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RESEARCH ARTICLE

New venture creation: innovativeness, speed-to-breakeven, and revenue tradeoffs

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Abstract We present a Schumpeterian model of new venture creation, under uncertainty, which explains the tradeoff between speed-to-breakeven and revenue-at-breakeven and relates this to the level of innovation. We then explore the tradeoffs between these outcomes empirically in a sample of 331 information and communication technology (ICT) ventures using a multi-input, multi-output stochastic frontier model. We estimate the contribution of financial capital and labor to the outcomes and the tradeoffs between them, as well as address heterogeneity across ventures. We find that more innovative (and therefore more uncertain) ventures have lower speed-to-breakeven and/or lower revenue-at-breakeven. Moreover, for all innovativeness levels, new ventures face a tradeoff between speed-to-breakeven and revenue-at-breakeven. Our results suggest that it is the availability of proprietary resources (founder equity and founder labor) that helps ventures overcome bottlenecks in the venture creation process, and we propose a line of research to explain the variation in venture creation efficiency.

Plain English Summary New study uncovers trade-offs in venture creation. Want to be innovative? It could increase time to breakeven. Need revenue fast? Innovation takes a hit. However, founder resources tip the scales for startups. #entrepreneurship #innovation #startupsuccess. This study examines how new businesses deal with uncertainty, focusing on the tradeoff between how quickly they become profitable (speed-to-breakeven) and how much revenue they generate when they do. We analyze data from 331 information and communication technology (ICT) ventures to understand these tradeoffs better, considering factors like financial resources and labor inputs. We find that more innovative ventures, which tend to be more uncertain,

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often take longer to reach profitability and may earn less when they do. Moreover, regardless of their level of innovation, all new ventures face a tradeoff between speed-to-breakeven and revenue. The study highlights that unique resources, such as founder equity and founder labor, help businesses overcome challenges in the venture creation process. It helps to understand why some ventures are more efficient than others in the early stage of creating new businesses.

Keywords Entrepreneurship · Innovation · New venture creation · Proprietary resources · Stochastic frontier analysis · Schumpeterian growth model

JEL Classification O31 · D22 · L26 · L29

1 Introduction

New venture creation (NVC) has been seen as a driving force behind economic growth and development since Schumpeter (2008[1934]), and understanding the process is a core focus in entrepreneurship research (Acs et al., 2013; Carlsson et al., 2013; Sternberg & Wennekers, 2005; Wiklund et al., 2011). NVC is the transformation process by which entrepreneurs acquire and organize resources to establish a viable new enterprise (Davidsson, 2016). In particular, the NVC process is multidimensional, complex, and heterogeneous (Gartner, 1985; Rocha & Grilli, 2024) and its analysis, while assuming some form of maximization, has been a longstanding but difficult issue in the entrepreneurship literature (e.g., Baumol, 1990; Evans & Jovanovic, 1989; Levine & Rubinstein, 2017; Lucas, 1978; Minniti & Lévesque, 2008; Parker, 2018).

Three major theoretical traditions in the entrepreneurship literature are concerned with organizing new firms, associated with Knight (1921), Schumpeter (2008[1934]), and Kirzner (1997). We follow Bylund and McCaffrey (2017) in focusing on the former two, namely 'Schumpeter's innovative entrepreneur' who 'introduces "new combinations" through starting new firms' and 'Knight's judgmental entrepreneur' (Ibid.: 461) who 'act … by allocating resources' and 'by organizing firms' while navigating uncertainty.[1] 'Schumpeterian' economic models (e.g., Aghion & Howitt, 1992; Aghion et al., 2014; Dinopoulos & Thompson, 1998; Segerstrom et al., 1990) conceptualize NVC as an unimportant step in the innovation process (Acs & Sanders, 2012, 2013; Henrekson et al., 2024) in the sense that the profitable opportunities to innovate, once new knowledge has been created, are matched with an entrepreneur without friction or cost. This implies that all innovation rents, in the end, accrue to the inventor, leaving nothing but 'normal' profits for the innovator. In contrast, Schumpeter (2008[1934]) himself argued that it is the anticipation of 'entrepreneurial profits' (rents), not the normal returns to inputs in production, that motivates the entrepreneur to start a new venture. Parallel to this, Knight (1921) emphasized the central role of uncertainty in the entrepreneurial process: uncertainty allows for monopolistic profits and for rents to endure, even in competitive markets with free entry. This explains why successful innovative startups may expect to cover their setup costs over the longer term. To the best of our knowledge, however, a formal, innovation-driven growth model incorporating NVC under uncertainty has not been developed yet (Henrekson et al., 2024), leaving a gap in the theoretical literature this article seeks to fill.

Meanwhile, on the empirical side, the literature on NVC (e.g., Davidsson & Gruenhagen, 2021; McMullen & Dimov, 2013; Samuelsson & Davidsson, 2009; Shane & Venkataraman, 2000; Shepherd et al., 2019) has documented a wide variety of outcome

[1] We thank an anonymous reviewer highlighting that in the literature it is common to contrast Schumpeterian to Kirznerian entrepreneurship (e.g., de Jong and Marsili, 2015). Kirznerian entrepreneurship is usually defined as entrepreneurs acting on arbitrage opportunities. The essence of arbitrage is that such opportunities are certain, or perhaps sometimes risky but not uncertain in a Knight's sense. This makes Kirznerian entrepreneurship less relevant for our discussion here. In contrast, the work of Knight (1921) is highly relevant for science-based entrepreneurship (see also Miozzo and DiVito, 2020, for a discussion of the role of uncertainty therein). Without uncertainty, the model we develop would reduce to that of Aghion and Howitt (1992). Note also that in our sample, all ventures exhibit some degree of innovativeness, which is related to the way we proxy for uncertainty.

measures (e.g., survival, profit, employment growth, investment, innovation) and has considered numerous additional determining factors, such as founder/team characteristics, resource inputs, and environmental variables (Davidsson & Gordon, 2012; Gartner & Liao, 2012; Gelderen et al., 2005; Held et al., 2018). These empirical articles inform our theorizing in that we build a model in which new ventures need to make a tradeoff between outcomes; at the same time, we make the role of proprietary financial and human resources explicit as key inputs in the process. Nevertheless, on the empirical front, the literature still grapples with the problem that NVC is highly heterogeneous.

To address these theoretical and empirical gaps in the literature, we first extend the canonical neo-Schumpeterian endogenous growth model (Aghion & Howitt, 1992) to better understand the NVC process. Key new ingredients in our model are uncertainty over the value of the innovation and the need to reduce this uncertainty by committing proprietary resources (founder's labor and equity). We build on the work of Evans and Jovanovic (1989) who argued that entrepreneurial venturing can be understood as a process whereby the founding team learns about the productivity and profitability of their venture, producing a model where post-innovation monopoly rents incentivize and reward the innovators.

From the model, we derive a number of propositions. Our model predicts tradeoffs between two outcomes of the NVC process: revenue at breakeven and speed-to-breakeven (e.g., Matthews et al., 2018). The level of uncertainty moderates this tradeoff, which captures the idea that more innovative ventures take longer to gestate (e.g., Hill & Rothaermel, 2003; Rocha & Grilli, 2024) and will generate lower revenue initially, but may have higher subsequent revenue growth rates (e.g., Freel, 2000; Gimmon & Levie, 2021; Klette & Kortum, 2004). Our model implies that all outcomes improve with the commitment of proprietary resources, notably, founder's equity and founder's labor.

Our theoretical model explains why, ex post, not all ventures will achieve the maximum possible outcomes: new ventures make choices under uncertainty ex ante, which will imply inefficient use of resources ex post. This is an important motivation for using stochastic frontier analysis (SFA) (Farrell, 1957) to analyze the outcomes of the NVC phase empirically, because ex post inefficiency represents a one-sided error. A firm with access to (more than) sufficient resources will survive the NVC phase, but if resources fall short of the minimum required level, the firm will exit before NVC is complete. Hence, estimating a normal input–output relationship in a sample of completed NVC processes would introduce survival bias. However, this can be eliminated using SFA (Hwang & Kim, 2022; Yang & Chen, 2009), and this leads us to use a multi-output SFA model that accommodates the predicted one-sided inefficiencies (Farrell, 1957; Kumbhakar & Lovell, 2003).

Using this empirical approach, we test our model's propositions using data from the Perfect Timing Database, which contains timestamped information on newly established ventures between 2004 and 2014 in the ICT sector in the US, UK, Germany, and Italy (see Held et al., 2018; Herrmann et al., 2024). We show that more innovative ventures tend to take longer to attain breakeven and have lower revenue at that time. In this data, we also find empirical support for the existence of the empirically well-established tradeoff between revenue-at-breakeven (RAB) and speed-to-breakeven (STB), our empirical proxies for, respectively, the levels of revenue and time to the end of the NVC process. We also find that of the labor employed and capital invested, it is especially the 'founder's sweat equity' (Bhandari & McGrattan, 2021) and the founder's financial equity that contribute to better outcomes in new ventures. This finding aligns with founders possessing greater relevant capabilities for their new venture and being more strongly motivated (He, 2008) and thus working more productively than paid employees or hired service providers (Santos & Cardon, 2019). Also, following the logic of Barney (1991) and Alvarez and Barney (2005), it is the proprietary founder's labor and equity that are fundamental in shaping a venture's advantage over its competitors. In contrast, hired labor and external capital are market resources for which we find that they do not constrain new venture choices at the frontier.

This article thus offers three distinct contributions. First, our model expands the canonical (neo-) Schumpeterian model of creative destruction by Aghion and Howitt (1992) with a new venture creation phase that precedes the phase of innovation-based monopolistic competition. This extension helps us to understand how NVC and limited access to proprietary resources may create important bottlenecks in the innovation process. Moreover, it introduces the quintessential entrepreneurial process that Schumpeter himself emphasized in his work, but that, to the best of our knowledge, has not yet been modelled in (neo-)Schumpeterian growth theory (Henrekson et al., 2024). Second, we empirically confirm the existence of our model's predicted tradeoffs between outcomes in NVCs in the ICT sector, especially between outcomes related to long-term benefits associated with innovation (Haschka & Herwartz, 2020, 2022) as against short-term financial gains. Moreover, we show that these tradeoffs are less constraining when new ventures have greater access to proprietary resources. The latter suggests that institutional reforms to increase the availability and access to founder equity and founder team labor will help relax bottlenecks in the innovation process and help turn knowledge creation into new business formation and growth. Third, we explore the idea that there will be ex post variation in the efficiency with which new ventures use their resources. Thus, we relax the assumption of homogeneity among ventures in the NVC phase and pioneer the use of the multi-output SFA for estimating NVC outcomes. Our results suggest that the inefficiency among new ventures is substantial, yet while accounting for that inefficiency we may still estimate unbiased, significant, and quantitatively relevant output elasticities for the inputs considered.

Section 2 presents our theory and develops our model. Section 3 motivates the empirical approach and presents the data. Section 4 offers the empirical results, which we discuss in Sect. 5. Section 6 concludes.

2 Theory and model

The theory of NVC we present starts from the assumption that NVC is ex ante uncertain. That is, the founding team cannot compute an expected value for the new venture. The founders will have to explore the opportunity they identified and learn about the value and productivity of their venture as they go. Next, we assume both that uncertainty is larger for more innovative ventures and that founders go on learning about the opportunity, up to the point when uncertainty becomes calculable risk. At that point, we assume venture creation is concluded, and the venture can be sold at a price equal to the (expected present) value of the new firm, as in the canonical neo-Schumpeterian Aghion and Howitt's (1992) model.

2.1 Basic setup

We begin with time-based constructs, where we denote a point in time by t, refer to continuous time by τ, and to the time the NVC phase is completed by T. The NVC phase starts with the registration of the new venture at $\tau = 0$ and ends with the venture achieving stable profit at $\tau = T$. We denote founder labor and hired labor employed in the venture at time t by f_t and h_t, respectively. Without loss of generality, founder labor and hired labor are perfect substitutes in production; in other words, the total labor function $(f_t + h_t)$ at time t allocates the same weight to each labor type, an assumption which does not impact our main results. Importantly, as we will further describe below, founder labor has an additional uncertainty-reducing effect that is consistent with Evans and Jovanovic's (1989) view of founders possessing capabilities that enable them to reduce uncertainty as they learn about the productivity and profitability of their venture.

Figure 1 illustrates how we deviate from the timeline in neo-Schumpeterian endogenous growth models in general and in Aghion and Howitt's (1992) model in particular. Specifically, we add a phase of new venture creation between the point in time $t = 0$, when invention has been made and the new venture is registered, and the time $t = T$, when the new venture starts earning stable profits in a market with monopolistic competition in which the present value of future expected rents is known and hence the venture can be (objectively) valued. To determine the revenue at any time t, we rely on a Cobb–Douglas production function, where the production inputs at time t are capital invested in the venture denoted by k_t, founder labor f_t, and hired labor h_t. In contrast to a linear production function, the multiplicative form of a Cobb–Douglas function ensures that both capital and labor are necessary to produce goods and generate revenues. Denoting observed productivity at time t by A_t, we can write total revenue in the venture (Walters, 1963) at time t as the multiplication of production quantity by unit price. Formally:

$$R_t = y_t p_t = \left[A_t k_t^{1-\beta} \left(h_t + f_t \right)^{\beta} \right] \times p_t, \tag{1}$$

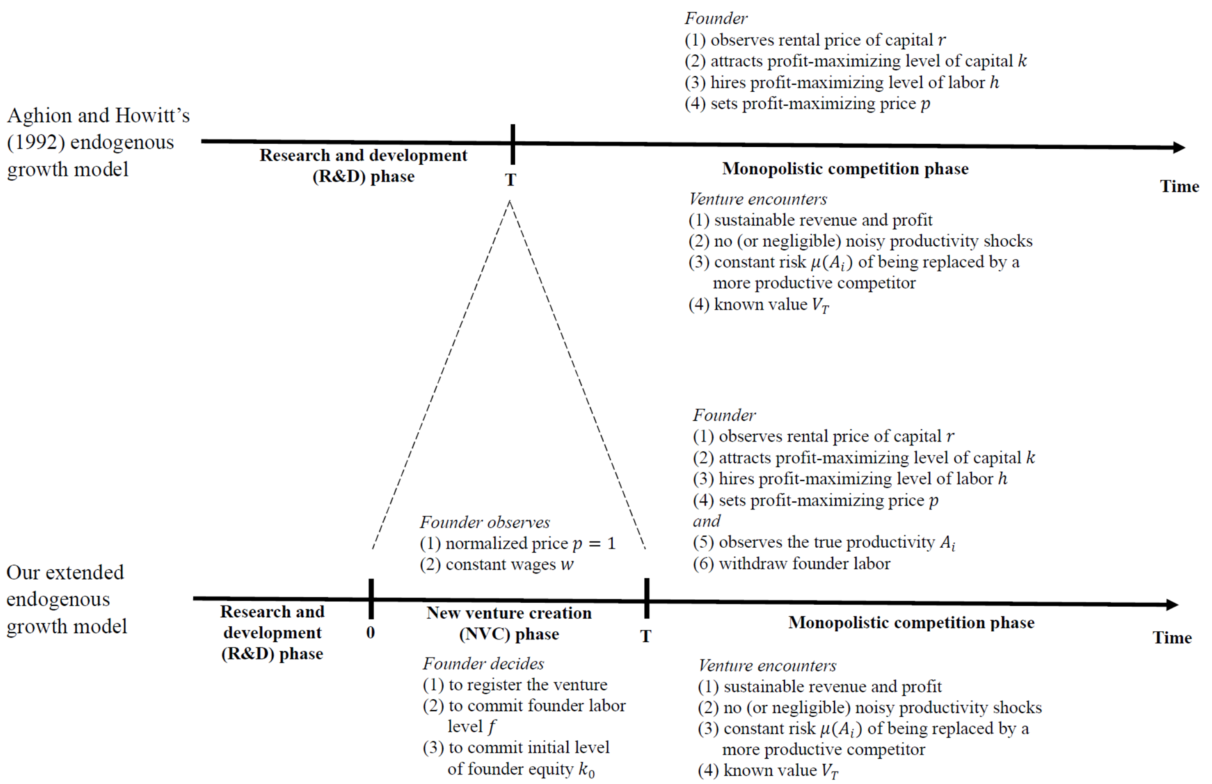

Fig. 1 Timeline of decisions and events

where $y_t = \left[A_t k_t^{1-\beta}\left(h_t + f_t\right)^{\beta}\right]$ is the produced quantity, $(h_t + f_t)$ is total labor production input, and p_t is the unit price, all at time t. Moreover, $0 < \beta < 1$ is the output elasticity of labor. We assume constant returns to scale in production, which is a reasonable assumption in the NVC phase, in contrast to a subsequent scaling-up stage when economies of scale are expected to play a large role.

Next, we operationalize uncertainty during the NVC phase. At the start of venture creation, a venture's productivity is assumed to be unknown by its founding team (or any other potential stakeholders). Consequently, we first define A_i as the unknown venture-specific *true* productivity parameter—*true* in the sense that the variance of the noise surrounding productivity becomes nil. Observed productivity, A_t, gives a noisy signal of the venture's true productivity during new venture creation. We operationalize uncertainty by introducing a noise term, denoted by I_t^2 (squared to remain nonnegative), where I_t is drawn from a normal probability distribution, that is, $I_t \sim N\left(0, \sigma_t^2\right)$. We then define:

$$A_t = A_i - I_t^2. \tag{2}$$

We assume that the variance σ_t^2 of the noise I_t and its distribution are unknown to the founders at time $t = 0$, such that observed productivity starts out as an uncertain variable with an ex ante unknown distribution. However, consistent with the view that founders possess capabilities that enable them to reduce uncertainty (Evans & Jovanovic, 1989), the cumulative time that founders spend working in the venture, which corresponds to $\int_0^t f_\tau d\tau$ at time t, is assumed to reduce the variance σ_t^2 of the noise I_t. Therefore, we can write $\sigma_t^2 = P(\int_0^t f_\tau d\tau)$, where the function P decreases as its argument, $\int_0^t f_\tau d\tau$, increases.

To further specify the function P, we set $f_t = f$ for all $t \in [0, T]$, where we will explain below why engaging all available founder labor (i.e., f) throughout the NVC phase is also optimal. Hence, $\int_0^t f_\tau d\tau = f(1+t)$ and we use $\sigma_t^2 = P(f(1+t)) = \max\left[\left[\frac{A_i}{f(1+t)}\right] - 1{,}0\right]$. Intuitively, this specification implies that founders' labor reduces the noise, and the founders thus get to know the venture's true productivity and consequently its market value (when the noise variance is reduced to 0) in finite time by committing their own labor to the venture (Moeen, 2017; Moeen et al., 2020). We also make the noise variance σ_t^2 a positive function of the true productivity A_i, reflecting the fact that more innovative ideas and more radical inventions typically imply more uncertainty of the venture value when it is created (e.g., Colarelli et al., 2013). Figures 2 and 3 show some illustrative simulations of how productivity may evolve over the NVC phase and converges to the true level of productivity over time when a positive amount of founder labor is committed (leading the variance of the noise to reach 0 in finite time). Consistent with the above specification, Fig. 2 shows that, all else equal, a higher true productivity A_i implies a higher variance and thus a longer NVC

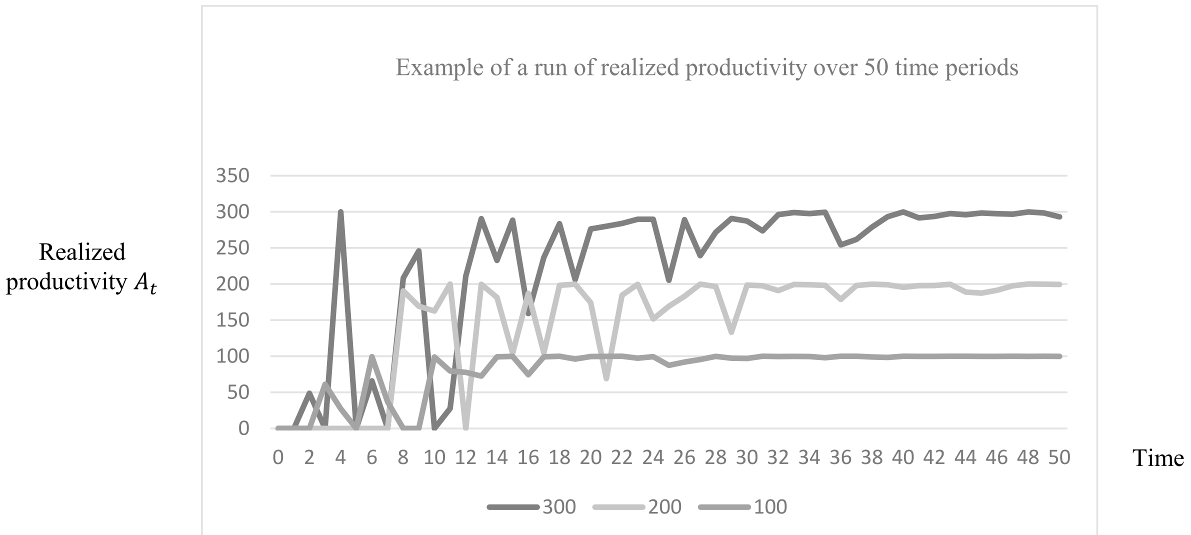

Fig. 2 Simulation of uncertainty reduction for the same level f (1.5) of founder labor and different levels A_i of the true productivity

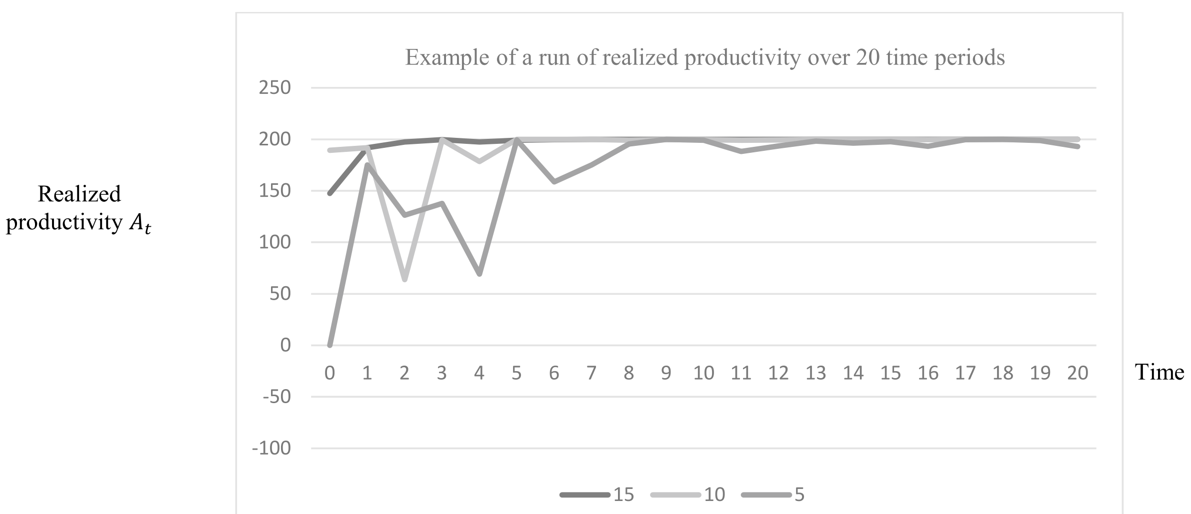

Fig. 3 Simulation of uncertainty reduction for same level A_i (200) of true productivity and different levels f of founder labor

phase, whereas Fig. 3 shows that, all else equal, more founder labor (i.e., larger f) implies faster elimination of such uncertainty.

The next step is to describe equity evolution during the NVC phase. Without loss of generality, we can normalize the unit price, p_t, during the NVC phase to 1; hence, revenue equals production quantity in that phase. We propose that the uncertainty during the NVC phase implies that the venture cannot be objectively valued, not even in expectation terms and not even by the founders themselves. This will limit access to external funding at this stage and we assume all capital goods are financed with founder equity only.[2] We can also expect that founder labor does not receive a wage to enable more investment in the venture (Wasserman, 2006). Consequently, costs during the NVC phase are given by $C_t = wh_t$ at time t (recall that h_t is hired labor at time t), where wages w are assumed to be known and constant.[3] With k_0 as the initial founder equity available to the venture at time $\tau = 0$ and R_τ as the revenue at time τ for $0 \leq \tau \leq t$, equity in the venture at time t (which must remain nonnegative) evolves according to:

$$k_t = k_0 + \int_0^t \left(R_\tau - C_\tau\right) d\tau \geq 0. \tag{3}$$

The last piece of the basic setup pertains to what happens once the NVC phase is over (i.e., after $t = T$). As founders learn about the venture, the variance σ_t^2 of the noisy productivity shocks I_t, over time, falls to zero. Once all uncertainty has been resolved at the end of the NVC phase at time T (i.e., $\sigma_T^2 = 0$), our model starts to mimic Aghion and Howitt's (1992) model of Schumpeterian growth, as portrayed in Fig. 1. From that point onwards, the venture can attract financial capital at the going market rate r and hire labor and rent capital to the (known) profit maximizing levels. Also, the venture has a monopoly on its innovative product, and we assume it faces a stable, isoelastic demand curve given by $y_t^d = p_t^{-\varsigma}$ with $\varsigma > 1$ (a commonly used demand function (e.g., Acs & Sanders, 2012, 2013; Jovanovic, 2019). Although there is no more uncertainty, all new ventures do risk being replaced by a new entrant with even better technology. Following Aghion and Howitt (1992), we assume that this happens at some constant (flow) probability $\mu(A_i)$ with $d\mu/dA_i < 0$. We keep the function $\mu(A_i)$ exogenously fixed, which implies that a less innovative venture is more likely to be replaced than a more innovative one, capturing 'creative destruction' (Aghion & Howitt, 1992).[4] Table 1 summarizes the notation we have introduced.

2.2 Behavior and equilibrium

We solve our model backward by first considering the phase beyond time T when uncertainty has been eliminated and the variance σ_t^2 of the venture's productivity noise at any $t \geq T$ is equal to 0. From that point onwards, we have set up above (in particular, following Aghion & Howitt, 1992; Evans & Jovanovic, 1989) that the venture will (i) engage in monopolistic competition; (ii) face a known and stable isoelastic demand curve, $y^d = p_t^{-\varsigma}$; and (iii) operate a deterministic production technology that generates revenue $R_t = \left[A_t k_t^{1-\beta}\left(h_t + f_t\right)^\beta\right] \times p_t$ (from Eq. (1)); note that p_t appears explicitly here because it is normalized to 1 only during NVC, but is set to the profit maximizing level afterwards. With all uncertainty over productivity and market viability resolved, the profit maximizing levels of capital, labor, and price are known and constant over time for a constant wage w and rental rate of capital r; in other words, $k_t = k$, $p_t = p$, and $h_t = h$ for any $t > T$, as in Aghion and Howitt (1992). Given profit maximizing inputs and price, the stable demand function implies a known profit flow and to value the venture at time T, we must discount that profit flow by the market interest rate plus the risk of the new venture

[2] In practice, financial innovations for new ventures deliver more flexibility than we allow in our model through, for example, convertible loan notes, which provide capital without valuation during NVC.

[3] We make this assumption to prevent market wages from causing dynamics in our model. We abstract from these dynamics since they are outside of our focus. Moreover, if hired employment in new ventures is small relative to total employment, this assumption may not be so restrictive.

[4] Note that in Aghion and Howitt (1992), the probability of being replaced depends on the economy wide level of R&D. As the focus here is on decisions made by founders in new ventures, we can abstract from that macro-level feedback loop that growth theory is primarily interested in. We assume that the risk of being replaced is given to the venture and depends only on its level of innovativeness.

Table 1 Notation summary and assumptions

Notation	Descriptions	Assumptions
t,τ, or , T	Time	• Time τ is continuous and strictly positive running from 0 to T for the NVC phase and from T onward for the monopolistic competition phase • Subscript t or τ indicates a value at time t or τ
f_t	Founder labor at t	Non-negative for any t
h_t	Hired labor at t	Non-negative for any t
$A_t = A_i - I_t^2$	• Realized productivity at t • For any t, A_t is a noisy signal of the true productivity A_i that becomes more precise as the variance falls over time with cumulative labor from the founder	• A random draw with $I_t \sim N(0, \sigma_t^2)$ • As time t unfolds, the uncertainty of the venture's productivity diminishes and A_t converges to the true productivity A_i • Hence, variance σ_t^2 (> 0) decreases as time t unfolds and the founder accumulates experience through that founder's labor, with$\sigma_t^2 = P(\int_0^t f_\tau d\tau) = \max\left[\frac{A_i}{f(1+t)} - 1,0\right]$, where $\int_0^t f_\tau d\tau = ft$ and f is the constant total available founder labor at each period t and thus$P(.) > 0$,$P(.)\prime < 0$, and$P(.)'' > 0$, such that the variance falls to 0 in finite time • Variance σ_t^2 is larger when the true A_i is larger than when it is smaller, and hired labor is not efficient in reducing uncertainty of the venture's productivity
p_t	Price charged for the product	• Normalized to 1 during the NVC phase over $t \in [0, T]$ such that revenue equals production output during that phase • Facing isoelastic demand $y_t^d = p_t^{-\varsigma}$, with $\varsigma > 1$, after the NVC phase (i.e., for the monopolistic competition phase where $t \geq T$), after setting the price to maximize profit
$R_t = y_t p_t = A_t k_t^{1-\beta} (h_t + f_t)^\beta p_t$	R_t is revenue y_t is production k_t is capital	Where $0 < \beta < 1$ implies a Cobb–Douglas production function in labor and capital, in which founder labor f_t and hired labor h_t are perfect substitutes in production
$C_t = wh_t$	Total cost from hired labor at t, where w is a fixed marginal labor cost	We only analyze new ventures and can thus assume that they are small relative to the total labor market
$k_t = k_0 + \int_0^t (R_\tau - C_\tau) d\tau \geq 0$	The venture's intertemporal budget constraint	• Initial equity k_0 is exogenous • Initial equity k_0 added to the revenues generated up to t are used to cover hired labor costs up to t • Equity must remain nonnegative at every point in time

being replaced by one with an even better technology.[5] The venture can thus be objectively valued at market prices, as in Aghion and Howitt (1992). This implies that the founders can sell their venture to external investors to recover founder equity plus any equity accumulated in the venture up to time T (or decide to leave it in the venture for the market return r). Considering that founders have marginally higher opportunity costs than the exogenous wage (or would charge a premium to work as paid employees in an established organization), we can also expect that founders

[5] The discounted expected value of a constant income flow that risks being terminated at a constant probability per period, is equal to the value of that constant income flow to infinity, discounted at the discount rate *plus* the probability the income is lost completely. See Aghion and Howitt (1992).

withdraw their labor from the venture at time T (i.e., $f_t = 0$ for any $t > T$).[6] With full access to labor and capital markets, the owners of the venture can now hire labor and rent capital to maximize the value V_t of the venture at time $t = T$.

Therefore, following Aghion and Howitt (1992), the value V_T of the venture at T is equal to the expected discounted present value of all future profit flows, which can be expressed in exogenous variables and parameters. This represents the value of the venture to outsiders considering buying the venture at time T, and cumulates the discounted (constant) profit up to infinity. The founders can thus sell the venture to investors at a price:

$$\max_{h,k,p} V_T = \int_T^{\infty} e^{-r\tau}(R_\tau - C_\tau)d\tau \ s.t. \begin{cases} R_\tau = yp = A_i(k)^{1-\beta}(h)^{\beta}p \\ y \geq y^d = p^{-\varsigma} \\ C_\tau = wh + rk \end{cases} \text{for } \tau > T. \tag{4}$$

Appendix A shows that V_T can be expressed as:

$$V_T = \int_0^{\infty} e^{-(r+\mu(A_i))\tau} \frac{1}{\varsigma}\left[\frac{\varsigma}{\varsigma-1}\left(\frac{w}{\beta}\right)^{\beta}\left(\frac{r}{1-\beta}\right)^{1-\beta}\frac{1}{A_i}\right]^{1-\varsigma} d\tau = \frac{1}{(r+\mu(A_i))\varsigma}\left[\frac{\varsigma}{\varsigma-1}\left(\frac{w}{\beta}\right)^{\beta}\left(\frac{r}{1-\beta}\right)^{1-\beta}\frac{1}{A_i}\right]^{1-\varsigma}, \tag{5}$$

where $\mu(A_i)$ is the (constant) probability that the new venture is made obsolete by future new ventures at any time $\tau > T$. If we also recall that $\varsigma > 1$, from Eq. (5), we can directly conclude that the established venture will, all else equal, be more valuable when (i) wages w are lower; (ii) capital costs r are lower; (iii) the venture's true productivity A_i is higher; (iv) the elasticity of demand, which is $\frac{dy^d}{dp}\frac{p}{y^d} = -\varsigma$, is lower; and (v) the impact of the output elasticity of labor β on an established venture's value will be ambiguous and depends on the relative factor price w/r. Results (i) to (v) are identical to the canonical (neo-)Schumpeterian growth model and our more interesting results are obtained from considering the NVC phase.

The founders receive the venture value V_T, as per Eq. (5), once the NVC phase ends at time T. At that point, the founders can also withdraw the equity that has been committed at the start plus any possible retained earnings during the NVC phase. From valuing the created venture for the founders at T and discounting that value to the point in time when the choice for committing founder equity and hiring labor during NVC is made, we obtain:

$$e^{-\rho T}V_T + e^{-\rho T}k_T = e^{-\rho T}\left(V_T + k_T\right), \tag{6}$$

where ρ is the founders' discount rate for $0 \leq \tau \leq T$. This parameter reflects the founders' attitudes towards uncertainty, risk, and time, and it may deviate from market rates. k_T is the value of accumulated equity in the venture at time T, which from that point onwards, the founders can invest at the rental rate of capital, both in and outside the new venture. That is, Eq. (6) captures the value of the venture to the founders and consists of the discounted present value of expected future profits (i.e., $e^{-\rho T}V_T$) added to the value of equity accumulated in the venture between the start and end of the NVC phase (i.e., $e^{-\rho T}k_T$), both discounted to the start of that process at time $t = 0$. For simplicity and tractability, we assume that all decisions to commit and hire resources for venture creation are made at the start of NVC.[7] The founders choose k_0, $h_0 = h_T$, and f at $t = 0$, when the venture

[6] Note that scholars offer ample evidence of founders leaving the venture after an initial public offering or trade sale, including Souitaris et al. (2020) and Rouse (2016).

[7] This is a simplification. We are aware that founding teams will keep adjusting the size of their own and hired labor inputs as well as look for investors to boost the equity and capital in the venture. Allowing for such dynamics, however, would significantly complicate the mathematics while adding little additional insight. If hiring and firing labor and attracting additional capital is costly, this will reduce adjustments to capital and labor employed during NVC. This simplifying assumption can then be interpreted as a limiting case with infinite resource adjustment costs.

starts producing output, at which point the founders start to also draw noisy signals of the true productivity in the form of (negative) productivity shocks (as per Eq. (2)).

Discounting to the start of the NVC phase implies that the founders will want to minimize T. Discounting drives the founders to engage all available founder labor, as it carries no opportunity costs in our model and is the only way to shorten the NVC phase. This explains why we could set $f_t = f$ for all $t \in [0, T]$ earlier. Our specification of σ_t^2 then also implies a negative correlation between the length of the NVC phase, T, and the level of true productivity, A_i. Moreover, since V_T does not depend on the choice variables, maximizing Eq. (6) implies choosing h_T and k_0 to maximize k_T. From Eq. (3), since an increase in k_0 will increase k_T (more than one-for-one as, conditional on survival, adding one unit to k_0 implies one extra unit of k_T directly and more k_0 increases revenue for given costs throughout NVC) and increases the probability of surviving the NVC phase (i.e., $\text{Prob}\left(k_t \geq 0 \forall t \in [0, T]\right)$ increases), the founders will commit all available founder equity, k_0, as capital in the venture. Then, recalling that price is normalized to 1 during that phase without loss of generality, the problem facing the founders at the start of the NVC phase can be simplified to:

$$\max_{h_T} k_T = k_0 + \int_0^T \left[R_t - C_t\right] dt \; s.t. \begin{cases} R_t = (A_i - I_t^2)\left(k_0\right)^{1-\beta}\left(f + h_T\right)^{\beta} \\ C_t = wh_T \\ E\left[I_t^2\right] = 0 + \sigma_t^2 = max\left[\frac{A_i}{f(1+t)} - 1{,}0\right] \end{cases} \text{for } t \in [0, T], \tag{7}$$

where we assume that founder equity, k_0, is used to finance the capital stock purchased at the start of NVC and available throughout the NVC phase.[8] Appendix B shows that for the optimal level of hired labor we then obtain:

$$h_T = k_0 \left(\frac{\beta}{w}\right)^{\frac{1}{1-\beta}} \left(1 + \left(1 - \frac{Log\left[\frac{A_i}{f}\right]}{A_i - f}\right) A_i\right)^{\frac{1}{1-\beta}} - f \tag{8}$$

From Eq. (8), given the founders' Knightian 'judgement call' on the true productivity $A_i (> f > 0)$, we can derive a set of results, namely that founders should hire more labor when (vi) initial founder equity k_0 is higher, (vii) wages w are lower, (viii) the output elasticity of labor β is higher, (ix) their initial guess on productivity A_i is higher,[9] and (*x*) less founder labor f is available.

2.3 Propositions and their translation into testable hypotheses

A major difficulty in testing predictions of a model on NVC arises from the fact that it is very difficult to observe ventures in the making. Such data, with sufficient observations for statistical inference, are backward-looking. Given this limitation, we now develop propositions that are expected to hold in a sample of ventures that have completed the NVC phase. Note that such a sample will, by construction, not be representative of the population of all ventures that are started. If new ventures are started continuously, a cohort of ventures that were started between any two points in time will always consist of (a) those that have completed the NVC phase, (b) those that have not yet done so and are still in the NVC

[8] The alternative of making capital employed in the venture equal to initial equity plus retained earnings, would contrast with our assumption that hired labor is fixed. Moreover, new ventures rarely have significant profits to retain and will typically burn financial capital during venture creation. We therefore assume the capital goods employed in the venture equal k_0 and require the new venture to remain solvent throughout, $k_t \geq 0$ for all $0 < t < T$.

[9] Note that for Result (ix), the sign of $\frac{\partial h_T}{\partial A_i}$ is equivalent to the sign of $\frac{\partial}{\partial A_i}\left[\left(1 + \frac{Log\left[\frac{A_i}{f}\right]}{f - A_i}\right)A_i\right] = \left(1 + \frac{Log\left[\frac{A_i}{f}\right]}{f - A_i}\right) + A_i \left[\frac{Log\left[\frac{A_i}{f}\right]}{[f - A_i]^2} + \frac{f}{A_i[f - A_i]}\right] = \frac{A_i Log\left[\frac{A_i}{f}\right] + f - A_i}{A_i[f - A_i]^2}$ or, equivalently, the sign of $A_i Log\left[\frac{A_i}{f}\right] + f - A_i = A_i\left[\frac{f}{A_i} - Log\left[\frac{f}{A_i}\right] - 1\right]$, which is positive since $x - (1 + Log[x]) > 0 \;\; x < 1$. Similarly for Result (x), $\frac{\partial h_T}{\partial f} < 0$ if $\frac{\partial}{\partial f}\left[\frac{Log\left[\frac{A_i}{f}\right]}{A_i - f}\right] = \frac{Log\left[\frac{A_i}{f}\right]}{[A_i - f]^2} + \frac{1}{fA_i[A_i - f]} = \frac{1}{[A_i - f]}\left[\frac{Log\left[\frac{A_i}{f}\right]}{[A_i - f]} + \frac{1}{fA_i}\right] > 0$, which holds true.

phase, (c) those that have started but already failed during the NVC phase, and (d) those that have completed the NVC phase and were subsequently displaced by more innovative ventures in their monopolistic competition phase (i.e., ventures that were destroyed by a next relevant innovation between the end of their NVC phase and the time of sampling). In a subsample of existing firms that have completed the NVC phase, we will thus not observe those that satisfy the conditions (b)–(d).

Given the results from the model, and assuming that numerous new business ventures are starting up, where each venture i starts with its own unique vector $\left(A_i, f, k_0\right)$, we derive the following two propositions:

Proposition 1: *All else equal, in a sample of ventures that completed their NVC phase, the correlation between true productivity* (A_i) *and venture creation speed* ($1/T$) *will be negative and thus a tradeoff will arise between true productivity and venture creation speed.*

Proposition 2: *All else equal, in a sample of ventures that completed the NVC phase, the correlation between revenue level* (R_T) *and venture creation speed* ($1/T$) *will be negative and thus a tradeoff will exist between revenue and venture creation speed.*

Proposition 1 follows directly from $T = (A_i - f)/f$, which is the time at which the variance of the noise term in productivity reaches 0 and the NVC phase is completed (see Appendix B). For a given f, a higher A_i implies a higher T and, consequently, a lower $1/T$. Considering that true productivity and remaining uncertainty cannot be measured directly, our empirical proxy for true productivity A_i will be the innovativeness of the venture (INN) and we will proxy for venture creation speed with speed-to-breakeven (STB).[10] We can then restate Proposition 1 in terms of these variables as a testable hypothesis:

Hypothesis 1: The elasticity of speed-to-breakeven (STB) with respect to innovativeness (INN) is negative.

For Proposition 2, since, for any $t \geq T$, $R_t = p^{1-\varsigma} = \left[\frac{\varsigma}{\varsigma-1}\left(\frac{w}{\beta}\right)^{\beta}\left(\frac{r}{1-\beta}\right)^{1-\beta}\frac{1}{A_i}\right]^{1-\varsigma}$ from Eq. (A7) in Appendix A, the revenue R_t is positively correlated with A_i and Proposition 2 follows from Proposition 1. We should also note that the elasticity of revenue with respect to true productivity A_i is $\varsigma - 1$, whereas the elasticity of venture creation speed with respect to true productivity is $A_i/(f - A_i) = -1/(1 - f/A_i)$. And because $1/(1 - f/A_i) > 1$ from our assumption that $A_i > f$, we should expect the tradeoff between venture creation speed and revenue at the end of the NVC phase to be smaller than the impact of true productivity on both outcomes if $1 < \varsigma < 2$, whereas this is ambiguous if $\varsigma \geq 2$. In our empirical model, where we will take revenue-at-breakeven (RAB) as our proxy for revenue at the end of the NVC phase (R_T), our testable hypothesis from Proposition 2 then becomes.[11]

Hypothesis 2: The elasticity of speed-to-breakeven (STB) with respect to revenue-at-breakeven (RAB) is negative.

Furthermore, we can relate our outcome variables (venture creation speed $1/T$ and revenue R_T) to the inputs (founder labor f, hired labor h, and founder equity k_0), for given true productivity (A_i) at the end of the NVC phase (i.e., at time T). Considering that h, the hired labor, does not affect the outcome variables directly, we formulate propositions for founder labor and initial equity only. Formally,

Proposition 3: *All else equal and given true productivity* (A_i) *in a sample of ventures that completed the NVC phase, the correlation between any of the two outcome variables (i.e., venture creation speed,* $1/T$, *and revenue at the end of the NVC phase,* R_T) *and founder labor* (f) *will be positive.*

Proposition 4: *All else equal and given true productivity* (A_i) *in a sample of ventures that completed the NVC phase, the correlation between venture creation speed* ($1/T$) *and initial equity*

10 Our proxy *innovativeness* (*INN*) is based on indicators of the novelty of the product or service provided. For the exact definition of our constructed variables, refer to Sect. 3.3. Proxying for true productivity by the innovativeness of the product is consistent with Crepon et al. (1998) and Hall (2011: 14) who concluded that: “innovative sales are associated with revenue productivity, and that the association is stronger for higher technology sectors”.

11 We will compare the size of the estimated elasticities between Hypotheses 1 and 2 to infer what demand elasticity seems most plausible empirically.

(k_0) will be (close to) zero, but the correlation between revenue at the end of the NVC phase (R_T) and initial equity (k_0) will be positive.

In Proposition 3, for venture creation speed, $1/T$, we observe that founder labor f reduces $T = (A_i - f)/f$. For the revenue R_T at the end of the NVC phase, more founder labor reduces the variance of the negative shocks on the productivity during the NVC phase, which implies, on average, a lower loss and higher revenue (and profit) over the NVC phase. Hence, more capital will remain in the venture, which will result in higher production and thus revenue at time T. If we allow for ventures to differ on true productivity A_i, ventures that start with a greater productivity (i.e., a greater A_i), all else equal, will have a higher probability of successfully completing their NVC phase when more founder labor is engaged, because the random shocks to the productivity will eliminate more ventures with less founder labor.

For Proposition 4, the founders' initial equity k_0 does not affect the length of the NVC phase since $T = (A_i - f)/f$ is unaffected by k_0. Nonetheless, more initial equity implies that more capital is employed in the venture, causing production at any time t and thus revenue R_T at time T to be greater. Ventures with greater true productivity (i.e., greater A_i), all else equal, have a higher probability of successfully completing their NVC phase when they have more initial equity. Thus, the random shocks to productivity will tend to eliminate ventures with less initial equity. We will accommodate this in our empirical specification by estimating the model with our proxy for true productivity, innovativeness (INN), as a third outcome variable. That way, we estimate the marginal effect of higher founder labor and higher initial founder equity on revenue-at-breakeven (RAB) and/or speed-to-breakeven (STB) for all different levels of innovativeness (INN). The testable hypotheses we can derive from Propositions 3 and 4 are thus:

Hypothesis 3: The elasticity of each of the three outcome variables, speed-to-breakeven (STB), revenue-at-breakeven (RAB), and innovativeness (INN) with respect to founder labor is positive.

Hypothesis 4: The elasticity of each of the three outcome variables, speed-to-breakeven (STB), revenue-at-breakeven (RAB), and innovativeness (INN) with respect to founder equity is positive.

Our final proposition motivates why we estimate our empirical model with a frontier estimation approach. This allows for one-sided heterogeneity whereby we expect to find new venture inefficiency, that is, there are ventures that do not maximize the outcomes for given inputs or, equivalently, spend more inputs to achieve the same outcomes as other ventures in the sample. In the NVC phase, this can happen because firms do not directly compete for the proprietary resources engaged. The founders do not have complete information and even lack the information to maximize their ventures' value in expectation terms. The zero lower-bound on venture equity (i.e., $k_t \geq 0$ for any $t \in [0, T]$) eliminates ventures that experience an unlucky sequence of draws for their productivity. The process is more likely to eliminate those that enter the NVC phase with low levels of equity or founder labor, such that after elimination, only those with relatively high levels of inputs for the measured outcomes will have survived the NVC phase and remain in the sample. Formally,

Proposition 5: *In a sample of ventures that completed (and survived) the NVC phase and for a given true productivity distribution, there is a one-sided (negative) heterogeneity in performance in the sample; that is, surviving ventures use more founder labor and more founder equity to achieve the same levels of revenue (at the end of the NVC phase) and venture creation speed as their most efficient peers, and/or surviving ventures achieve lower outcomes for similar levels of inputs*

Proposition 5 follows from first noticing that in our model, true productivity (A_i) is exogenously given and together with the exogenously available founder labor (f), fully determines the venture creation speed (since $1/T = f/(A_i - f)$). Endogenous heterogeneity in performance can thus only come from the level of revenue realized during venture creation. Consider the ventures that successfully complete the NVC phase. The ex post best performers have guessed their true productivity most accurately ex ante and therefore hired an optimal level of labor for that level of productivity. This level is also optimal ex post if the realization of the productivity shocks remains close to zero, and thus actual productivity was always close to true productivity. Given their productivity and level of founder labor, such ventures would then maximize revenue. Note that the random productivity shocks always reduce productivity (they are squared and subtracted) and, consequently, a very noisy initial signal would cause an underestimation of the true productivity level. These founders would then hire too little labor. Moreover, in the realization of the productivity shocks, ventures can experience larger or smaller shocks than ex ante expected. If the realized shocks turn out to be larger (unlucky draws), they would, all else equal, lose equity and these shocks could even drive the venture into insolvency. If the shocks are smaller (lucky draws), the ventures would turn a positive profit, but the initial negative signal implies that the venture has hired too little labor ex post and therefore reaches stable profits at a sub-optimally low level of employment and, therefore, production and revenue at time T. In sum, because of the random shocks to new venture's productivity and cashflows, those that enter the NVC process with inefficiently high levels of founder equity and/or founder labor, are more likely to survive, whereas those with too little will drop out of the sample, causing only a few lucky ventures to achieve maximum outcomes given inputs and many more to fall below these efficient frontier ventures.

We would expect the interaction of random productivity shocks and proprietary resource allocation decisions to generate non-random attrition in our sample that results in relatively high levels of inefficiency that are likely to be truncated normally distributed around some positive mean.

3 Empirical method and dataw

From our stylized formal model, we have derived five hypotheses under the assumption that NVC is an inherently unpredictable process. In our theoretical model, we assume that every new venture is unique and develops under deep uncertainty for external parties and founders alike. The success of the NVC phase depends largely on the complex and unpredictable interactions between the founders' talents and resources, the technology that is being explored, and the environment in which the venture is launched. We cannot usefully model this in the traditional way as a process where the decision makers rationally and efficiently employ resources by setting the market price equal to the input's (expected) marginal value product. Instead, founders must engage with uncertainty and, although external labor can be employed at the market wage, it is the proprietary resources which drive this process. When testing Hypotheses 1–4, we must consider that, in the data, the complex interactions between the resources, technology, and venture environment cause heterogeneity across firms during their NVC phase, potentially reducing their speed-to-breakeven or revenue-at-breakeven level for different levels of innovativeness. Such 'inefficiency' is, as we have shown in Proposition 5, to be expected in a sample where only firms that have completed the venture creation process are represented. We use an empirical method that explicitly accounts for this inefficiency to ensure that it does not bias our estimates.

3.1 Empirical method

It is helpful to introduce some additional notation at this point. A firm's NVC phase can be conceptualized as a transformation process in which an entrepreneurial team acquires and (re)arranges a set of N resources that we can represent by an $N \times 1$ input vector x_i^N. These inputs are used to achieve a set of M objectives (or outputs) that can be represented by an $M \times 1$ vector y_i^M. We assume that the mapping of inputs onto outputs is stable over all observations i and can be described by the function $y_i^M = f(x_i^N)$. Standard regression analysis then proceeds with the implicit assumption that all firms follow a common transformation process during their NVC phase, and the variation across observations can be used to identify the parameters of the process by assuming that observations are randomly distributed around the true model. Assuming that inputs are (log) linearly combined into a single objective measure (as for revenue in the NVC phase in our formal model), one would estimate[12]:

$$\ln y_i = \alpha + \sum_{n=1}^{N} \beta_n \ln x_i^n + \varepsilon_i, \tag{9}$$

[12] It is possible to estimate more general specifications, such as a constant elasticity of substitution or translog specification, that allows for the elasticity of substitution between inputs to be different from 1 or even dependent on the level of inputs used. We keep that part of the modelling simple and develop our argument around the Cobb–Douglas specification. What limits us in pursuing more complex models is primarily the size of our dataset.

where i indexes the observations (in this case, new ventures) over which we generalize. The empirical literature on NVC then tries to identify relevant inputs (such as founding team characteristics, environmental variables, and investor inputs) by estimating the output elasticities, β, for inputs, which are theorized to affect venture creation, in a dataset of nascent ventures.

However, this approach is problematic if we cannot assume that the underlying data generating process is similar across all units of observation. Importantly, the entrepreneurship literature (Davidsson & Gruenhagen, 2021; Gartner, 1985) has frequently made the point that this assumption of homogeneity is particularly problematic in the NVC phase.[13] Given the predicted importance of biased attrition in our sample, a way to account for an important part of this heterogeneity in NVC is to allow for individual venture creation processes to yield different outcomes for the same vector of inputs. In production theory, scholars have developed stochastic frontier analysis (SFA) (Hwang & Kim, 2022; Kumbhakar & Lovell, 2003; Yang & Chen, 2009) exactly for such cases. Figure 4 shows how, using the same observations, an SFA model separates between the firms at (area A) and below (area B) an 'efficient frontier'. The slope of the frontier, which we assume is homogeneous across observations, represents the output elasticity of the input, whereas the SFA model allows for observations to lie below the line for a host of (unobserved) reasons.

By making some assumptions (see below) on the distribution of the additional, one-sided error term, the model to be estimated now changes from Eq. (9) to:

$$\ln y_i = \alpha + \sum_{n=1}^{N} \beta_n \ln x_i^n + \varepsilon_i - v_i. \tag{10}$$

The additional error term, v_i, is assumed to be strictly positive and following a truncated normal, exponential, or half-normal distribution, and it measures the vertical distance from observation i to the maximum attainable output for that vector of inputs at the efficient frontier. One advantage of this approach is that output elasticities are estimated at the frontier. That is, in the simple one-output example of Fig. 4, we estimate the marginal contribution of input factors to output amongst the firms that attain the highest levels of output in the sample.[14] The ventures at the frontier are also most likely to be constrained by the measured inputs in trying to achieve the measured outcomes.

The estimated parameters of the transformation process over the NVC phase can differ significantly between frontier and more standard estimation methods. The sample selection bias in Proposition 5 means that estimation using data points for which, for example, the input constraints were not binding causes the estimated parameters to be biased in an unknown direction. That is, when the inputs were not used efficiently, the true output elasticities for these inputs can be higher or lower than estimated. Our model introduced a one-sided error by assuming that all ventures experience one-sided (lucky or unlucky) productivity shocks. In empirical data, such information is unobserved, and the resulting missing variable bias can also be addressed by allowing for an (unexplained) distance from the frontier. If we do not allow for this, sample selection bias and missing variable bias could affect the estimated trade-offs and substitution elasticities, and traditional estimation methods would yield biased and imprecise results.

SFA has the advantage of not requiring measures for all possible sources of heterogeneity. Without a full set of controls, the distance to the frontier still captures a significant share of any unobserved heterogeneity and isolates the bias that would otherwise affect our parameter estimates. A final advantage of the SFA method in the NVC context is that it allows for multidimensionality, not only in the input vector but also in the outcome vector, which is highly relevant for NVCs, according to, for instance, Gartner (1985).[15]

[13] One could go so far as to suggest that every firm's NVC phase is unique and idiosyncratic, which would imply that generalization across these processes is impossible. But this would imply that we cannot learn from comparing across NVC processes. We propose a middle ground between these views.

[14] More precisely, all observations are used to estimate the slope of the frontier, but the estimation procedure considers that not all observations are at the frontier. The assumption here is that all observations face the same output elasticity (slope) but need not have the same intercept in their production function. This gives more weight to the observations close to the frontier in estimating the common output elasticities, as their remaining distance to the regression line will reduce the likelihood function most.

[15] Another source of potential bias is that the same resource inputs during NVC may have been employed to achieve objectives other than the ones being modeled. This will bias estimated elasticities downwards.

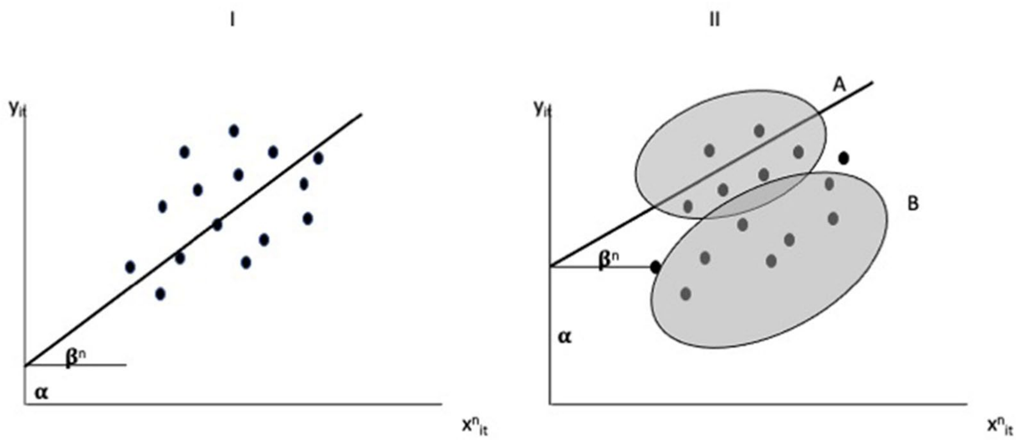

Fig. 4 Unobserved heterogeneity in NVC treated as noise (Panel I) and inefficiency (Panel II)

Multiple output frontiers are a straightforward extension of the single output SFA model in Eq. (10). Building on the single output production frontier, Appendix C shows that, under some additional assumptions, notably that the frontier is homogeneous of degree one in outputs, we can estimate a multiple output model as follows:

$$\ln y_i^1 = \alpha + \sum_{n=1}^{N} \beta_n \ln x_i^n + \sum_{m=2}^{M} \gamma_m \ln \frac{y_i^m}{y_i^1} + \varepsilon_i - v_i. \quad (11)$$

As in the single objective case, the variance of v_i over the total variance can be interpreted as a measure of importance of unobserved heterogeneity in factors that prevents a venture from achieving its objectives with maximum efficiency (Kumbhakar et al., 2015). In Eq. (11), the distance to the frontier is $-v_i \leq 0$, which is assumed to follow a half-normal, truncated normal, or exponential distribution. ε_i is the usual mean-zero normally distributed noise component, which is independently and identically distributed (Kumbhakar & Lovell, 2003). Because the distribution of v_i is asymmetric, so is the distribution of the composite error term $\epsilon_i = \varepsilon_i - v_i$. Equation (11) is the SFA model we use to analyze how resources contributed to new ventures' achievement of their objectives.

To test Hypotheses 1–4, we look at labor (founder and hired) and capital (founder equity and loans) and relate these to (our proxies for) the speed-to-breakeven ($1/T$) and revenue-at-breakeven (R_T). We proxy for the true productivity of the venture (A_i) by including innovativeness as a third outcome. This approach enables us to estimate the elasticities at which new ventures decrease their speed-to-breakeven and revenue-at-breakeven when innovativeness and therefore, arguably, uncertainty increases. In our formal model, innovativeness (in the form of productivity) and, consequently, uncertainty are given exogenously at the start of NVC. With this specification we wanted to account for the fact that founders can tweak the innovativeness of their venture during NVC, making it, to some extent, an endogenous outcome variable. Nonetheless, this should not change the signs of the predicted correlations.

With $y_1 = \frac{1}{T}$, $y_2 = A_i$, $y_3 = R_T$, $x_1 = f$, and $x_2 = k_0$, the tests for Hypotheses 1–4 are H1: $\gamma_2 < 0$; H2: $\gamma_3 < 0$; H3: $\beta_1 > 0$; H4: $\beta_2 > 0$. While not testing it formally, we also expect $\lambda \equiv \frac{\sigma_v^2}{\sigma_\varepsilon^2} \gg 0$. Note that if $\lambda = 0$, the empirical analysis is the same as a standard regression and the 'inefficiency' carries no variance. However, in practice λ (thus σ_v^2) will never be zero because no error term is ever precisely normally distributed such that all variance is captured in the denominator (i.e., σ_ε^2). Therefore, to conclude that inefficiency indeed plays the predicted significant role in our model, we require that the ratio be sufficiently large.

3.2 Data

To estimate our empirical model, we use data on the NVC phase of ICT firms, with three independently measured outcomes, as well as several relevant input variables. We draw our proprietary data from a unique firm-level dataset containing information on the startup processes of 331 observations on nascent ventures, collected with an explicit focus on how their activities were sequenced.[16] ICT firms were identified from the NACE Rev.2, NAICS 2007, and US SIC industry classifications available in the Orbis database. Whenever a firm was registered, its founders had to indicate the industry in which it operates. For each classification category, we used the corresponding classifications for 'Telecommunications' and 'Computer Programming and Related Activities' As a result, the sample includes both products (e.g., components for mobile phones and satellites, or apps) as well as services (e.g., website programming). We focus on the ICT sector for two reasons discussed by Haschka and Herwartz (2020, 2022): (i) the link between innovation and long-run performance outcomes we postulate is particularly pronounced in high-tech firms, (ii) narrowing down the sample to one sector rules out additional inter-sectoral unobserved heterogeneity.

Founders were interviewed about their startup activities since the creation of the venture (i.e., during the entire NVC phase). The interviews were conducted in two waves between 2011 and 2018, based on computer-assisted telephone interviews (CATI) in the US, UK, Germany, and Italy. The population considered includes ICT ventures of all legal forms except sole proprietorships, registered between 2004 and 2014. From this population, founders were randomly selected and invited to participate in a structured interview for which a guide was developed. The guide made it possible to trace how each venture creation process evolved from one month to the next. The questionnaire also recorded the venture details and circumstances of venture creation, such as the venture's *location*, *year of registration*, *legal form*, *business idea (product or service)*, *novelty*, and *degree of innovativeness*. It also identified the start and end dates of the NVC phase. In line with the process-oriented entrepreneurship literature (Davidsson & Gruenhagen, 2021; Reynolds, 2018; Rotger et al., 2012), we used the venture's registration date as the start date, while the end date was defined as the point in time when the venture had generated *profits* for more than three consecutive months.[17] If this had not occurred by the date of the interview, the firm's NVC phase was categorized as ongoing, to a maximum of 84 months. As ongoing NVC do not have a speed-to-breakeven (STB), they were dropped from the analysis. The shortest NVC phase in the sample was three months. Also, the questionnaire traced per month how many *founders*, *employees*, and *service providers* worked for the venture on a part- or full-time basis, and when. It also reported the different financial sources that the venture acquired, which were categorized into *founder capital* and *loans* and *subsidies/grants.*

3.3 Constructed variables

We now describe how we constructed our dependent variables (the outcomes), our resource inputs, and the control variables for the NVC phase. The Stata™ do files we have compiled to construct the variables and generate the results are available on request.

The dependent variables in Eq. (11) are the three outcomes of the NVC process. For *speed-to-breakeven* (*STB*), we first calculate the time (in months) that elapsed between the venture registration and the first month of three consecutive months of positive profits (*MTP*). We cut off the extreme values (top and bottom 1%) so they do not distort the frontier location.[18] We then computed *STB* as[19]:

[16] We lose 2 observations when we estimate the model distinguishing founder from total equity and founder from total labor employed.

[17] It is possible to estimate profit frontier models that explicitly model profit maximizing behavior (Kumbhakar et al., 2015), but this would require information about prices of inputs and outputs that we do not have. Also note that we referred to this point in time in our theoretical model as the moment the founders have eliminated the uncertainty over their true productivity, whereas in the discussion above and below we refer to this moment in time as the time-of-breakeven.

[18] This procedure may strike some as too casual, given the discussion in the literature on how to identify and handle outliers (e.g., Simar, 2003). We have also computed our variables without this procedure and obtain almost the same results, apart for coefficients for constants (see Table 3 and Appendix G), because the observations dropped here also have other variables missing.

[19] Equation (12) does not correspond perfectly to the definition of venture creation speed in our formal model, where it is defines as the inverse of the time T that it would take to reduce uncertainty over productivity to zero. Beyond T, the venture would generate maximum positive profit, otherwise it would have failed. In principle, it would be possible in our model that a venture experiences three consecutive months of positive profit during the NVC phase. The likelihood that this would occur, however, is low owing to our assumption that productivity shocks/signals are strictly negative.

$$STB = 1/MTP. \tag{12}$$

Normalizing on the fastest observation in the sample, *STB* takes a value of 1 for the venture that has the smallest number of months to sustainable positive profits and approaches 0.01 for those that score the highest number of months. We present the descriptive statistics in Table 2, and the resulting variable in a histogram in Appendix D (Figure D1). *STB* has a right-skewed distribution, suggesting that many ventures are close to the slowest one in completing their NVC phase.

Our proxy for the second outcome, *revenue-at-breakeven*, is measured at the end of the NVC phase as defined above (i.e., first month of three consecutive months of positive profits), labelled *RAB*. To ensure that our variable is well behaved, we again drop the outliers above 99% and below 1%, respectively. Appendix D (Figure D2) provides the histogram of this variable, both in the original form and in the logarithmic transformation that we will use in the estimations.

Our proxy for true productivity is *innovativeness* of the venture (*INN*), and it is constructed as follows. In the survey, founders were asked to assess whether their product or service was new to the customers (*CUS*: 1= yes, 2= no), indicate the novelty of their product or service (*NOV*: 1= radical, 2= incremental, 3= replicative), and to list if the firm was (1 =yes, 0= no) developing a new product (D^{PT}), process (D^{PS}), service (D^{SE}), technology (D^{TY}) or application (D^{AN}), and selling the product or service abroad (D^{EX}).[20] Based on their answers, we defined our proxy for 'true productivity' as:

$$INN = 1 + 99\left\{\frac{[2 - CUS] + [3 - NOV] + D^{PT} + D^{PS} + D^{SE} + D^{TY} + D^{AN} + D^{EX}}{9}\right\} \tag{13}$$

The variable in Eq. (13) takes a value of 100 for ventures that have the maximum score on all components and takes a value of 1 in the opposite case. Appendix D (Figure D3) presents the histogram, which is relatively flat. Although the *INN* variable has only nine possible values by construction, it is enough to treat this variable as continuous for the purpose of our estimations. This empirical proxy does not correspond perfectly to true productivity, A_i, from our formal model; A_i captures total factor productivity in the new venture, which is likely correlated but not perfectly with the (ex post) assessment of innovativeness in Eq. (13). Nevertheless, we propose that founders will report higher values on this variable when they have experienced high levels of uncertainty in NVC. By the assumed positive relationship between A_i and $\sigma_t^2(A_i)$, we obtain that *INN* may serve as our proxy for A_i.

To estimate Eq. (11), we also need to specify the inputs used in the production process: labor (LAB) and capital (CAP). To measure these inputs, we include the labor and financial capital used between the moment of registration and the end of NVC. We divide these by the months to profit (MTP) to express these as an average level of labor and capital employed. This procedure implies that any capital and labor committed to the venture between registration and breakeven is treated as if they were committed to the venture throughout the NVC at an average intensity (as in our formal model). Within labor and capital, we distinguish between the founders' labor and equity and hired labor and loans. The latter two categories of inputs are less prevalent in our sample, because few firms hire labor in the early stage and even fewer acquire significant loans or external equity. The baseline model we estimate is the following:

$$\ln STB = \alpha + \beta_1 \ln LAB + \beta_2 \ln CAP + \beta_3 \ln \frac{INN}{STB} + \beta_4 \ln \frac{RAB}{STB} + \varepsilon_i - v_i. \tag{14}$$

[20] Given that the type of product or service developed, its novelty, and newness to customers were all self-reported by the founders interviewed, the reliability of these three indicators was evaluated using a three-step approach. First, founders were asked to self-report the type, novelty, and customer newness of their product/service. In the second step, the interviewer verified this assessment by comparing the venture's product/service, its novelty, and newness, with those of other ventures previously interviewed. In the third step, the data cleaner reviewed the assigned degree of innovativeness, using a classification scheme they had developed during the data-cleaning process. Therefore, while both the interviewer and data cleaner relied on the founder's input and online information about the venture, the process helped mitigate the common tendency of founders to overestimate the innovativeness of their venture.

4 Results

4.1 Estimators

Appendix D discusses tests of the distributional assumptions; the data satisfy the conditions needed to justify the use of a frontier framework. To motivate our assumption on the distribution of the inefficiency error term, we first evaluated deviations from the frontier, which is $\exp[-\nu_i] \in [0,1]$ (Kumbhakar et al., 2015), as presented in Figure D4, Appendix D. Our interpretation of this result is that some ventures operate at the frontier, but a substantial mass of ventures are inefficient, that is, they lie within the frontier. If all ventures were to use labor and capital efficiently to achieve maximum speed-to-breakeven and revenue-at-breakeven, given innovativeness, then we would expect to see most ventures clustered close to the frontier. The fact that they are not indicates that survival bias may indeed have played the predicted role. Consequently, we should use SFA to estimate the outcome elasticities for the inputs for those ventures operating at the estimated frontier, as well as the tradeoffs between the observed outcomes.

4.2 Testing the hypotheses

Table 3 presents the estimates from SFA, where we first used labor and capital inputs but estimated the coefficients using alternative distributional assumptions. The first three columns present the estimates with assumed, respectively, half-normal, truncated normal, and exponential distributions for the one-sided residual distribution. These are our benchmark models.

Table 3 shows that the expected negative signs on the tradeoffs between the outcomes are highly significant, thus providing support for Hypotheses 1 and 2. For the truncated normal distribution, the estimated coefficient on the tradeoff between speed-to-breakeven and innovativeness is −0.514. This implies that a one standard deviation increase in $\log(INN/STB)$ implies on average a 0.631 standard deviation lower log(speed-to-breakeven), indicating a strong tradeoff.[21] Also, for the truncated normal distribution, the estimated coefficient on the tradeoff between speed-to-breakeven and the revenue-at-breakeven is−0.050.[22] This implies that a one standard deviation increase in $\log(RAB/STB)$ on average corresponds to a −0.080 standard deviation reduction in the dependent variable, log(speed-to-breakeven), which we consider a weak tradeoff. In a post-estimation test on the difference between coefficients, the difference is significant at the 10% level for all models.

We also find significant unobserved heterogeneity in performance as indicated by the estimated values for λ and mean inefficiency. The distance from the common frontier is positive and accounts for a significant part of the variation in outcomes across ventures. In Table 3, the variance picked up by inefficiency is largest when we assume the truncated normal distribution for inefficiency and lowest for the exponential distribution. This indicates that the assumption that the mass of the distribution lies close to, but below the frontier (a positive truncation parameter on inefficiency), fits our data best. The LR test comparing the truncated-normal estimates with half-normal estimates also comes in favor of the truncated-normal distribution at $p < 0.05$, which is consistent with preference for this distribution in recent SFA by Haschka and Herwartz (2020, 2022).

[21] See Table 2 for the standard deviations of our variables and Table 3 for the estimated coefficients. We compute $\sigma_X \times b_X / \sigma_Y$ to obtain the predicted effect of a one standard deviation increase in X on Y, expressed in standard deviations of the dependent variable, respectively: $-0.514 \times \frac{1.399}{1.139} = -0.631$ and $-0.050 \times \frac{1.817}{1.139} = -0.080$.

[22] We cannot directly compute the tradeoff between revenue-at-breakeven and innovativeness. This tradeoff must be excluded to avoid perfect correlation. However, by implication, given the sign of the other two tradeoffs, that tradeoff also exists, and is negative. We verified that the results remain unchanged when we choose the other outcome variables as our benchmark/dependent variable, running alternative models.

Table 2 Descriptive statistics, ICT sector

Variable	Obs	Mean	Std. Dev	Min	Max
Frontier					
SPB: speed-to-breakeven	499	0.203	0.183	0.011	0.982
INN: innovativeness	563	31.972	17.255	9.091	81.818
RAB: revenue-at-breakeven	363	15,382	32,259	0	400,000
SPB: speed-to-breakeven (log)	499	− 2.126	1.139	− 4.532	− 0.018
INN: innovativeness (log)	563	3.293	0.622	2.207	4.405
RAB: revenue-at-breakeven (log)	362	8.603	1.577	2.303	12.899
INN—SPB (log difference)	499	5.396	1.399	2.869	8.572
RAB—SPB (log difference)	334	10.719	1.817	5.527	15.969
Inputs					
Financial capital (log, scaled)	361	2.975	3.400	0.000	23.516
Equity capital (log, scaled)	366	1.089	1.013	0.000	4.508
Loans, grants (log, scaled)	361	2.869	3.272	0.000	14.926
Labor (log, scaled)	361	0.347	1.641	0.000	23.491
Founders labor (log, scaled)	363	0.885	0.884	− 0.002	4.456
Employees and services (log, scaled)	361	0.640	0.709	0.000	3.722

In our formal model of Sect. 2, the one-sided ex post inefficiency can be attributed to the interaction of sample attrition and one-sided shocks to productivity, making a truncated normal distribution theoretically and a priori plausible; however, we should not overinterpret this result and, notably, the estimated inefficiency remains an unexplained residual.

We then estimate the impact of factor inputs by taking a more careful account of the heterogeneity in both labor[23] and capital[24] inputs (and thus test Hypotheses 3 and 4). The model of Sect. 2 linked founder labor to innovativeness and speed-to-breakeven directly by assuming founder labor (only) helped to reduce the uncertainty over the venture's true productivity. Similarly, we abstracted from the possibility of acquiring external financing during the NVC phase in the formal model of Sect. 2. Empirically, these assumptions do not hold for all ventures, but we start from the idea that equity will have a greater impact on the outcomes than debt.[25] Appendix E explains how we constructed these categories of labor and capital inputs. Our dataset provides information on the first five founders, employees, and service providers, and we are also able to compute founder equity, debt, and grants that were invested during the NVC phase. In the estimations that follow, we use the same methods as in columns 1–3 of Table 3 but distinguish between categories of labor and capital.

[23] We also experimented with models where we further distinguished between employees' labor input and externally hired services. The differences in coefficients between the two were insignificant, while founder labor remained significant. We thus report the more parsimonious models.

[24] Similar to labor, further distinctions in finance proved insignificant, while equity remained highly significant, which again led us to report the more parsimonious model.

[25] Equity finance, especially founders' equity investment, implies that there is incentive compatibility between the providers of finance and the management of the venture. Both downside risks and upside gains are shared equally. In contrast, when the new venture takes on external debt, there is asymmetry in the gains and losses because debt is a fixed financial-cost contract. This implies that providers of debt face a potential moral hazard problem, because the borrowers may gamble. As a result, debt providers typically insist on collateral from the debtors to protect themselves by securing their loans, and debt finance comes with a higher risk of foreclosure by banks. Thus, depending on the way it is secured, debt may lead to too little or too much risk taking and is less likely to lead to an optimum level of risk-taking than equity finance. Government grants, although formally equity, come with similar problems, if the granting bodies are held accountable for how the money is spent (Parker, 2018).

Table 3 Estimates of the productivity frontier (ICT-sector)

Dependent: speed-to-breakeven (log)	(1) Half-normal	(2) Truncated	(3) Exponential	(4) Half-normal	(5) Truncated	(6) Exponential
Innovativeness—speed-to-breakeven (log difference)	− 0.502***	− 0.514***	− 0.500***	− 0.523***	− 0.536***	− 0.518***
	(0.024)	(0.025)	(0.023)	(0.024)	(0.025)	(0.023)
Revenue-at-breakeven—speed-to-breakeven (log difference)	− 0.045**	− 0.050**	− 0.042**	− 0.043**	− 0.042**	− 0.040**
	(0.015)	(0.017)	(0.014)	(0.016)	(0.014)	(0.015)
Capital (log scaled)	0.031**	0.028**	0.032**			
	(0.010)	(0.010)	(0.010)			
Labor (log scaled)	0.303***	0.297***	0.306***			
	(0.039)	(0.037)	(0.038)			
Equity (log scaled)				0.047***	0.045***	0.049***
				(0.010)	(0.010)	(0.010)
Loans and grants (log scaled)				0.005	0.009	0.004
				(0.013)	(0.011)	(0.013)
Founders' labor (log scaled)				0.294***	0.295***	0.305***
				(0.043)	(0.041)	(0.043)
Non-Founders' labor (log scaled)				− 0.027	− 0.048	− 0.031
				(0.044)	(0.041)	(0.045)
Constant	2.769***	3.228***	2.599***	2.843***	3.228***	2.650***
	(0.089)	(0.080)	(0.080)	(0.100)	(0.090)	(0.085)
Mean inefficiency	*0.355*	*0.799*	*0.191*	*0.365*	*0.722*	*0.181*
Standard deviation of inefficiency	*0.444*	*0.414*	*0.191*	*0.456*	*0.431*	*0.181*
λ(variance in inefficiency/variance in noise)	*1.600*	*8.976*	*0.569*	*1.626*	*4.876*	*0.521*
Observations	*331*	*331*	*331*	*329*	*329*	*329*

Notes: standard errors are in parentheses

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; +$p < 0.10$

The results in columns 4–6 of Table 3 suggests significant variation in the impact of different categories of factor inputs on venture outcomes. Labor input by founders, and capital input through founder equity, have significantly greater effects than the other categories of inputs. Table 3 shows that labor input by founders has a highly significant positive impact on the output frontier ($p < 0.001$ in all models), in contrast to that of service providers' and hired employees' labor (where the coefficients are consistently insignificant). These results provide support for the view that founder labor in NVC is critical to the performance of the venture, thus supporting Hypothesis 3.

For capital, the p-values for the founder equity coefficients are always below 0.001 in Models 4 to 6, as reported in Table 3. In sharp contrast, the coefficients on other forms of capital are consistently insignificant, providing support for Hypothesis 4. Note that although our theoretical model does not link founder equity to speed-to-breakeven, the empirical model in Table 3 shows a positive and significant coefficient for founder equity on speed-to-breakeven. This discrepancy is probably because the empirical and theoretical definitions of venture creation speed and speed-to-breakeven do not fully coincide. We have defined speed-to-breakeven in our dataset as one over the number of months to sustainable profits/revenue, while the theoretical concept of venture creation speed was defined as one over the time to eliminate uncertainty such that the venture can be priced and sold. Nonetheless, with more founder equity, our model also predicts in Hypothesis 4 that ventures can be more innovative and achieve higher levels of revenue-at-breakeven, such that if the tradeoff between speed-to-breakeven and these two outcomes is negative, then ventures can choose to 'sacrifice' some of these outcomes for a higher speed-to-breakeven. Founder equity is then a proxy for capital employed in the venture during NVC, which increases all outcomes.

4.3 Robustness checks

We focused solely on the ICT sector in our core set of results to avoid confounding intersectoral differences with the effects we wish to estimate (Haschka & Herwartz, 2020, 2022). However, we obtain similar results when using a wider range of sectors, which increases the number of observations as well as the heterogeneity. These results apply models that mirror Table 3 and appear in Appendix F (Table F1).

Also, in the theoretical model we assume no reverse causality from output to capital and labor in the earliest stage of NVC. However, we can assess endogeneity in our empirical counterpart. We chose the approach recommended in Karakaplan and Kutlu (2017) and applied the routine described in Karakaplan (2017), which is the *sfkk* module for *Stata*. This method proposes an estimator based on maximum likelihood and generalizes the earlier stochastic frontier model of Battese and Coelli (1995). The model allows for the explanatory variables not to be independent of the error term, and for the (two-sided) error term and the (one-sided) inefficiency term to be dependent through observables that shape both distributions (but conditionally independent). Karakaplan and Kutlu (2017) then assume that the two-sided error is normally distributed, similar to the approach applied in nonlinear choice estimators, as in Wooldridge (2010). A bias-correction term is applied in parameter estimation, after which the endogeneity test is based on the Durbin-Wu-Hausman approach, in which residuals from the first step are added as additional regressors in the model. We used the *sfkk* module to test if endogeneity correction is needed for either capital or labor and found that a simple set of country dummies works best as the set of instruments in both cases. For labor, the endogeneity test of correlation between explanatory variables and residuals resulted in $\chi^2 = 0.01$ with $p = 0.92$. For capital, the same test resulted in $\chi^2 = 0.14$ and $p = 0.71$. Thus, in both cases we could not reject the null hypothesis under which correction for endogeneity is unnecessary.

We also experimented with using simple two-stage least-squares instrumental variables models instead, to increase our confidence in these results. Using the *ivregress* command in *Stata*, for labor we could not reject the null hypothesis that it is not endogenous, using both Durbin and Wu-Hausman tests. For the first test we obtain $\chi^2 = 0.0864$ with $p = 0.768$. For the second test, the *F*-statistics was 0.085 with $p = 0.771$. Furthermore, the tests of overidentifying restrictions suggested that the instruments are valid (Sargan $\chi^2 = 1.436$, $p = 0.481$; Basmann $\chi^2 = 1.438$, $p = 0.487$). In turn, for capital we obtained Durbin $\chi^2 = 0.0145$ with $p = 0.904$, and Wu-Hausman $F = 0.0143$ with $p = 0.905$. Likewise, the set of country dummies worked well again as instruments (Sargan $\chi^2 = 1.532$, $p = 0.465$; Basmann $\chi^2 = 1.507$, $p = 0.471$).[26] Nevertheless, we acknowledge that reverse causality/endogeneity of labor and capital could be an issue for more established business startups (as in Haschka & Herwartz, 2020, 2022), but our data focus on the venture creation process.

5 Discussion

We combine Schumpeter's (2008 [1934]; 2012[1942]) and Knight's (1921) intuitions (Bylund & McCaffrey, 2017; Henrekson et al., 2024) and present a parsimonious formal model that adds the NVC process into a neo-Schumpeterian growth model. The model describes an NVC process over time in which (proprietary) resources constrain the degree to which innovative entrepreneurs can achieve competing objectives under uncertainty. Our theoretical model illustrates the causal mechanisms at work, whereas our empirical approach allows us to link strategic choices in the allocation and acquisition of resources to the achievement of entrepreneurial outcomes. Moreover, the SFA approach allows us to systematically research the remaining sources of heterogeneity in our proposed three-outcome, two-input stochastic frontier model of the venture creation process.

Our results are consistent with the assumptions made and hypotheses derived from our theoretical model and with prior empirical results in the literature. The importance of founder labor, or 'sweat equity', is in line with recent findings by Bhandari and McGrattan (2021). Likewise, the findings are also consistent with Peteraf (1993), Rumelt (1984), and Wernerfelt (1984), in that it

[26] The country dummies may proxy for institutional differences in labor and financial regulations that affect use of labor and finance by founders correspondingly (Acs and Szerb, 2007).

is the firm-specific proprietary inputs that matter most for the ventures that operate at the frontier. In contrast, factors that can be hired or attracted in open markets do not seem to constrain the venture creation process, as they can be adjusted to fit the ventures' needs, and as uncertainty is reduced, they can be hired or acquired up to the point that marginal costs equal marginal benefits.

We considered three outcomes, each critical for new ventures: speed-to-breakeven, revenue-at-breakeven, and the innovativeness of the venture. An important limitation to consider in interpreting our results is that our measure of innovativeness captures mostly product innovation and therefore proxies for sales productivity. In addition, we only estimate the elasticities of *average* labor and financial resources committed during venture creation. Unfortunately, our dataset is not rich enough to differentiate between types of innovation or investigate the potentially interesting effects of different timings of resource commitments during NVC.[27] We therefore put this on the agenda for future research. Consistent with the propositions and hypotheses derived from our model, the first set of results confirms the existence of tradeoffs at the frontier between these three outcomes. The tradeoffs entrepreneurs face in bringing new products and services to markets constrain them in turning knowledge into innovation and ultimately economic growth. We identify negative tradeoffs at the frontier between speed-to-breakeven and revenue-at-breakeven; between speed-to-breakeven and innovativeness; and between revenue-at-breakeven and innovativeness. We also find that the coefficient on innovation/speed-to-breakeven is greater than the one on revenue/speed-to-breakeven, suggesting that the former tradeoff is stronger. This implies that, in terms of the entrepreneur's strategic allocation of time (Ge et al., 2022) and other resources between these outcomes (Lévesque & Stephan, 2020), the opportunity cost of choosing more innovative strategies in terms of lower speed-to-breakeven is greater than the opportunity cost of choosing strategies that generate higher levels of early revenue. This also suggests that, while entrepreneurs may emphasize different outcomes in different phases of NVC, innovativeness is the most expensive one in terms of resources (Dai et al., 2014).[28] Our model allows us to understand the relevant mechanisms driving this, and the SFA estimations help to empirically quantify these tradeoffs with more confidence that the estimates are not biased by unobserved heterogeneity.

Our second set of results concerns the extent to which new ventures succeed in attaining their desired outcomes. We find a great deal of heterogeneity in this respect; most new ventures in our dataset are (ex post) inefficient in their use of resources to obtain their objectives. For the half-normal and truncated normal models for which we estimated the ratio of variance in distance to the frontier to variance in residual noise (λ), the former plays a tangible role as reported in Table 3. Our model would suggest that this implies that new ventures indeed face significant levels of uncertainty, and 'luck' is a major determinant of inefficiency. Nonetheless, we propose that further empirical research is needed to identify additional systematic sources of this heterogeneity. We think that the characteristics of the local, regional, and national entrepreneurial ecosystem (Haschka & Herwartz, 2020), the (unobserved) qualities of capital and labor inputs, as well as the characteristics of founders and technologies, might all play an important role and our proposed empirical approach provides a solid basis for doing so in future work.

Our third set of results confirms the intuition in the 'sweat equity' approach (Bhandari & McGrattan, 2021) and Peteraf (1993) that it is firm-specific inputs that are the relevant constraints for a new venture in building a sustainable competitive advantage. We find that imitable resources available on the external markets, such as hired labor and debt finance, do not constrain new venture outcomes. Instead, it is proprietary resources, the labor inputs of the founding team and its equity investments, that affect performance at the frontier of NVC. Hence, innovations cannot find their way to the market unless entrepreneurs are willing and able to use their own labor to organize

[27] Some work on identifying and classifying patterns of resource commitments over time, based on the Perfect Timing database, has already been published in Held et al. (2018), Herrmann et al. (2020), and Herrmann et al. (2024).

[28] The labor elasticity at the frontier ranges from 0.30 to 0.34, while the capital elasticity is 0.03 in all specifications of Table 3. Our results thus indicate that during NVC, outputs respond more strongly to a proportional change in labor than to a proportional change in capital.

and mobilize other resources around that idea. Further, the positive effect of founder equity may imply that wealthy founders will be the more successful ones and, in turn, useful business ideas that fail to find proprietary capital may have a smaller chance of being turned into successful offerings. For example, serial entrepreneurs may have accumulated wealth that affords them high levels of founders' initial equity (Plehn-Dujowich, 2010). Identifying proprietary resources in NVC as an important bottleneck brings into focus the institutions that might be fundamental causes. The institutions that motivate entrepreneurs to commit the proprietary resources they need for building new ventures and challenging the *status quo* in markets are the institutions that help turn knowledge creation into actual growth.

Allowing for unobserved heterogeneity in NVC by estimating stochastic frontier models represents a major step forward in studying this inherently heterogeneous process. Understanding what multidimensional vector of inputs and characteristics drives new ventures in achieving a multidimensional vector of outcomes may take us a long way in better understanding entrepreneurship and innovation. It is our contention that, once we understand how new ventures reach their outcomes, we can help them improve their performance by choosing a more appropriate mix of outcomes, setting more efficient initial configurations, as well as by improving the environmental factors that prevent ventures from being best-in-class within a category of outcomes. Our work thus has important implications for future researchers, for practitioners, and for policymakers. Our model extends the neo-Schumpeterian growth model in the directions indicated by, for example, Acs and Sanders (2013) and more recently Henrekson et al. (2024). Our empirical method is new to the field and is easily extended to contexts where different outcomes, resources, characteristics, and environmental variables are deemed relevant. For example, in social entrepreneurship one might consider multiple nonmonetary outcomes, whereas in corporate venturing one might zoom in on access to parent firm distribution networks and knowledge base as strategic inputs.

6 Conclusions

Our primary aim in this article has been to model and analyze the new venture creation process in terms of tradeoffs among alternative outcomes, dealing with resource heterogeneity and the vast heterogeneity in entrepreneurial performance. A secondary aim has been to operationalize that approach empirically and to quantify the principal tradeoffs and input–output relationships. Furthermore, we have stressed the distinction between proprietary and market resources that are subject to strategic decision-making by entrepreneurs (i.e., labor and capital inputs that we further differentiate between the imitable and proprietary). We have chosen in this initial study not to delve into the factors that drive the residual heterogeneity[29] but rather sought to quantify its importance. In that way, we have 'measured our ignorance'. Future research might focus on providing a fuller and more nuanced account of the factors (for example, at the level of the firm, region, and industry) that might explain the distance to the frontier among startups.

Our results nevertheless have important policy implications. While additional external resources always allow entrepreneurs to achieve better outcomes, the most effective policy will be to support and incentivize the provision of both founders' equity (Elert et al., 2019) and founder labor. Also, policymakers will be interested in factors that enhance the long-term prospects of new ventures by making them more innovative, especially since this seems to trade off markedly sharply against short-term factors, like the need for firm income and speed to breakeven. Our framework helps to understand how these outcomes are interrelated and which interventions may relax constraints and affect the way entrepreneurs may better navigate these tradeoffs.

[29] Primarily because of sample size. In small samples, the conditional heteroskedastic estimators lack precision for the parameters of variance.

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Data availability The data used in this paper and the do file are available from the authors on request.

Declarations

Ethics approval and consent to participate In writing this paper, we have followed the rules of good scientific practice and the ethical guidelines laid out by the Journal.

Conflict of interest The authors declare no competing interests.

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