk in the research decision, and the research-scalability reward is high, then the VC-backed startup will choose to scale more aggressively than would the independent startup.

9.2 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 (42) into (38) and s_V^* from (41) into (39), we obtain the objective functions

$$\Pi(r) = (1-r)\cdot\{(1-s^*(r))\cdot\pi(s^*(r),r)-(F-f(r))\} \tag{44}$$

$$V(r) = (1-r)\cdot\{(1-s_V^*(r))\cdot[\pi(s_V^*(r),r)-C_E]-(F-f(r))\}\,. \tag{45}$$

Using the envelope theorem, the first-order conditions become

$$\underbrace{(1-r)\cdot f'(r)+(1-r)\cdot((1-s^*(r))\cdot\frac{\partial\pi(s^*(r),r)}{\partial r}}_{MB(r=r^*)} = \underbrace{(1-s^*(r))\cdot\pi(s^*(r),r)-(F-f(r))}_{MC(r=r^*)}. \tag{46}$$

$$\underbrace{(1-r)\cdot f'(r)+(1-r)\cdot((1-s_V^*(r))\cdot\frac{\partial\pi(s_V^*(r),r)}{\partial r}}_{MB(r=r_V^*)} = \underbrace{(1-s_V^*(r))\cdot\left(\pi(s_V^*(r),r)-\overbrace{C_E}^{\text{Exit cost}}\right)-(F-f(r))}_{MC_V(r=r_V^*)} \tag{47}$$

We can then state the following proposition:

Proposition 7. *If the direct effect* $\frac{\partial\pi(s,r)}{\partial r}>0$ *is limited in size, then* $r_V^*>r^*$.

The proof of the proposition is immediate noting that if $\frac{\partial\pi(s,r)}{\partial r}$ is small, (46) and (47) approximate to (6) and (11) in our previous analysis.

On a final note, we can observe that scaling activity will most likely differ between different industries. It is outside the scope of this paper to fully address this issue but we here highlight a mechanism that we believe is of relevance. If a startup takes more risk in research and is successful, it will possess a more unique high-quality business and/or product. In some industries, this will increase scalability substantially (e.g. in digital network industries), whereas in other industries this will not be the case (e.g. in mining). Following the analysis above we would then conjecture that: In industries with a higher research risk-scalability reward, startups will take higher risk in their research projects. (ii) In industries with a higher research risk-scalability, the difference between risk taking in research is larger between VC-backed startups and independent startups. Thus, the emergence of a VC industry will increase the risk level more in such industries.

10 Conclusions

In this paper, we have investigated how an active VC market affects the creation and scaling of startups. We developed a model in which (i) independent startups could create and scale startups themselves or seek support from VC firms, (ii) the creation and scaling process of startups are characterized by risk, and (iii) the independent startup maximize future profit streams while the VC-backed startup maximizes the exit value (IPO or trade sale) accounting for exit costs (either direct exit costs or indirect exit costs arising from the compensation structures used in the VC industry). Under plausible assumptions regarding how profits depend on chosen risk levels in the research and scaling process, we show that VC-backed startups will choose more high-risk, high-reward research and scaling strategies than independent independent startups. The reason is that the compensation structures and exit costs of VC-backed startups imply that only big (risky) exits pay off. We also show that an active VC market induces independent startups to take on more risky research strategies since VC support may give them a chance to pivot their startup in case of failure, i.e. the VC market provides and option value to startups to pivot in case of early failure.

Our conceptual framework and results have several important implications for academics, practitioners, and policymakers. The conceptualization of risk as an inherent component of scaling firms means that theoretical and empirical researchers should consider the risk of failure in addition to growth of businesses as key objects of analysis. We emphasize that traditional growth metrics such as employment or rate of change in sales revenue are not sufficient to capture what it means to scale as these omit the dimension of risk and we thus add this dimension to established characteristics needed for growth (Demir, Wennberg and McKelvie, 2017). Thus, we point to that ownership type matters for high firm growth as owners that develop startups for sale (VC firms) will have a stronger incentive to take on risk in their scaling decision and this implies that they will be more likely to fail but also the that are successful will grow faster. We also show that the existence of owners that develop startups for sale (VC firms) will create incentive for independent startups to take on more risk in their initial venture since a failure in such high-stake project may improve the terms in a second chance venture with VC financing. Thus, it is important that policy makers, create ecosystems where different type of ownership forms can flourish in order to support and scaling-driven creative destruction process. For practitioners, our framework underscores that business owners willing to scale aggressively must be willing to bear a high risk of failure.

Our framework also underscores the importance of a local VC market in developing scalable business plans and implementing aggressive scaling strategies. A key feature that VC brings to the table are strong incentives to scale due to costs associated with buying and selling businesses. This is a feature of VC that is quite separate from the traditional role academics have highlighted that these investors play, i.e. providing capital, networks, and expertise to the firms they invest in (Rin, Hellmann and Puri, 2013). This also means that our framework has direct policy implications. Because we show that VC firms are key in generating incentives to develop and grow scale-ups, policymakers willing to encourage scale-ups locally should focus on supporting the local VC market. The literature has highlighted many avenues to do this, ranging from government VC programs to getting the right institutional environment in place (Lerner and Tåg, 2013; Bradley, Duruflé, Hellmann and Wilson, 2019; Hellmann and Thiele, 2019).

There are several areas that seem of particular interest for future research. We do not allow for asymmetric information problems. This might affect which type of scaling decision VC-backed startups will choose. It might be the case that very novel scaling strategies could be associated with larger asymmetric information problems and this might put restrictions on the VC-backed startup's scaling decision. On the other hand, it might be of extra value to be successful with a very novel scaling decision when opting for future financing rounds. Thus, examining how the scaling decision and asymmetric information problems generating financing constraints interact seems to be a fruitful avenue for future research.

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A Expected gross profit

Let us now explore the effect of VC on the expected gross profit. Let π^{NVC} be the expected gross-profit when VC is not available to the industry:

$$\pi^{NVC} = (1 - r^*) \cdot (1 - s^*) \cdot \pi(s^*).$$

Let π^{VC} be the expected gross-profit when VC is available to the industry.

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

Then

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