Entrepreneurs and Investors: Funding-Induced Distortions in Lean Startup Product Experiments and Innovation

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The lean startup method (LSM) is an experimentation-driven approach to learning about product-market fit and improving startup success, yet it overlooks the entrepreneur's funding needs. This paper models an LSM process in which an entrepreneur tests a product to gauge consumer preferences and seeks funding for a product launch from an investor with incomplete information about the entrepreneur's type. We show that the investor cannot deduce the entrepreneur's type from his actions and must rely on the test product's sales outcome for inference. This reliance can incentivize the entrepreneur to distort his experimentation strategy. Our analysis identifies two distortions in product experimentation relative to LSM without the need for external funding: one prioritizes funding over learning, while the other minimizes false positives but discards promising innovations. Consequently, the learning-funding tradeoff may induce systemic inefficiency in the LSM ecosystem. Moreover, our model implies that negative investor stereotypes towards certain entrepreneur groups (e.g., women, minorities) may cause them to sacrifice learning to secure funding—hence when funded, they launch less successful ventures, reinforcing the stereotype. Remarkably, while the inefficiency cost of positive stereotypes is borne by investors, the inefficiency cost of negative stereotypes falls on high-type entrepreneurs from the stereotyped groups.

Key words: Lean Startup, Product Development, Product-Market Fit, Consumer Preferences, Entrepreneurship, Innovation, Stereotypes, Inequality

1. Introduction

The lean startup method (LSM) is an iterative approach to early product development based on experimentation. It involves a process of iteratively designing a minimum viable product as a test product that embodies the unique value proposition envisioned by the entrepreneur, launching it to learn about its "product-market fit," and then pivoting to a different value proposition as necessary based on market feedback (Ries 2011, Blank 2013). In highly uncertain startup environments where failure is the norm, these "build-test-learn" experimentation cycles as recommended by LSM promote inexpensive failures early and enable entrepreneurs to learn about consumer preferences for new product ideas that are difficult to obtain through traditional market research. As such, LSM has become popular among startup entrepreneurs and intrapreneurs within large firms (Blank 2013).

To fix ideas around the lean startup method, the minimum viable product and the "build-test learn" cycle, we provide an illustrative example. Consider a startup that has developed an AI technology that can process large quantities of fashion images from social media to assess real-time fashion trends. The startup believes this technology could help create a product targeted towards fashion designers, but is unsure about the segment's needs. Should they develop an AI assistant to aid the design process? Or should they develop a sales prediction tool for a given design? LSM recommends that rather than conduct market research on which of these two ideas is better, it is best to launch a test product around the value proposition that the startup believes is most likely to succeed for the segment (Ries 2011). Further, the launched product should be a *minimum viable product*, that captures the essence of the value proposition, without incorporating "bells and whistles" (e.g., vertical attributes unrelated to the primary value proposition that are known and guaranteed to increase demand). Such a minimum viable product maximizes the validated learning from the success or failure of the product, because the success of the product can be attributed to the value proposition and not other features. If the minimum viable product succeeds, indicating good product-market fit, the startup can further invest in the product, if not, it can pivot to the alternative idea.

But this standard narrative around LSM as an effective tool for entrepreneurs to learn early about product-market fit abstracts away from an important consideration—the funding incentives of the entrepreneur. For example, after learning about the product-market fit, the AI startup would need to raise funding to purchase data and cloud computing power to train their AI model. To the extent that the strength of evidence in the experimentation outcomes impacts the funding decision of investors and the funding terms, entrepreneurs have a motivation to distort the experimentation process by including unrelated vertical attributes to maximize the appearance of high success likelihood. For example, As Asghar (2014) notes, "The stakes and the paydays are so high that many startups increasingly call on 'growth hackers' who seek to accelerate success or who at least lay on a veneer of success for the benefit of investors, media and other key audiences." Entrepreneurs therefore often

take shortcuts to "create the illusion of viability" (Asghar 2014), to avoid loss of investor confidence from early failures (Kim 2016). Such distortion can lead to greater rates of "false positive" outcomes that would suggest that a product idea is viable when, in reality, it is not.[1]

In this paper, we investigate how the funding incentives generate possible distortion in the entrepreneur's product experimentation process, and investigate its broader implications for LSM-based innovation ecosystems. Specifically, we address the following research questions. First, will the minimum viable product intended to maximize learning about the product market fit emerge in equilibrium when the entrepreneur's funding incentives are considered? If not, how would an entrepreneur deviate from this test product, and what is the impact on equilibrium innovation outcomes? Second, and more broadly, how do funding frictions arising from the entrepreneur's incentives for funding lead to inefficiencies in innovation ecosystems? Relatedly, how do investor biases about entrepreneur groups impact product development, payoff inequalities, and innovation outcomes?

To address these questions, we develop a formal game-theoretic model of the LSM experimentation process that accounts for their downstream funding incentives. In our model, an entrepreneur is endowed with a private type (high or low) and makes an equity offer to an investor after the test product's sales outcome. The investor wishes to invest in a venture managed by the high-type entrepreneur and avoid investing in the low-type, but faces uncertainty about the entrepreneur's type. The investor, who holds a prior belief about the entrepreneur's type, seeks to infer the entrepreneur's type based on the entrepreneur's actions and the sales outcome of test product launch. Our model endogenizes both types of entrepreneurs' LSM experimentation strategy and the follow-up negotiation with the investor, through which we analyze the equilibrium outcomes. Our analysis reveals the following insights.

We find that, in equilibrium, the low-type entrepreneur always mimics the high-type's strategy in experimentation and negotiation, making it impossible for the investor to discern the two types through the entrepreneur's actions. Instead, the investors must rely on the test product's sales outcome to infer the entrepreneur's type. This can create a burden on the high-type entrepreneur to demonstrate a positive test outcome to obtain funding at mutually acceptable terms. This *learning-funding tradeoff* can lead to two types of distortions to the experimentation strategy relative to the benchmark case where the entrepreneur can self-fund the venture. Specifically, when his reservation payoff is low, the high-type entrepreneur distorts the product experimentation strategy to increase the likelihood of a test product sale to obtain funding. The increased likelihood of funding, however, comes at the cost of learning about product-market fit. In contrast, when his reservation

[1] List (2022, p.23) argues that "the first pitfall everyone hoping to scale an idea or enterprise must avoid is a false positive." Such misaligned incentives also exist for intrapreneurs at large companies to obtain ongoing support for projects from senior management (Simester and Zhang 2010).

payoff is high, the high-type entrepreneur distorts the product experimentation to reduce the likelihood of launching an unsuccessful product in the event of a positive test outcome and offers smaller equity. However, this excessive caution means that many potentially valuable innovation ideas are not launched.

Our model reveals how the presence of the learning-funding tradeoff can create structural inefficiency in the LSM ecosystem relative to the case without funding considerations. When the investor's initial confidence (i.e., belief that the entrepreneur is a high type) towards the venture is high, experimentation outcome does not impact whether the venture is funded, and the high-type entrepreneur does not face the learning-funding tradeoff when practicing LSM. However, this also means that the low-type entrepreneur gets funded, and this cost of inefficient funding is borne by the high-type entrepreneur in his funding process. When the investor's initial confidence is low, the high-type entrepreneur is not funded in the event of a negative test outcome leading to systemic under-funding. This also effectively eliminates the opportunity for the high-type entrepreneur to pivot after learning, and does not lead to a better-positioned final product.

Our model also sheds insight into how investor's biases towards entrepreneurs can impact the innovation process and outcomes. There is abundant empirical evidence that investors have biases in their beliefs about the success potential of entrepreneurs based on race or gender (Lyons-Padilla et al. 2019). One illustrative finding is that when the high-type entrepreneurs face negative stereotypes, funding becomes more dependent on a positive test outcome; in response, entrepreneurs distort product experimentation at the expense of overall learning. Therefore, when funded, these entrepreneurs have a lower overall venture success rate compared to their counterparts with similar qualifications who do not face such negative stereotypes. Thus, stereotypes can be self-reinforcing. Further, we find that while the cost of a positive stereotype of a group is borne by the investor, the cost of the negative stereotype is borne by the high-type members of the group facing the negative stereotype. Thus, racial and gender stereotypes accentuate the payoff inequality among these entrepreneur subgroups.

The rest of the paper is organized as follows. In §2, we clarify how our paper relates to the established literature on product development and innovation, and discuss how it addresses new LSM-related issues. We then describe our model of the lean startup method with entrepreneur's subsequent funding incentives in §3. We present the analysis of optimal LSM implementation without and with funding incentives in §4. In §5, we discuss the broad implications of the entrepreneur's incentive for funding affects the equilibrium outcomes, and also how investor stereotypes on entrepreneurs affect these outcomes. Unless otherwise noted, the proofs of all formal results are relegated to the Online Appendix. We conclude in §6.

2. Related Literature

There is a large marketing literature on the issues of new product development relating to specific stages of the process such as in the ideation stage (Toubia 2006, Huang et al. 2014), management of the product development process (Datar et al. 1997, Bajaj et al. 2004), and strategic information and incentive issues (Simester and Zhang 2010). Central to these studies is the role of market research (e.g., surveys, conjoint analysis) aimed to learn and discover consumer needs. However, these techniques typically require that consumers are knowledgeable about the product category so that the marketers are able to elicit needs and preferences (Green and Srinivasan 1990, Mahajan and Wind 1992). Therefore, they are effective for launching incremental innovations, or planning their sequential launches (Ramachandran and Krishnan 2008, Krishnan and Ramachandran 2011, Bhaskaran et al. 2021). However, such market research is not very effective for discontinuous innovations, or when developing "really new products," for which there are no pre-existing products or consumers (Hoeffler 2003, Nijssen 2017). Yet these are the typical types of innovations that entrepreneurs and their early-stage equity investors often pursue, and LSM focuses on such innovations. This paper investigates how the entrepreneurs' need for financing could dampen their incentive to learn when they embark on the LSM's consumer-preference discovery process. Our findings formalize the presence of systemic learning failures that can exist when implementing LSM in practice, and is similar in spirit to an earlier literature that shows why rational managers of firms would sacrifice long-term gains to boost short-term signals in the presence of efficient financing markets (Stein 1989), or why product managers (intrapreneurs) can suppress or withhold information from senior management and make "killing" bad products difficult in the product development process (Simester and Zhang 2010).

Learning through iterative experimentation, another theme of LSM, has also been a major theme in the new product development literature. Early focus has been on product development settings where prototyping and testing are costly (Thomke 1998, Krishnan and Ulrich 2001, Terwiesch and Loch 2004), and on solving complex problems for which known solutions do not exist (Loch et al. 2001, Sommer and Loch 2004, Erat and Kavadias 2008). Therefore, the emphasis has been on the tradeoff between cost and accuracy of experimentation (e.g., crash testing of car seats), and on addressing the technological uncertainty associated in product development (e.g., drug development). However, LSM originates from startup settings where the costs of experimentation and development are inherently low, and the technical challenges are often secondary to identifying consumer needs

(e.g., combining open-source software codes). Such products often include software,[2] but also other (physical) products that can be easily prototyped and built.[3]

Yoo et al. (2021) provide the first formal analysis of the lean startup method and show the optimal level of "bells and whistles" (i.e., increased vertical attributes) necessary in the minimum viable product, the test product that maximizes the learning from market outcomes. Their analysis has shown that learning using LSM is inherently challenging as the test product must strike a delicate balance between minimizing both false positive and false negative market responses. Our paper points to an additional fundamental challenge due to the entrepreneur's downstream incentives arising from funding frictions. We introduce to the literature the *learning-funding tradeoff* in the context of an entrepreneur practicing LSM, and shed light on how it can impact the experimentation process and ultimately the products developed and launched. Though it has been recognized in the presence of financial frictions, operational and financial decisions cannot be decoupled (Modigliani and Miller 1958), the literature on LSM has thus far abstracted away from financial considerations which are critical in startups. This paper addresses this gap and examines the implications of financing frictions on early experimentation in the product development process.

The paper is also connected to the literature on early-stage financing of startups. Early-stage financing plays a critical role in advancing entrepreneurship and innovation (Gompers and Lerner 2006), and there has been a growing literature that examines the impact investors have on innovation (Kerr et al. 2014). For example, Bergemann and Hege (2005) show how the equilibrium funding behavior of the financiers changes based on whether they can observe the entrepreneur's decisions and how the observability impacts innovation. Manso (2011) finds that investors who seek to motivate innovation should devise incentive schemes that tolerate and sometimes reward failures. Hsu (2004) quantifies the "extra-financial" value that investors can add to a venture, while Sørensen (2007) finds that entrepreneurs backed by more experienced VCs are more successful in going public. Erzurumlu et al. (2019) find that angel investors that can provide greater "know-how" provide synergy by taking smaller equity and motivating the entrepreneur to expand the size of pie. As this literature is largely grounded in finance and economics, it is not surprising that its focus has been investor-centric. Here, we take a complementary entrepreneur-centric perspective. By focusing on the entrepreneur, we evaluate how their micro product development choices are impacted by the financing needs and how this impacts innovation output and investor returns.

[2] According to Entrepreneur (2018), several of today's well-known brands including YouTube, Slack, Groupon and Yelp failed in the market with their initial value propositions before pivoting to their current ones. As an example, YouTube started off initially as a video based dating service with the slogan, "Tune In, Hook Up" before it simply became a host for online videos.

[3] Similar iterative learning is used in the nuclear energy sector, where startups such as TerraPower use advances in supercomputing to learn about the potential viability of nuclear technology (Nanda and Rhodes-Kropf 2016).

3. Model

We first describe the model setup for each stakeholder in entrepreneurial product development—consumers (§3.1), entrepreneur (§3.2), and investor (§3.3). We then discuss the parameterization of the model (§3.4) and summarize the timeline of LSM experimentation model that involves the entrepreneur's funding incentives (§3.5).

3.1. Consumers

We consider a unit-massed continuum of consumers each of whom has a hitherto unsatisfied need, which can be satisfied by a product characterized by a single-dimensional horizontal attribute. A consumer's horizontal preference is represented by a point on a circle of integer-valued circumference N, a setup similar to that in Salop (1979). We let $[0, N)$ denote the set of positions on the circle. A consumer with horizontal preference $w \in [0, N)$ buys a product with horizontal attribute $\lambda \in [0, N)$ and vertical quality $V - p \in \mathbb{R}_+$ if and only if

$$V - p - |w - \lambda| \geq 0, \tag{1}$$

where $|w-\lambda|$ measures the disutility from the mismatch between the consumer's horizontal preference and the product's horizontal attribute. We assume consumers' horizontal preferences are uniformly distributed on a closed arc of length 2ϵ for some $\epsilon > 0$. The length of the arc (2ϵ) is known, so the distribution of horizontal consumer preferences is fully characterized by the midpoint of the arc, which we denote as W.

We fix V as an exogenously given maximum utility that can be derived from the final product. The term p represents the reduction in utility from the maximum utility V. A higher p can be interpreted generally as a higher price or lower vertical quality in general. For convenience, we will call a product's vertical attribute p as its "price", and the difference $V - p$ as its vertical quality.

The following assumption highlights the relevance of the uncertainty in consumers' horizontal preferences, as appropriate for the investigation of the LSM setting.

ASSUMPTION 1 **(Horizontal preference uncertainty).** $\epsilon < V < 2 - \epsilon$.

The assumption $V > \epsilon$ ensures that a product can cover the entire market if the product's horizontal attribute matches W; it also ensures that if the product is launched at an adjacent location, then the demand can still be positive. Moreover, the assumption $V < 2 - \epsilon$ implies that the demand of the product would be zero if the distance between the product's horizontal attribute and W is at least 2. Thus, Assumption 1 ensures that the essential feature of a successful product launch is to locate the product's horizontal attribute Λ close to W.

3.2. Entrepreneur

An entrepreneur (he) can develop and launch a product that can potentially satisfy consumer demand. He does not know W, but it is common knowledge that W is uniformly distributed on N equally spaced points on the circle $\Omega = \{0, 1, \ldots, N-1\}$. Due to technological constraints, the entrepreneur can only develop products with horizontal attribute in the discrete set Ω.

3.2.1. Entrepreneur Type. Entrepreneurs differ in their entrepreneurial talent. We assume that the entrepreneur can be one of two types—low and high—which we denote as $\theta \in \{L, H\}$. In our model, the key feature that separates the two types is the *informational advantage* high-type entrepreneurs have about horizontal consumer preferences. Specifically, entrepreneurs receive a type-dependent observable signal $S \in \Omega$ correlated with the horizontal preference parameter W. The signal can be thought of as market research or trade news, and can also be interpreted as the entrepreneur's discovery of a market opportunity. A high-type entrepreneur is assumed to obtain a more informative signal about W than a low-type entrepreneur. Specifically, we assume the following signal distribution conditional on W and θ:

$$\Pr(S = n | W, \theta = L) = \frac{1}{N},$$
$$\Pr(S = n | W, \theta = H) = \begin{cases} r & \text{if } n = W \\ 1 - r & \text{if } n = W + 1 \\ 0 & \text{otherwise,} \end{cases}$$

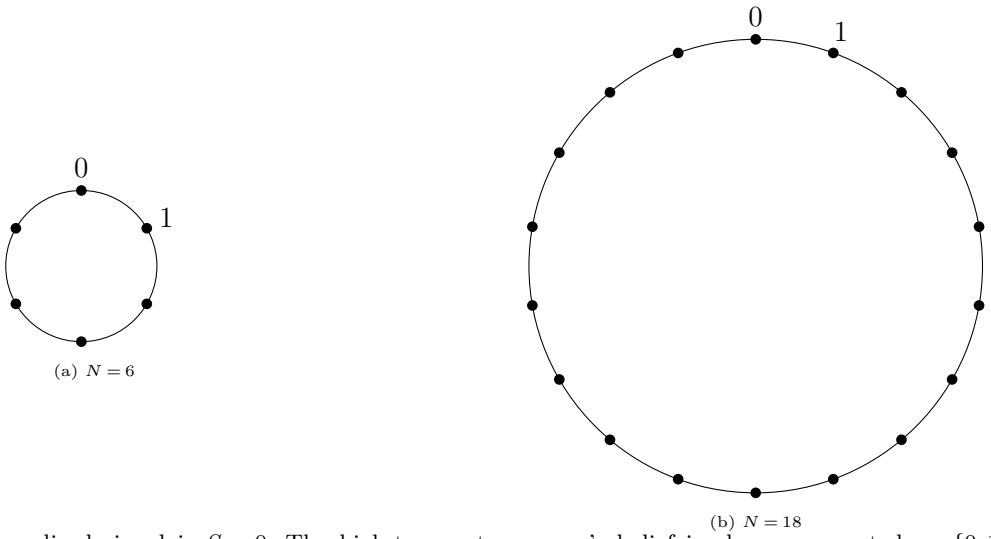
for every $n \in \Omega$ and some $r \in (1/2, 1)$.[4] Given this signal structure, Bayes' rule immediately implies the following *prior belief* about W that each type of entrepreneur has.

PROPOSITION 1 **(Type-dependent prior)**. *For every $n, s \in \Omega$, we have*

$$\Pr(W = n | S = s, \theta = L) = \frac{1}{N},$$
$$\Pr(W = n | S = s, \theta = H) = \begin{cases} r & \textit{if } n = s \\ 1 - r & \textit{if } n = s + 1 \\ 0 & \textit{otherwise.} \end{cases}$$

Proposition 1 states that upon receiving the signal $S = s$, the low-type entrepreneur will need to search for the ideal product location W from the set $\Omega = \{0, \ldots, N-1\}$, where $|\Omega| = N$; whereas the high-type entrepreneur can search for it from the smaller subset $\{s, s+1\} \subseteq \Omega$. The parameter N illustrates the extent of the information advantage a high-type entrepreneur holds over a low-type (see Figure 1).

[4] We let N and -1 denote 0 and $N-1$ in Ω, respectively. Doing so makes $W+1$ and $W-1$ both defined for every $W \in \Omega$.



(a) $N = 6$ (b) $N = 18$

Note: Assume the realized signal is $S = 0$. The high-type entrepreneur's belief is always supported on $\{0,1\}$ on both cases. In contrast, the low-type entrepreneur's belief's support changes from $\{0,\ldots,5\}$ to the even more diffuse $\{0,\ldots,17\}$ as N increases from 6 (panel a) to 18 (panel b).

Figure 1 Example of LSM with different possible designs.

In addition to the informational advantage, we consider two secondary features that further differentiates the two types. First, to expand on the substantive insights related to negotiation dynamics, we assume that the high-type entrepreneur and low-type entrepreneur derive their reservation payoffs u_H and u_L from their respective outside options. Since in practice, higher talent is likely to be correlated with better outside option, we assume that $u_H \geq u_L = 0$. Note that the $u_H = u_L = 0$ is a special case of our analysis: u_H need not be greater than u_L for our results and we vary u_H to analyze how the high-type entrepreneur strategizes with different financing needs.

Next, we consider the difference in execution efficiencies to capture the notion that running a successful startup requires more than recognizing market opportunities. Since higher talent is likely to be positively correlated with execution efficiency, we assume that high-type has a superior execution efficiency. Namely, if the two types of entrepreneurs launch the same final product, then the demand generated by the low-type entrepreneur would be a fraction $m \in (0,1)$ of that by the high-type entrepreneur. We note that the high-type's superiority in execution efficiency is not necessary for the intuition of our results (as shown in Appendix A), but is useful for ensuring analytical tractability and delivering the key insights clearly.

3.2.2. Entrepreneur's Expected Payoff from Final Product Launch. If the entrepreneur launches a final product (Λ, P), each consumer makes a purchase decision according to the decision-making rule in (1) and the resulting demand of the product is: $P^{tp} = \min\left\{1, \frac{V-P}{\epsilon}\right\}$ if $\Lambda = W$ (where "tp" stands for "true positive" to reflect sales when W matches the product's horizontal attribute);

and $P^{fp} = \max\left\{0, \frac{P-1+\epsilon}{2\epsilon}\right\}$ if $|\Lambda - W| = 1$ (where "fp" for false positive to reflect sales occurring when W deviates from Λ by 1); and 0 when $|\Lambda - W| > 1$ by Assumption 1. We assume that the final product's vertical attribute $p = P \in [0, V]$ is exogenous to focus on the horizontal attribute Λ, as it is consistent with the focus of LSM. Since P is exogenous, P^{tp} and P^{fp} are exogenous parameters.

Given that the demand for the final product is based on the proximity of horizontal attribute Λ to W, the expected demand seen by the entrepreneur depends entirely on his belief about W. Let $\beta = (\beta_0, \ldots, \beta_{N-1})$ denote a probability vector for W where β_n denotes the probability of $W = n$. If the high-type entrepreneur chooses horizontal attribute location Λ, the demand would be:

$$\Pi(\beta; \Lambda) := \beta_\Lambda P^{tp} + (\beta_{\Lambda-1} + \beta_{\Lambda+1}) P^{fp}.$$

If the low-type entrepreneur launches the same product with the same belief, the demand is $m\Pi(\beta; \Lambda)$.

The entrepreneur's ultimate objective is to launch a final product with the horizontal attribute $\Lambda \in \Omega$ that best satisfies the unmet consumer demand based on his belief about W. Thus, given a probability vector β, the optimal final product's horizontal attribute Λ that both types of entrepreneurs will launch is a solution to the following optimization problem:

$$\Pi^*(\beta) := \max_{\Lambda \in \Omega} \Pi(\beta; \Lambda). \tag{2}$$

As the high-type entrepreneur's belief is always supported on $\{s, s+1\}$, when the context is clear, we abuse the notation of Π^* such that, for every $\hat{r} \in (0,1)$, $\Pi^*(\hat{r}) := \Pi^*(\hat{\beta})$, where $\hat{\beta}$ is the probability vector such that $\hat{\beta}_s = \hat{r}$ and $\hat{\beta}_{s+1} = 1 - \hat{r}$.

3.2.3. Learning through Experimentation. To increase $\Pi^*(\beta)$, the entrepreneur can use LSM to learn about W, which leads to a different belief β. Namely, he can build a test product (λ, ρ), where $\lambda \in \Omega$ is the chosen horizontal attribute and $\rho \in [0, V]$ is the vertical attribute. We assume that the entrepreneur can costlessly adjust the test product's horizontal and vertical attributes. This assumption can be motivated by the reasoning that a prototype produced in small quantities does not require the same degree of planning and costly commitment to a supply chain geared towards the mass production of the final product. Afterward, a customer is randomly sampled and decides whether to buy the test product according to (1). For every $W, \lambda \in \Omega$, the probability of the test product (λ, ρ) selling is similar to the conditional demand function of the final product. It is: $f^{tp}(\rho) := \min\left\{1, \frac{V-\rho}{\epsilon}\right\}$ if $W = \lambda$; $f^{fp}(\rho) := \max\left\{0, \frac{\rho-1+\epsilon}{2\epsilon}\right\}$ if $|W - \lambda| = 1$; or 0 otherwise by Assumption 1. (We omit the argument of f^{tp} and f^{fp} when the context is clear.)

Let $X \in \{0, 1\}$ denote the outcome of the test product sales, where 1 indicates that the test product sells and 0 indicates that the test product does not sell. After observing the test (product sales) outcome X, the entrepreneur updates his belief about W using Bayes' rule.

The following definition is useful to compare any pairs of beliefs about W:

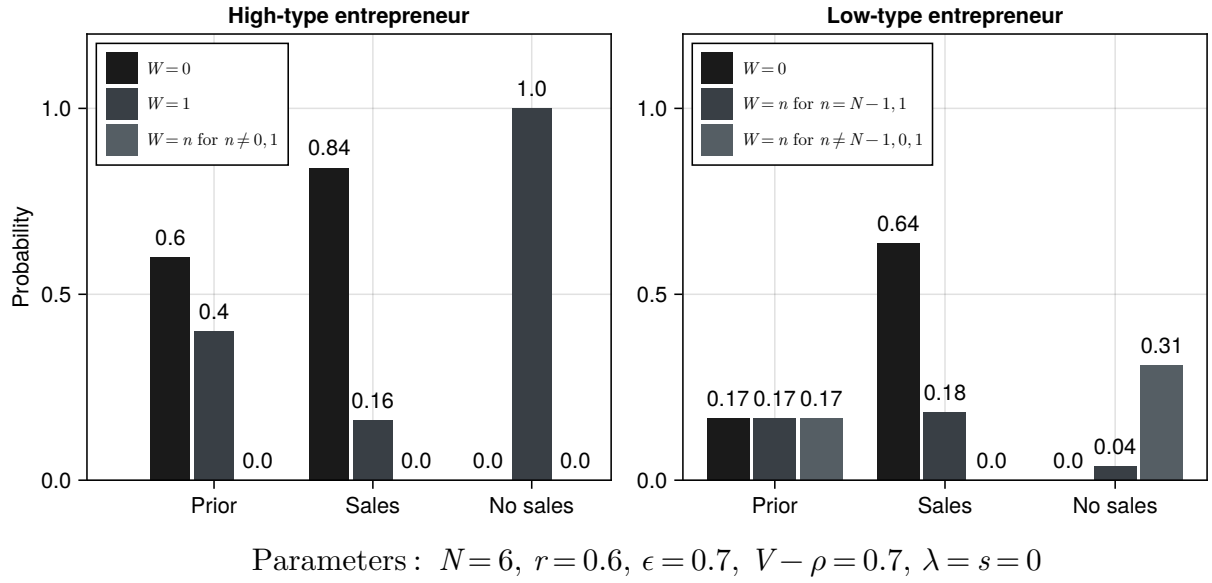


Figure 2 **Posterior belief after test outcome. Bars with zero values are omitted**

Definition 1 (Belief informativeness). Given two probability vectors β and $\tilde{\beta}$, we say that β is *more informative* than $\tilde{\beta}$ about consumer preferences if and only if $\Pi^*(\beta) \geq \Pi^*(\tilde{\beta})$.

Intuitively, a more informative belief tends to be more concentrated. Figure 2 contrasts how the two types of entrepreneurs update their beliefs. When $X=1$ for test product with $\lambda=s$, both types update their belief about $W=s$ upwards. Observe that the high-type entrepreneur's posterior belief is more informative than the low type's due to his smaller search set. When the test product does not sell, the high-type entrepreneur becomes certain that $W=s+1$, which is the most informative belief. In contrast, for a low-type entrepreneur, while a negative test outcome similarly decreases the probability of $W=s$, it equally increases the probability of locations outside the set $\{s-1,s,s+1\}$, leading to a posterior belief that is relatively less informative. Thus, the high-type entrepreneur can obtain more learning from a negative test outcome than the low-type entrepreneur does.[5]

3.3. Investor

After observing the test outcome X, the entrepreneur seeks funding $K>0$ that is necessary to develop and launch the final product. To secure funding, the entrepreneur offers an equity share $\alpha \in [0,1]$ to an investor (she), who will in turn accept or reject the offer based on her evaluation of the return from the venture.

[5] In practice, the entrepreneur may design a sequence of test products over multiple rounds before launching the final product. As such we note that our abstraction to one-shot product experiments in the model serves as a device to generate insights while keeping the analysis tractable. Future research should explore how the dynamics of multi-round experimentation may differentially impact the experimentation strategies across different entrepreneur types, and how this impact interacts with the investor's funding decisions and stereotypes on entrepreneurs.

The investor cannot observe the entrepreneur's type or his reservation payoff. Instead, it is common knowledge that she has a prior belief that an entrepreneur's type is high with probability $q \in (0,1)$. The investor can observe the realized signal S received by the entrepreneur, the entrepreneur's choice of test product (λ, ρ), the test outcome X, and the equity share α offered by the entrepreneur. She updates her belief about the entrepreneur's type using Bayes' rule. For example, if the entrepreneur demonstrates a sale, the belief that entrepreneur is a high-type may increase; when he fails to demonstrate a sale, the belief may decrease. Based on the updated belief, the investor computes the expected payoff and accepts if it is greater than the upfront cost K. (This assumes without a loss of generality that the required rate of return $u_I = 0$.)[6]

3.4. Restrictions on Model Parameters

To focus on the settings relevant to LSM, we restrict our model's parameter space.

3.4.1. Imperfect Learning from Test Outcomes. The uncertainty about the horizontal consumer preference is rarely fully resolved for entrepreneurs (even for the high-type) through product experimentation for the contexts relevant to LSM. To ensure imperfect learning, we make the following assumption.

ASSUMPTION 2 **(Imperfect learning).** $\frac{1}{2} < \epsilon < 1 - \frac{V}{3}$.

The lower bound $\epsilon > 1/2$ ensures that after any test outcome, the entrepreneur's updated belief is non-degenerate for at least one test outcome. To see this, suppose $\epsilon < 1/2$. Then by choosing $\lambda = s$ and $\rho \in (V - \epsilon, V - 1 + \epsilon)$, the high-type entrepreneur would always reveal the location of W with certainty both when test product results in sale $(W = s)$ and no sale $(W = s + 1)$. The upper bound $\epsilon < 1 - V/3$ ensures that, when there is no information asymmetry, the high-type entrepreneur does not set the test product's horizontal attribute to $\lambda = s - 1$, which is outside his belief's support $\{s, s + 1\}$.

3.4.2. Investor Seeks to Invest in High-Type Entrepreneur Only. To sharpen the key insights, we want to focus on settings where the investor prefers to invest in the high-type entrepreneur and avoid investing in the low-type. This setting is included in the formalization below.

ASSUMPTION 3 **(Type Efficiencies).** *(a)* $mP^{tp} < K$;
(b) $\max\{1 - r, rf^{fp}(V - \epsilon)\}(P^{tp} - K - u_H) + \min\{1 - r, rf^{fp}(V - \epsilon)\}(P^{fp} - K - u_H) > 0$.

[6] We have also implicitly assumed that the equity share is the only contractible parameter. Other parameters such as the designs of the test and final products are not contractible. This assumption is motivated by the reasoning that although the investor can assess the statistical implications of a test product's sales outcome, only the entrepreneur has the know-how to specify and execute the product design, making the contract between the entrepreneur and the investor incomplete about the choice of the test product.

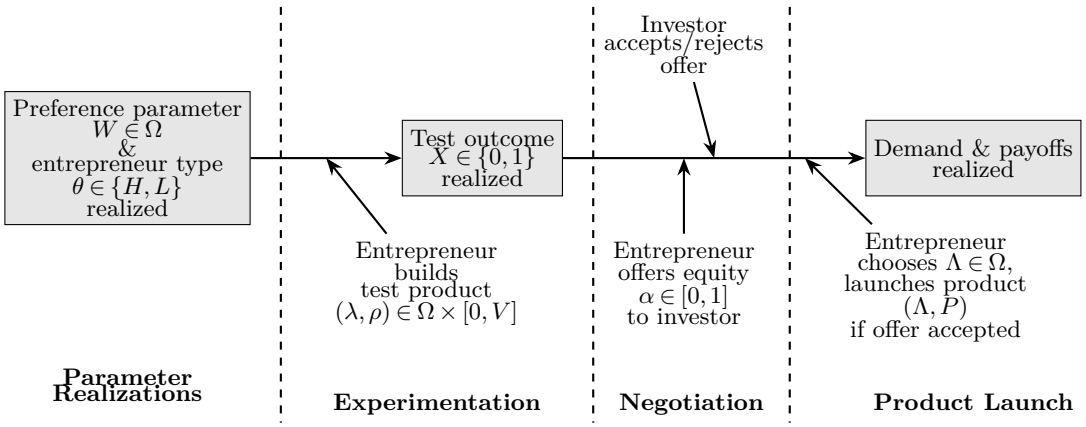


Figure 3 Model timeline

Assumption 3(a) implies that the low-type entrepreneur's execution efficiency is sufficiently low that the project is not worth the investment cost even if the low-type entrepreneur has chosen the correct horizontal attribute for the final product. The immediate implication of this assumption is that the investor will reject any equity offer $\alpha \in [0, 1]$ if she knows the entrepreneur is of a low type. This assumption gives the low-type entrepreneur a strong incentive to care about the investor's belief about his type, which turns out to significantly improve the tractability of our analysis and helps us deliver clear insights.

Assumption 3(b) puts a lower bound on the payoff from the final product launched by the high-type entrepreneur. Specifically, the assumption requires that, if the investor *knows* that the entrepreneur's type is high, when the entrepreneur chooses test product $(s+1, V-\epsilon)$ and the test product sells, then there exists a mutually acceptable equity share offer. Without this assumption, even if a high-type entrepreneur's type is known to the investor, the final product may not be launched when the test product sells. This assumption eliminates such distractions to the analysis. Moreover, the choice of test product in Assumption 3(b) turns out to help ensure that the high-type entrepreneur chooses $\lambda = s$ instead of $\lambda = s+1$ when there is no information asymmetry.

For the results that follow in the remainder of the paper, unless stated otherwise, we assume that Assumptions 1–3 hold. We separately investigate the role of Assumption 3(a) in Appendix A.

3.5. Model Timeline

Our model's timeline is summarized in Figure 3. There are four stages in our model: parameter realizations, experimentation, negotiation, and product launch. Nature determines the parameter realization stage; the entrepreneur makes decisions in the experimentation, negotiation, and product-launch stages; and the investor takes action only in the negotiation stage. Customers make their decisions in the experimentation and product launch stages.

Parameter Realizations. In this stage, horizontal consumer preference parameter $W \in \Omega$, the entrepreneur's type $\theta \in \{L, H\}$, and the signal received by the entrepreneur $S \in \Omega$ are realized.

Experimentation. The entrepreneur's experimentation strategy is a mapping that takes (θ, S) as input and outputs the test product $(\lambda, \rho) \in \Omega \times [0, V]$. Given test product (λ, ρ), at the end of this stage, a randomly sampled consumer decides whether to buy the test product according to (1) and the test product's sales outcome $X \in \{0, 1\}$ is realized.

Negotiation. The negotiation is modeled as a sequential game between entrepreneur (leader) and investor (follower).[7] The entrepreneur's negotiation strategy is a mapping that takes $(\theta, S, \lambda, \rho, X)$ as input and outputs the equity share offer $\alpha \in [0, 1]$ to the investor. The investor's strategy is a mapping that takes $(S, \lambda, \rho, X, \alpha)$ as input and outputs her decision whether to accept the equity offer. The investor accepts the equity share offer if and only if she believes her expected payoff from accepting the offer is at least the upfront investment cost K.

If the investor rejects the offer, the venture is aborted; everyone obtains their respective reservation payoffs, and the model terminates.

If the investor accepts the offer, the model proceeds to the product-launch stage.

Product Launch. Conditional on obtaining the funding from the investor, the entrepreneur chooses the final product's horizontal attribute $\Lambda \in \Omega$ according to (2) to launch the final product (Λ, P) to the market. The demand of the final product is then realized, and everyone receives their respective payoffs according to the agreed equity contract.

For ease of reference, Table 1 summarizes the notation that is used throughout the paper.

4. Analysis

We first establish the LSM benchmark case where the entrepreneur can self-fund the venture in §4.1. We then investigate the external funding case and study the learning-funding tradeoff and its impact on experimentation and product development relative to the benchmark in §4.2.

4.1. Benchmark Model: LSM under Self-funding

In this benchmark model, the entrepreneur chooses whether to use his own funds K to finance the venture and launch the final product. This model can also be interpreted as LSM without the information asymmetry between the entrepreneur and the investor. By symmetry, it is without loss of generality to assume that the realized signal received by the entrepreneur is $S = 0$. The following result characterizes the entrepreneur's optimal test product with self-funding.

[7] The outcome of this sequential move game is akin to that of a model where an entrepreneur bargains with multiple investors, and thus can be considered as its technical shortcut (Maskin and Tirole 1992, Bouvard 2014).

Symbol	Description
V	Maximum consumer utility from a product, exogenously given
W	Horizontal consumer preference distribution parameter
ϵ	Half-length of support of horizontal consumer preference distribution
Λ	Horizontal attribute of the final product
P	Exogenous final product price
λ	Horizontal attribute of the test product
ρ	Vertical attribute (price) of the test product
Ω	Set of possible horizontal attributes a product can have
N	The size of Ω, i.e., the number of possible product locations
θ	Entrepreneur type
S	Signal about W
r	Maximum probability in high-type entrepreneur's prior
m	Execution efficiency of low-type entrepreneur
u_H	Reservation payoff of high-type entrepreneur
X	Test product's sales outcome $X \in \{0,1\}$
K	Upfront investment cost of launching the final product
q	Investor's prior probability that entrepreneur is high-type
α	Equity share offer to investor
$f^{tp}(\rho)$	True positive rate of test product with price ρ when $W=\lambda$
$f^{fp}(\rho)$	False positive rate of test product with price ρ when $\lvert W-\lambda\rvert=1$
P^{tp}	True positive rate of the final product when $W=\Lambda$
P^{fp}	False positive rate of the final product when $\lvert W-\Lambda\rvert=1$

Table 1 Summary of notation

THEOREM 1 **(Test product under self-funding).** *(i) For the low-type entrepreneur, it is optimal to abort the venture.*

(ii) For the high-type entrepreneur, it is optimal to launch the test product $(\lambda,\rho)=(0,V-\epsilon)$*. If the test product sells, he stays course and launches the final product with* $\Lambda=0$*; otherwise, he pivots and launches the final product with* $\Lambda=1$*.*

For the low-type entrepreneur, even if $\Lambda=W$, the demand of the final product does not justify the upfront investment cost K, since $mP^{tp}<K$ by Assumption 3(a). For the high-type entrepreneur, his prior probability vector β is such that $\beta_0=r>1/2$ and $\beta_1=1-r<1/2$, and the optimal test product is to set $\lambda=0$, which matches his signal and has the highest prior probability. It is optimal to set the test product's vertical attribute ρ so that its vertical quality is $V-\rho=\epsilon$. If this test product sells, the entrepreneur becomes even more confident that $W=0$ and chooses $\Lambda=0$ for the final product; if it does not sell, he will become certain that $W=1$ instead and pivot to $\Lambda=1$.

This test product also coincides with the optimal test product that maximizes the expected demand of the final product demand in (2), thus making it the *minimum viable product* that maximizes validated learning.

The following result shows the value of learning from a negative test outcome for the high-type entrepreneur when he can self-fund the venture.

COROLLARY 1 **(Learning from Negative/Positive Test Outcome).** *Given the test product* $(0,V-\epsilon)$*, the demand of the final product after the negative test outcome and the ensuing pivot is* P^{tp}*, which is strictly higher than that after the positive test outcome without a pivot.*

The optimal test product $(0,V-\epsilon)$ eliminates the possibility of a false negative by ensuring that the test product sells with probability 1 conditional on $W=0$. By (2), P^{tp} is the demand of the final

product when W is known. Thus, the high-type entrepreneur obtains the most informative posterior belief when the test product does not sell. This demonstrates the value obtained from a negative test outcome and pivoting after experimenting via LSM.

The high-type entrepreneur's launching of test product $(0, V-\epsilon)$ with the option to pivot accordingly result in the following expected payoff:

$$\underbrace{r(P^{tp}-K)+\frac{(1-r)(2\epsilon-1)}{2\epsilon}(P^{fp}-K)}_{\text{When test product sells}}+\underbrace{\frac{1-r}{2\epsilon}(P^{tp}-K)}_{\text{When test product does not sell}}. \tag{3}$$

We will later use the expression to compare how the information asymmetry between the entrepreneur and the investor affects the high-type entrepreneur's expected payoff.

4.2. LSM under External Funding

We now examine the entrepreneur's equilibrium test product choices with LSM under external funding. Recall that the investor forms a belief about the entrepreneur's type given the entrepreneur's experiment history and the equity offer. For this belief update to be well-defined, the investor is assumed to have a *belief mapping* that takes $(S, \lambda, \rho, X, \alpha)$ as inputs and outputs her belief about the entrepreneur's type. We use (pure-strategy) *perfect Bayesian equilibrium* (henceforth "equilibrium" when there is no ambiguity) as our solution concept. A strategy profile is an equilibrium if given the investor's belief mapping, the entrepreneur's and the investor's strategies are the best responses to each other, and the investor's belief mapping is consistent with Bayes' rule on every supported path, (i.e., it could be reached with positive probability according to the strategy profile). In case of multiple equilibria, we select the equilibrium most preferred by the high-type entrepreneur, which we will refer to as the *high-type-optimal* equilibrium or just the equilibrium if there is no ambiguity.

We say that a strategy profile is *label-independent* if: (a) for any two realized signals s_1 and s_2, if the entrepreneur chooses horizontal attribute λ_1 and λ_2 respectively for the two signals, then $\lambda_1 - \lambda_2 = s_1 - s_2$; and (b) the entrepreneur's choices of ρ and α are independent of the signal received. By focusing on label-independent equilibria, we can assume without loss of generality that the signal received by the entrepreneur is $S = 0$ for the rest of the paper. Since by backward induction the investor always rejects the zero-equity offer, it is without loss of generality to focus on strategy profiles where whenever the venture is aborted, the entrepreneur's equity share offer is $\alpha = 0$. Lastly, we make the tie-breaking assumption that when the entrepreneur is indifferent between launching the final product and aborting the venture, he aborts the venture.

The investor's belief about the entrepreneur's type greatly influences her strategic considerations. For example, in the numerical example illustrated in Figure 2, after a negative test outcome, if the investor believes that the entrepreneur's type is high, then she will have high confidence in the

final product since the negative test outcome leads the high-type entrepreneur to become certain that $W = s + 1$. In contrast, if the investor believes that the entrepreneur is a low type, then her confidence in the final product will be very low since the low-type entrepreneur's posterior belief remains very diffuse and hence uninformative. Thus, the entrepreneur's strategic consideration will take into account not only the learning of consumers' horizontal preferences but also the investor's belief about his type.

Importantly, entrepreneurs can affect the investor's belief about the entrepreneur's type through their choice of test product and equity share offer, formalized through the investor's belief mapping in our model. There are two types of (pure-strategy) strategy profiles: pooling and separating. A strategy profile is *pooling* if conditional on every realized signal S, both types of entrepreneurs choose the same test product and given each test outcome, the two types offer the same equity share; it is *separating* if conditional on some realized signal S, the two types of entrepreneurs choose different test products, or given some test outcome, the two types offer different equity shares.

At first glance, both types of equilibria seem possible. On the one hand, given the investor's preference to invest in the high-type entrepreneur, the low-type entrepreneur may have an incentive to mimic the high-type entrepreneur's strategy so that he is considered as pooling with the high-type entrepreneur. On the other hand, the low-type entrepreneur may seek to learn about consumers' preferences in hope of launching a product with positive demand after a positive test outcome. This strategy on learning may incentivize him to separate from the high-type entrepreneur. The following result shows that the low-type entrepreneur's benefit of pooling with the high-type entrepreneur outweighs that of learning about consumer preferences.

THEOREM 2 **(Properties of Equilibria)**. *Every label-independent equilibrium where the high-type entrepreneur's expected payoff is strictly above u_H is a pooling equilibrium.*

Intuitively, the investor wants to avoid investing in the low-type entrepreneur (by Assumption 3(a)). Consequently, the low-type entrepreneur has an incentive not to reveal his type. In other words, the low-type entrepreneur has the incentive to imitate the high-type to seek a positive payoff from the venture instead of revealing his type and receiving his reservation payoff $u_L = 0$, which makes every equilibrium pooling.

The low-type entrepreneur's incentive to mimic the high-type also makes our analysis tractable by making it straightforward to verify whether a pooling strategy profile is an equilibrium. Hence, solving our model boils down to analyzing the high-type entrepreneur's expected payoffs by backward induction.[8] Theorem 2 is substantively appealing because it is consistent with the anecdotal

[8] When Assumption 3(a) does not hold, it is possible that a pooling equilibrium does not exist. Nevertheless, in Appendix A, we show that even when Assumption 3(a) is relaxed, we can identify a different set of intuitive conditions under which a pooling equilibrium exists and the same key insights of our subsequent analysis persist.

observation that it is difficult for the investor to discern the "true talents" (high-type entrepreneurs) based on their *observable actions* due to the existence of "pretenders" (low-type entrepreneurs). Yet the investor must strive to differentiate the two types of entrepreneurs in a pooling equilibrium. The only way that the investor can do so is by relying on *realized test outcome*. Unlike that of the high-type entrepreneur, the probability for the low-type entrepreneur to generate a positive test outcome is low for large N. Thus, after observing a positive test outcome, the investor is confident about the entrepreneur being a high-type. Theorem 2 thus brings forth the implication that the entrepreneur needs to consider how the test outcome will affect the investor's belief about his type when designing the experimentation strategy.

We next analyze the high-type entrepreneur's optimal strategy via backward induction.

4.2.1. Product-Launch Stage. In the final product-launch stage, conditional on the venture getting funded, by the definition of Π^* in (2), the high-type entrepreneur stays the course and chooses $\Lambda = 0$ if the posterior probability of $W = 0$ is larger than that of $W = 1$; otherwise, he pivots to $\Lambda = 1$.

By comparison, the low-type entrepreneur will stay the course to select $\Lambda = \lambda$ if the test product sells. If it does not sell, the entrepreneur will choose another Λ that is not in the set $\{\lambda - 1, \lambda, \lambda + 1\}$.

4.2.2. Negotiation Stage. In the negotiation stage, the investor decides whether to accept the entrepreneur's equity share offer α by assessing whether the expected payoff of accepting the offer is at least K. After the sale of the test product $X = 1$, the investor's belief about the entrepreneur's type being high increases. It can be shown that this probability converges to 1 when $N \to \infty$, since the probability that the low-type entrepreneur sells his test product converges to 0. Thus, after observing $X = 1$, the investor's expected payoff converges to $\alpha\Pi^*(\hat{r}_1)$, where $\hat{r}_1$ denotes the high-type entrepreneur's posterior belief about $W = 0$ conditional on $X = 1$.

If the test product does not sell, the investor would revise the belief q downward to $\underline{q}$, where

$$\lim_{N\to\infty} \underline{q} = \frac{q \Pr(X = 0|\lambda, \rho, S = 0, \theta = 1)}{q \Pr(X = 0|\lambda, \rho, S = 0, \theta = 1) + (1 - q)}.$$

Thus, when $N \to \infty$, the investor's expected payoff from accepting the offer converges to $\alpha \underline{q} \Pi^*(\tilde{r}_0)$, where $\hat{r}_0$ denotes the high-type entrepreneur's posterior belief about $W = 0$ conditional on $X = 0$.

Anticipating the investor's negotiation strategy, the entrepreneur decides the equity share offered to the investor. If there exists some equity share $\alpha \in (0, 1)$ that is mutually acceptable to both the entrepreneur and the investor, then by backward induction the entrepreneur will offer the minimum mutually acceptable equity share; otherwise, the entrepreneur will offer $\alpha = 0$, which the investor will reject and the venture will be aborted.

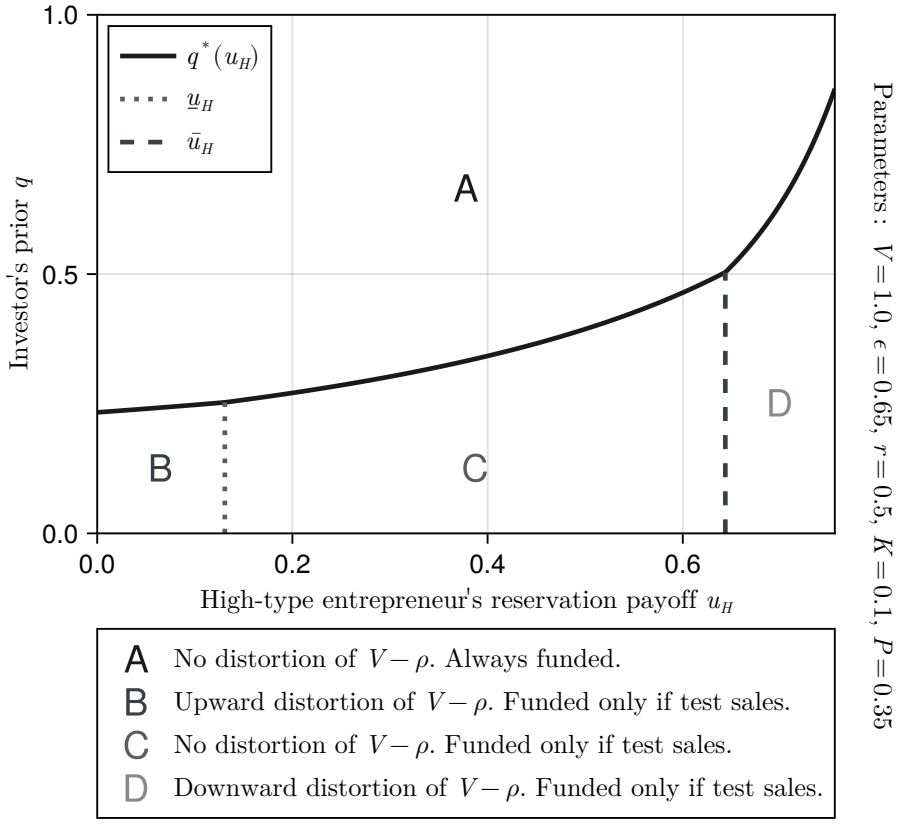


Figure 4 Equilibrium characterization in the asymptotic case

4.2.3. Experimentation Stage. The main analysis of our model concerns the entrepreneur's choice of test product (λ, ρ) in the experimentation stage. The following result characterizes the equilibrium test product choice for the high-type entrepreneur for all investor's prior belief q and high type entrepreneur's reservation payoff u_H.

THEOREM 3 **(Equilibrium Characterization)**. *For each parameter set, there exists* $q^*(u_H)$, $\underline{u}_H$, *and* $\bar{u}_H$ *such that each following equilibrium characterization holds for large enough* N*:*

(a) If $q > q^*(u_H)$*, then the equilibrium test product is* $(\lambda, \rho) = (0, V-\epsilon)$ *and the final product is launched regardless of the test outcome. The final product has* $\Lambda = 0$ *if the test product sells and* $\Lambda = 1$ *if otherwise.*

(b) If $q < q^*(u_H)$*, then the equilibrium test product is*

$$(\lambda, \rho) = \begin{cases} (0,0), & \text{if } u_H < \underline{u}_H, \\ (0, V-\epsilon), & \text{if } u_H \in (\underline{u}_H, \bar{u}_H), \\ (0, V-1+\epsilon), & \text{if } u_H > \bar{u}_H. \end{cases}$$

The final product is launched only if the test product sells and always has $\Lambda = 0$.

Since Theorem 3 shows that the equilibrium test product remains the same beyond some finitely large N, we shall consider the asymptotic case where $N \to \infty$ throughout to focus on the key intuition

from the model. Theorem 3 shows that, the equilibrium test product's horizontal attribute λ is always positioned at 0, consistent with the benchmark case (Theorem 1). Yet the choice of price ρ that determines the vertical quality varies depending on the investor's prior belief q ad the high-type entrepreneur's reservation payoff u_H. Figure 4 illustrates Theorem 3 for all values of q and u_H. First, we observe two regions based on the investor's prior belief: the *LSM region* where the investor's prior belief q is above the threshold $q^*(u_H)$ (Region A), and the *Learning-Funding Tradeoff region* where q is below the threshold $q^*(u_H)$ (Regions B, C, and D).

In the LSM region, the investor is initially sufficiently confident that the entrepreneur is a high type in the sense $q > q^*(u_H)$, and the venture is funded regardless of the test outcome. Thus, there is no distortion in the experimentation and funding to the high-type entrepreneur relative to the benchmark case with self-funding (§4.1), and the high-type entrepreneur chooses the test product $(\lambda, \rho) = (0, V - \epsilon)$. The proof of Theorem 3 shows that the high-type entrepreneur's expected payoff in this case is

$$\underbrace{r(P^{tp} - K) + \frac{(1-r)(2\epsilon - 1)}{2\epsilon}(P^{fp} - K)}_{\text{When test product sells}} + \underbrace{\frac{1-r}{2\epsilon}(P^{tp} - K) - \frac{(1-q)K}{q}}_{\text{When test product does not sell}}. \tag{4}$$

In comparison to his payoff in the benchmark case as shown in (3), the high-type entrepreneur's expected payoff differ by the last term $(1-q)K/q$. This term reflects the rent the entrepreneur must pay to the investor in the form of equity to assuage the investor concern when the test product does not sell. We observe that $(1-q)K/q$ converges to 0 as $q \to 1$, in which case the expected payoff is identical to the benchmark model with self-funding.

In the learning-funding tradeoff region, the investor is initially pessimistic about the entrepreneur's type in the sense $q < q^*(u_H)$. When q is low, the investor's demand for extra equity after a negative test outcome becomes so high that the high-type entrepreneur prefers to abandon the venture and opt for his outside option with payoff u_H. This potential lack of funding creates the *learning-funding tradeoff* that impacts the entrepreneur's experimentation process. The high-type entrepreneur needs to trade off the probability of the test product selling and the informativeness of the posterior belief when the test product sells: the former affects the funding probability, and the latter affects the success of the final product launch.

When u_H is small in the sense $u_H < \underline{u}_H$ (Region B), the high-type entrepreneur wishes to avoid his outside option and is desperate for funding. The entrepreneur consequently maximizes the probability of the test product selling by choosing the test product $(\lambda, \rho) = (0, V)$, which gives consumers the maximum vertical utility V. While this test product maximizes the sales probability of the test product, the positive test outcome leads to less learning about the product-market fit since the probability of a false positive is higher.

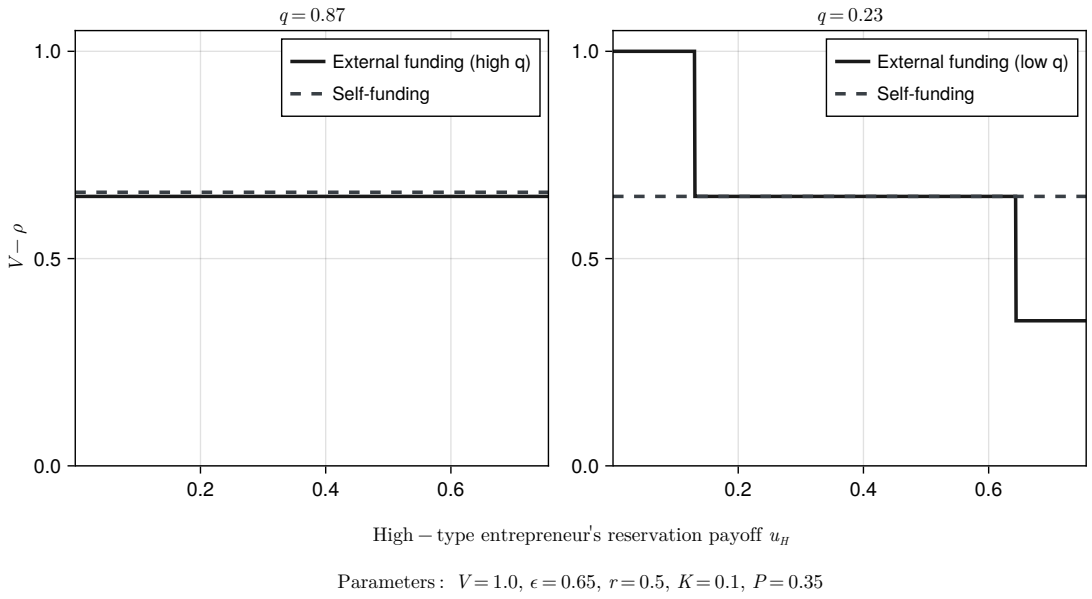


Figure 5 **Equilibrium test product vertical quality $\lambda - \rho$ with respect to u_H.**

When u_H is intermediate in the sense $u_H \in (\underline{u}_H, \bar{u}_H)$ (Region C), the high-type entrepreneur chooses the test product $(\lambda, \rho) = (0, V - \epsilon)$, leaving the vertical quality $V - \rho$ at an intermediate level of ϵ. This test product balances the learning from a positive test outcome and probability of funding. While it coincides with the benchmark test product, the venture is not funded when the test product does not sell, and there is no opportunity for pivoting after learning.

Finally, when u_H is large in the sense $u_H > \bar{u}_H$ (Region D), the high-type entrepreneur's outside option is very good. Hence, the entrepreneur is willing to forego this outside option and launch the optimal final product only if he is confident that the final product is likely to have high demand. Thus, he seeks to minimize the false positives by choosing test product $(\lambda, \rho) = (0, V - 1 + \epsilon)$, which has a *low* vertical quality $V - \rho = 1 - \epsilon$. This test product has a lower probability of selling than the test product in the benchmark model, but once the test product sells, the entrepreneur can be certain that $W = 0$.

A cross-section of the vertical quality of the test product is illustrated in Figure 5 for high (LSM region) and low (Learning-funding tradeoff region) values of q. The left panel of Figure 5 illustrates that in the LSM region, the high-type entrepreneur has the same test product launched as in the benchmark case with self-funding. The right panel illustrates that the learning-funding tradeoff can result in two types of distortions in the high-type entrepreneur's experimentation based on his reservation payoff u_H. Namely, those with low reservation payoff u_H distort vertical quality $(V - \rho)$ upwards to maximize the chances of test sales at the expense of learning, whereas those with higher

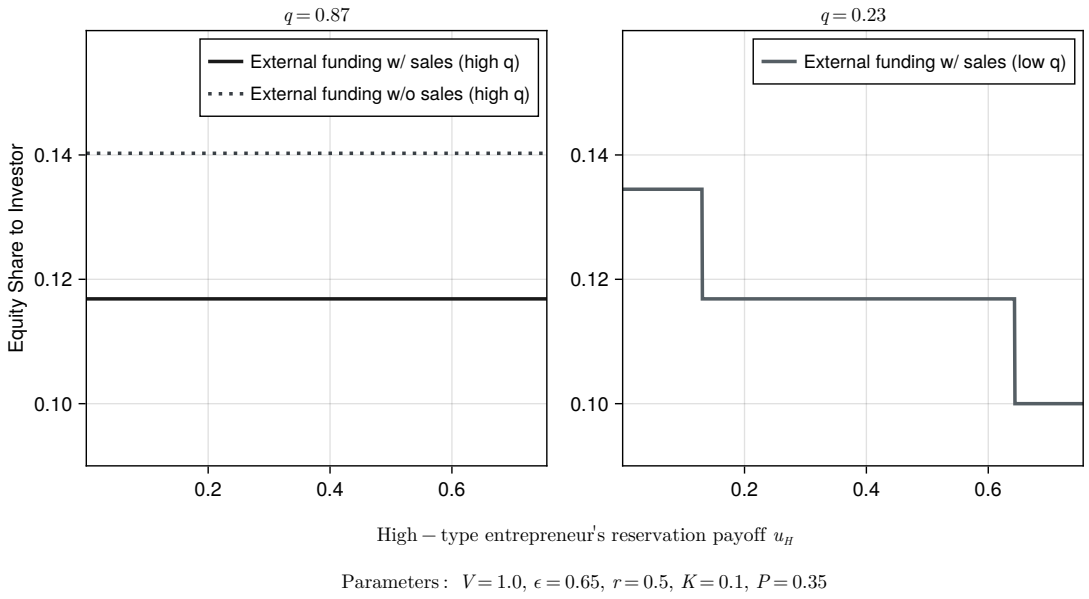


Figure 6 **Equilibrium equity share offer to the investor with respect to u_H**

reservation payoff u_H distort it downwards to minimize false positive at the expense of funding probability.

The different experimentation strategies for different parameter values in Theorem 3 lead to heterogeneity in the equity share offered to the investor, which we describe in the following.

PROPOSITION 2 **(Equilibrium equity offer to the investor)**. *The following statements are true from the high-type entrepreneur's perspective.*

(a) LSM region ($q > q^*(u_H)$): If the test product sells, the entrepreneur offers equity share so that the investor's expected payoff is exactly K; If the test product does not sell, entrepreneur offers equity share so that the investor's expected payoff is strictly above K.

(b) Learning-funding tradeoff region ($q < q^*(u_H)$): If the test product sells, the entrepreneur offers equity so that the investor's expected payoff is exactly K. Moreover, the equity share is a decreasing step function in u_H.

The left panel of Figure 6 illustrates the equity offered to the investor. When the test product sells, the investor becomes certain that the entrepreneur's type is high, making her belief the same as the entrepreneur's. Thus, the entrepreneur just needs to offer equity to the investor so that her expected payoff is exactly K. When the test product does not sell, the investor becomes more pessimistic about the entrepreneur's type, which makes her belief about the final product's demand to be lower than the entrepreneur's. Therefore, from the high-type entrepreneur's perspective, he needs to offer more equity to the investor so that her expected payoff is more than K.

The right panel of Figure 6 illustrates the entrepreneur's equity offer in the learning-funding tradeoff region. Recall that a deal occurs only when the test product sells. As u_H increases, the informativeness of the posterior belief increases after a positive test outcome (because the false positive rate decreases). We see that the entrepreneurs with worse outside options offer higher equity to the investor. This is not because their lower outside options directly impact the negotiations, but rather because their lower outside option made them experiment in a way that a positive test outcome is less informative.

5. Impact of Learning-funding Tradeoff on Innovation Ecosystem

We now present the broader implications when entrepreneurs distort their experimentation strategies as a result of the learning-funding tradeoff.

5.1. Implication of the Learning-Funding Tradeoff Region

Proposition 3 characterizes the funding probability for the high-type entrepreneur with different u_H.

PROPOSITION 3 **(Funding probability)**. *The following statements are true from the high-type entrepreneur's perspective.*

(a) LSM region ($q > q^*(u_H)$): the funding probability is 1.

(b) Learning-funding tradeoff region ($q < q^*(u_H)$): the funding probability is strictly below 1*, and is a decreasing step function in u_H.*

The left panel of Figure 7 illustrates Proposition 3. In the learning-funding tradeoff region, the probability of the venture being funded equals the probability that the test product sells. This probability is decreasing in u_H because those with worse outside options are more eager to get funded to avoid their outside options by distorting the test product's vertical quality upwards. Thus, the high-type entrepreneurs with lower u_H tend to have more of their product ideas funded relative to those with higher u_H.

The distortion in the experimentation that impacts probability of funding also impacts the learning about the product-market fit. Thus, once funded, there is heterogeneity in the demand of the final product, as characterized next.

PROPOSITION 4 **(Demand conditional on funding)**. *The following statements are true from the high-type entrepreneur's perspective.*

(a) LSM region ($q > q^*(u_H)$): the venture is funded regardless of the test outcome, and when the test product does not sell, the expected demand of the final product conditional on funding is the maximum demand P^{tp}.

(b) Learning-funding Trade region ($q < q^*(u_H)$): the venture is funded only if the test product sells, and the expected demand of the final product conditional on funding is an increasing step function in u_H and has maximum P^{tp}.

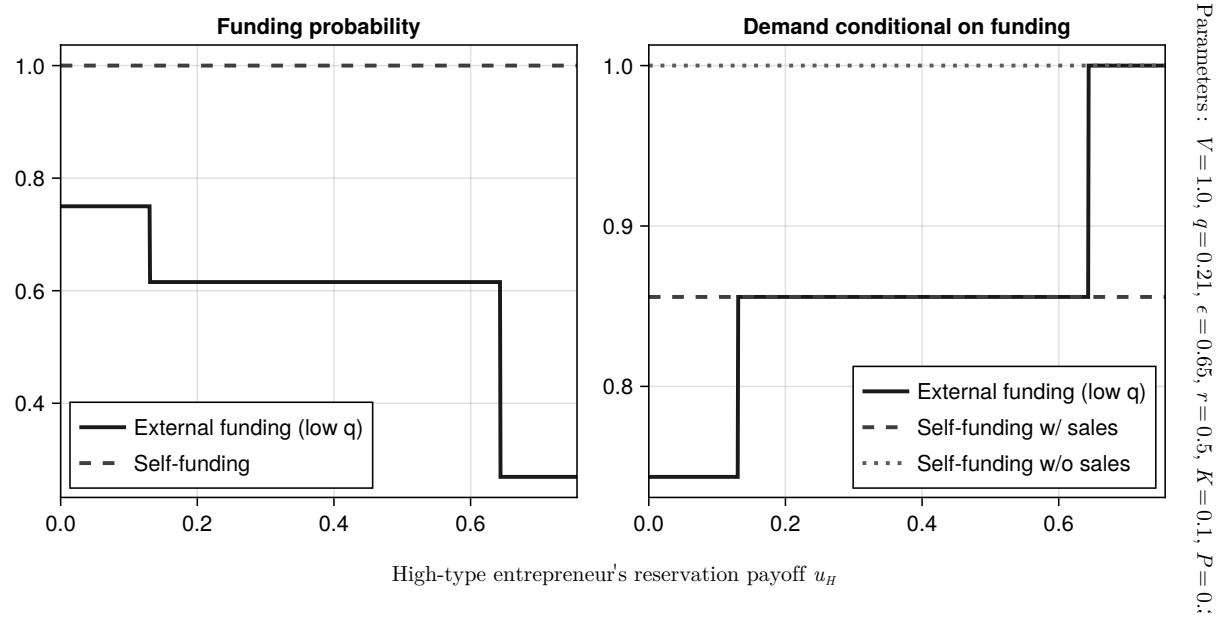


Figure 7 **Equilibrium funding probability and demand conditional on funding with respect to u_H from the high-type entrepreneur's perspective in the asymptotic case**

The right panel of Figure 7 illustrates Proposition 4. We see that as the funding probability falls, the expected demand of the final product conditional on funding increases. Propositions 3 and 4 together show that, in the learning-funding tradeoff region, once funded, those endowed with outside options tend to launch fewer yet more successful products, whereas those with worse outside options tend to launch more yet less successful products.

The following result informs how the venture performance varies with u_H in the learning-funding tradeoff region.

PROPOSITION 5 **(Equilibrium demand before test)**. *From the high-type entrepreneur's perspective, if $q < q^*(u_H)$, then the unconditional expected demand generated by the venture in the learning-funding tradeoff region is strictly less than that in the LSM region, and is a decreasing step function in u_H.*

Figure 8 illustrates that the expected demand generated by the venture when $q < q^*(u_H)$ is strictly less than that in the self-funding case (and equivalently, the LSM region). This difference is primarily driven by the lack of funding following a failed test product launch. Specifically, there is no opportunity to "pivot" after learning, and the final product launch $\Lambda = 0$ will always be the same as the test product $\lambda = 0$. This means that the key benefit of LSM experimentation—learning from a negative test outcome, and changing the course of action—is never realized, making the venture performance inferior to that in the self-funding case or in the LSM region.

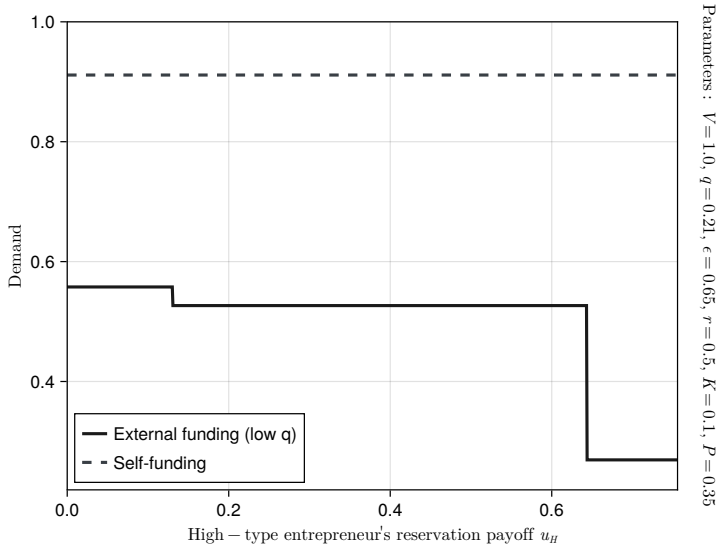


Figure 8 **Equilibrium demand generated by the venture from the high-type entrepreneur's perspective with respect to u_H in the asymptotic case**

Multiplying the funding probability with the demand conditional on funding provides the expected demand from the venture, which is a decreasing step function of u_H. This suggests that in the learning-funding tradeoff region, the *quantity* of innovation attempts (in the form of funding probability) is more critical than the *quality* of each attempt (in the form of demand conditional on funding).

5.2. Innovation Efficiency in Equilibrium

We now examine the impact the investor's prior belief q has on the efficiency of the innovation ecosystem. Suppose that investor's prior belief q accurately reflects the proportion of high-type entrepreneurs in the sector. In the benchmark self-funding case, the outcome is *efficient* in the sense that, the $1-q$ proportion of low-type entrepreneur never launches the product and the q proportion of high-type entrepreneur chooses the test product that is optimal for learning. Accordingly, we consider the welfare measure defined as the sum of the entrepreneur's and the investor's expected payoffs. The welfare of the benchmark self-funding case is:

$$\underbrace{q\{rP^{tp} + \frac{(1-r)(2\epsilon-1)}{2\epsilon}P^{fp} + \frac{1-r}{2\epsilon}P^{tp}\}}_{\text{welfare from high-types}} + \underbrace{(1-q)K}_{\text{welfare from low-types}}. \tag{5}$$

For ventures led by a low-type entrepreneur, the payoff of the entrepreneur would be 0 and the payoff of the investor (entrepreneur himself) is K, summing to be K. For ventures led by a high-type entrepreneur, the venture is always funded, so the sum of expected payoff of the entrepreneur and that of the investor is the demand of the final product.

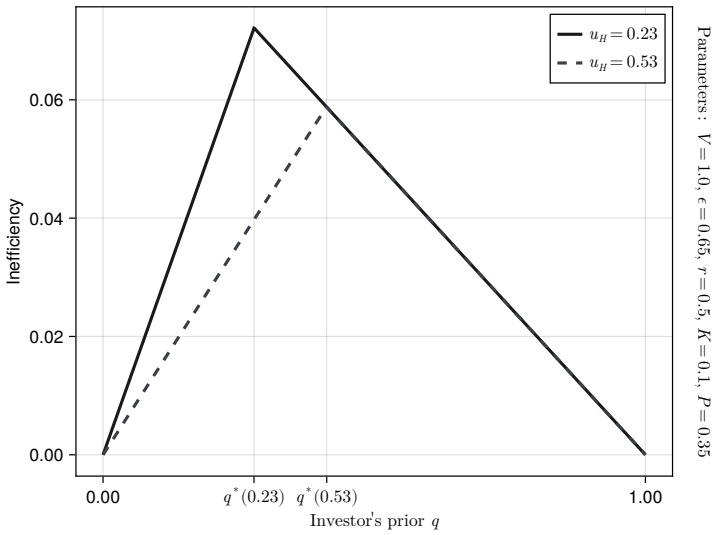


Figure 9 Inefficiency of equilibrium outcome in the asymptotic case

Using this welfare benchmark, we can define the *inefficiency* of the equilibrium outcome in the external-funding case as the decrease in welfare relative to that of the benchmark case. The following result presents the inefficiency of the equilibrium outcome in the external-funding case.

PROPOSITION 6 **(Equilibrium inefficiency)**. *For any given u_H, the inefficiency of the equilibrium outcome is linear and increasing in q for $q \le q^*(u_H)$; it is linear and decreasing in q for $q > q^*(u_H)$. Moreover, for any given q, the inefficiency is decreasing in u_H for $q < q^*(u_H)$, and invariant in u_H for $q > q^*(u_H)$.*

Figure 9 illustrates Proposition 6. We observe that inefficiency is maximized at $q^*(u_H)$ or intermediate levels of q when the investor has greater uncertainty about the entrepreneur's type; and as investor belief $q \to 0$ or $q \to 1$, uncertainty about entrepreneur types disappears and the welfare is same as the self-funding case.

The LSM region where $q > q^*(u_H)$ represents a "loose money" situation where the high-type entrepreneur always receives funding. So the inefficiency is driven by the misallocation to the low-type entrepreneur with whom she will never recover the investment. The learning-funding tradeoff region where $q < q^*(u_H)$ represents the "tight money" situation where the inefficiency arises from not funding the high-type entrepreneur when the product does not sell, leaving money on the table.

5.3. Effects of Investor Stereotypes (biased beliefs) about Entrepreneurs

We have seen that the investor's prior belief on the entrepreneur's type q plays an important role. In practice, these beliefs are subjectively formed by various observable characteristics of entrepreneurs or the founding team that they believe affect a startup's success, such as education (Dickson et al.

2008), prior entrepreneurial experience (Gruber et al. 2012), and other observable socioeconomic factors such as race and gender (Lyons-Padilla et al. 2019). We now examine how investor's biased beliefs (or stereotypes) about entrepreneurs can impact funding decisions, innovation outcomes, and the individual entrepreneur payoffs.

We operationalize the concept of stereotypes in the context of our model as follows. While the investor's prior belief q about the overall proportion of high-type entrepreneurs in a sector may be accurate, she incorrectly believes that there is additional variation around this overall proportion among different subgroups based on some observable characteristics (e.g., race, gender) of the entrepreneurs, even when there is no such variation. For example, the investor may believe that the proportion of high-type entrepreneurs is higher among men (positive stereotypes), but lower among women (negative stereotype), even when the proportion is identical across the two groups.

Let q_0 be the true proportion of high-type entrepreneurs in a group of entrepreneurs. We say that a group of entrepreneurs is *negatively stereotyped* if $q < q_0$ and *positively stereotyped* if $q > q_0$. The following result, which follows from Propositions 3, 4, and 5, shows that the investor's biased belief can change the equilibrium outcome.

COROLLARY 2 **(Effect of stereotypes on equilibrium outcomes)**. *Assume the proportion of high-type entrepreneurs in a group of entrepreneurs is q_0 and the investor's prior belief about this proportion is q.*

(a) If the entrepreneurs are negatively stereotyped such that $q < q^*(u_H) < q_0$, in comparison to the case without stereotypes, they are less likely to get funded, generate less (unconditional) demand from the venture, and obtain lower expected payoffs. Moreover, when funded,

(i) If $u_H < \underline{u}_H$, the entrepreneurs distort the test product choice to maximize the funding probability, and the demand of the final product is lower.

(ii) If $u_H > \bar{u}_H$, the entrepreneurs distort the test product choice to ensure a successful product launch, and the demand of the final product is the maximum demand P^{tp}.

(b) If the entrepreneurs are positively stereotyped such that $q > q^*(u_H) > q_0$, in comparison to the case without stereotypes, they are more likely to get funded, generate more (unconditional) demand from the venture, and obtain a higher expected payoff.

Intuitively, a negative stereotype deprives entrepreneurs of funding after a negative test outcome, leading them to endogenously distort the test product choice. Negatively stereotyped entrepreneurs with low reservation payoffs (i.e., $u_H < \underline{u}_h$) are caught in a vicious cycle: they cannot afford to learn from failures, so are forced to prioritize funding over learning. If funded, due to the lack of learning, they will end up with poorer track records of launching successful products, which reinforces the negative stereotype.

For the negatively stereotyped entrepreneurs with high reservation payoffs (i.e., $u_H > \bar{u}_H$), their good outside options incentivize them to prioritize minimizing false positive test outcome over funding. As a result, once funded, they are more likely to launch successful products. In this case, an outside observer that observe the product launches by this group of entrepreneurs may conclude that the negative stereotype pushes them to become more successful. However, this is an illusion of success for these entrepreneurs since the negative stereotype actually makes them worse off by forcing them to experiment suboptimally with the consequence of foregoing many opportunities.

In contrast, a positive stereotype leads the investor to hold a more forgiving assessment of a negative test outcome, as shown through the term $K(1-q)/q$ in (4). By reducing the cost of negative test outcome, the positive stereotype affords the entrepreneur to experiment freely and leads to higher payoff for the entrepreneur. Moreover, due to the optimal learning, once funded, they are more likely to launch successful products which reinforces the original positive stereotypes.

As the investor's stereotypes change the equilibrium outcomes, it is intuitive that the stereotypes introduce further inefficiency. The allocation of this extra inefficiency, however, is unclear. The following result shows the asymmetry in who bears the cost of the investor's positive and negative stereotypes.

PROPOSITION 7 **(Who bears the cost of stereotype-induced inefficiency?)**. *Assume the proportion of high-type entrepreneurs in a group of entrepreneurs is q_0 and the investor's prior belief about this proportion is q such that either $q < q^*(u_H) < q_0$ or $q > q^*(u_H) > q_0$. In comparison to the case without stereotypes, the equilibrium outcome with stereotypes is less efficient. Moreover, the bearer of this extra inefficiency differs between the two types of stereotypes:*

(a) When the investor has a negative stereotype of a group ($q < q^*(u_H) < q_0$), the high-type entrepreneurs of that group bear the cost of the induced inefficiency.

(b) When the investor has a positive stereotype of a group ($q > q^*(u_H) > q_0$), the investor bears the cost of the induced inefficiency.

When the stereotype is negative such that $q < q^*(u_H) < q_0$, the investor always gets her money back since only the high-type entrepreneurs are funded. But high-type entrepreneurs are forced to abandon the venture after a negative test outcome. This funding shortfall deprives high-type entrepreneurs facing negative stereotypes of the payoff from the final product launch, which they could have obtained if there were no stereotype. Thus, the high-type entrepreneurs from the negatively stereotyped group bear the cost of the inefficiency.

In contrast, when the stereotype is positive such that $q > q^*(u_H) > q_0$, given a negative test outcome, the investor's expected payoff in excess of K is $\frac{(1-q)}{q}K$ if the entrepreneur's type is high, which happens with probability q_0. But she loses her investment K when investing in the low-type

entrepreneur; this happens with probability $1-q_0$. Thus, when $q > q_0$, the investor bears the cost of inefficiency relative to the case without stereotypes because the expected excess payoff from investing in the high-type entrepreneur is not sufficient to cover her expected loss from investing in the low-type entrepreneur.

In both cases of stereotypes, the main intuition is that the investor's stereotypes on entrepreneurs can be thought of exogenously affecting her bargaining power. That is, the investor's bargaining position is strengthened when the stereotype is negative, which forces the high-type entrepreneurs to accept worse terms, and it is weakened when the stereotype is positive, which allows the entrepreneur to offer less equity. We expect this intuition surrounding the investor's bargaining power to continue to hold under different model setups.

Proposition 7 is powerful in that it highlights the fundamental asymmetry between those facing positive and negative stereotypes as well as the fairness implication of this asymmetry. Specifically, when the investor holds a positive stereotype, she bears the cost of her incorrect beliefs, which can be considered fair. In contrast, when the stereotype is negative, it is the negatively stereotyped high-type entrepreneurs rather than the investor that bear the burden of her incorrect beliefs, which is not only clearly unfair but also clarifies the error in the often-used argument that stereotypes cannot be long-lasting since those who hold the stereotypes will pay for their own mistakes: Proposition 7 shows that this is not the case for negative stereotypes.[9]

Since endogenous factors such as entrepreneurs' test product choices and investments in learning are typically unobservable to external researchers, greater effort is needed to isolate and disentangle the self-perpetuating forces in product development that ultimately determine venture success or failure. A naive examination of startup failure rates might reveal higher failures among negatively stereotyped groups, such as women and minorities. However, our results indicate that these higher failure rates may be driven by negative investor stereotypes rather than a lack of competence. Conversely, positive investor stereotypes can reduce failure rates for these groups, further magnifying the differences in observed outcomes and reinforcing perceived differences in group capabilities. We hope that our insight about how investor stereotypes asymmetrically impact entrepreneur startup outcomes and payoffs will inform and guide empirical scholarship on the relationship between entrepreneur performance and demographics (e.g. Lyons-Padilla et al. 2019). We encourage empirical entrepreneurship scholars to develop methods that isolate the influence of stereotypes when assessing

[9] While not the focus of this paper, Proposition 7 also suggests that when we are dealing with societal stereotypes, society pays for the cost of positive stereotypes on selected groups, whereas society makes the higher quality members of the negatively stereotyped group pay for the cost of negative stereotypes.

entrepreneurial success rates, so as to avoid erroneous conclusions that can inadvertently reinforce these stereotypes.[10]

6. Conclusion

LSM is widely accepted by the entrepreneurial community as an efficient product development method that helps the entrepreneurs to learn about the market and consumer needs. This method involves a build-test-learn cycle in which firms build test products that capture the essential attributes, launch them to learn about the product-market fit, and then pivot by modifying the product for better product-market fit, in response to negative test outcomes. While this validated learning approach is reasonable from a product development perspective, it abstracts away from the frictions created by their incentives to raise funding. Heterogeneity among the entrepreneurs and the information asymmetry between entrepreneurs and investors lead to funding frictions, which systematically distorts LSM's implementation and impacts the venture's success.

In this paper, we have developed a model to analytically capture the learning-funding tradeoff in the context of entrepreneurs practicing LSM. By examining from the perspective of the entrepreneurs practicing experimentation in early product development process rather than the investors that fund them, our paper offers novel insights into the linkages between product experimentation and funding. Specifically, in the presence of funding incentives, experiments may be designed to make a positive test outcome more likely (sacrificing learning to increase chance of funding) or to make the final product more successful when the test product sells (leaving potentially more innovative ideas unfunded).

On the innovation ecosystem level, our findings suggest that distortions in product experimentation can result in the loss of innovative products to the consumers, and makes the ecosystem less efficient. Moreover, we have drawn implications for how investor stereotypes on entrepreneurs, such as race and gender, can distort the entrepreneur's incentives for product experimentation that lead to self-reinforcing stereotypes. Finally, the cost of investor's negative stereotypes can be borne unfairly by the high-type entrepreneurs, furthering the payoff inequality among entrepreneurs.

Overall, as the share of digital technologies in the economy continues to increase, the role of LSM in developing innovations will continue to grow in importance. By illustrating how we can account for the impact of entrepreneurial incentives for funding in the practice of LSM, we hope this paper will serve as an impetus for more research on the topic. In particular, as to our results on how stereotypes can impact product experimentation and payoff inequality, we hope future empirical work will investigate and parse out how much of the lower entrepreneurial performance of women and minorities documented in the literature may be explained by investor stereotypes.

[10] Our work contributes to the recent interest among marketing scholars on how biases and stereotypes based on gender and race impact market outcomes in equilibrium. See, for example, Teng et al. (2023) for a recent empirical study on how consumer biases against minorities bring about earnings inequality.

We conclude with some suggestions for future work. Our focus has been on how funding incentives impact the entrepreneurs choice of product experimentation. In modeling the funding incentives, we restricted our analysis to equity share contacts—one of the most common form of investment contracts—between the entrepreneur and investors. It would be interesting in future work to assess whether the distortion effects we identify in this paper remain robust or can be mitigated through other forms of contracting. Moreover, as noted before, to isolate the entrepreneur's learning-funding tradeoff in an analytically tractable manner, we only considered one-shot experiments in this paper. While we expect the tradeoff between learning and funding to persist under different model setups, having multiple rounds of experiments can potentially introduce more complex dynamics between funding and product learning across different entrepreneur types, which may lead to novel insights. We hope future research will explore the implications of multi-round experimentation in lean-startup product development and funding.

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Appendix A: Assessing Sensitivity of Results to Assumption 3(a)

In this appendix, we analyze the case where Assumption 3(a) does not hold, i.e., $mP^{tp} > K$. In this case, it becomes possible for the low-type entrepreneur to be funded even if his type is known to the investor. This implies that the low-type entrepreneur now cares about the learning of product-market fit after a positive test outcome instead of just the investor's belief about his type, and thus may not always want to mimic the high-type entrepreneur's strategy. Moreover, it becomes less detrimental for the high-type entrepreneur to be mistakenly considered as a low-type, potentially impacting his strategy. These complications introduce difficulty in tracking each type's incentive constraints, making the equilibrium analysis across the full range of parameters not tractable.

In what follows, §A.1 presents numerical insights on why pooling equilibrium may not be guaranteed; in §A.2, we provide intuitive conditions under which a pooling equilibrium exists and our key results continue to hold; in §A.3, we establish conditions to show that the high-type entrepreneur still distorts in a separating equilibrium.

A.1. Implications on Pooling Equilibrium without Assumption 3(a): A Numerical Example

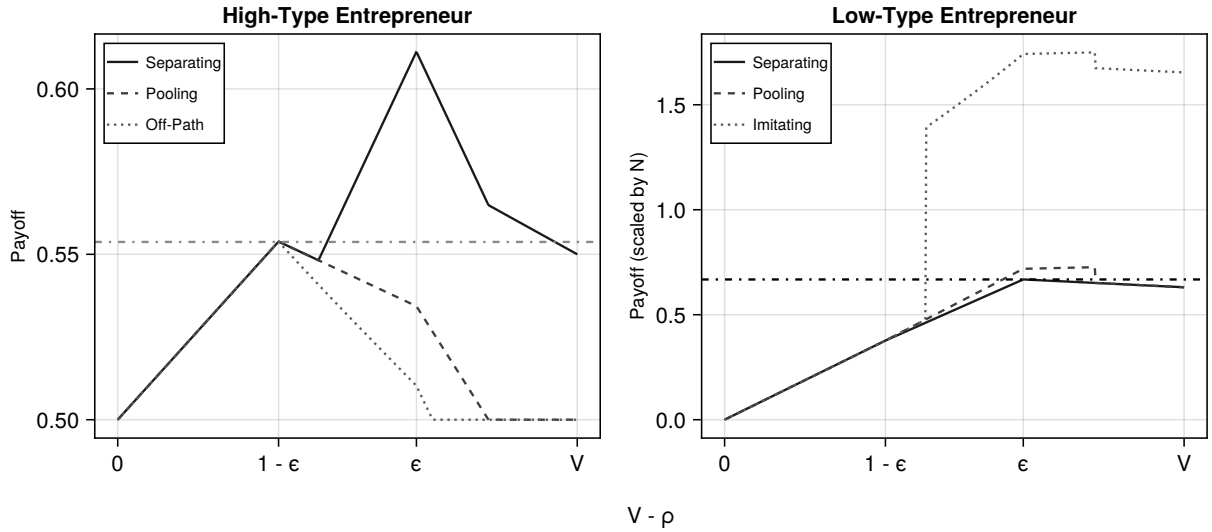
To start off, the existence of a pooling equilibrium is not guaranteed. We demonstrate with a numerical example illustrated by Figure A1. Each subplot shows each type of entrepreneur's payoff over the test product's location $\lambda = 0$ and vertical quality $V - \rho$ given different beliefs held by the investor upon observing the test product choice (before the test outcome realization). To both types of entrepreneurs, being considered as a low-type entrepreneur minimizes the entrepreneur's payoff given any strategy. Thus, the maximum payoff in the case of being considered as a low-type entrepreneur (which is the off-path payoff for the high-type and the separating payoff for the low-type) serves as a lower bound of the entrepreneur's payoff, which is shown as the horizontal line in each subplot: any on-path payoffs profile strictly below any of the two horizontal lines cannot be supported as an equilibrium.

According to the left panel of Figure A1, the high-type entrepreneur's payoffs in a pooling equilibrium and in an off-equilibrium path both achieve the same maximum when the test product's vertical attribute is $\rho = V - 1 + \epsilon$. This implies that, if there is a pooling equilibrium, then we must have $V - \rho = 1 - \epsilon$. However, for the low-type entrepreneur, whose payoffs are illustrated in the right panel, his pooling payoff for $V - \rho = 1 - \epsilon$ is strictly below his payoff for $V - \rho = \epsilon$ when he is considered as a low-type entrepreneur. Therefore, there is no pooling equilibrium in this numerical example.

A.2. Distortions in Pooling Equilibrium without Assumption 3(a)

Despite the complications above, we are able to show that our main characterization of the high-type entrepreneur's equilibrium distortion characterized in Theorem 3, continues to hold even when Assumption 3(a) is relaxed. In the following result, we provide intuitive conditions under which the high-type entrepreneur will have the same pattern of distortion to the test product's vertical attribute as in Theorem 3.

Proposition A1 **(Existence of Pooling Equilibrium and Distortion)**. *Let $q^*(u_H)$ have the same definition as in Theorem 3 and assume $q < q^*(u_H)$. For every fixed set of parameters except for u_H, there exists some $\bar{u}_H^* > 0$ such that, for large enough N, if $u_H < \bar{u}_H^*$, then a pooling equilibrium exists and the high-type-optimal pooling equilibrium is the same as that characterized in Theorem 3.*



Parameters: $K=0.3,\ \epsilon=0.65,\ V=1.0,\ V-P=0.65,\ r=0.5,\ u_h=0.5,\ r=0.5,\ m=1.0$

Figure A1 A numerical example where a pooling equilibrium does not exist but a separating equilibrium does

Proposition A1 shows that Assumption 3(a) is not crucial to the main insights of Theorem 3. Specifically, the proposition implies that Assumption 3(a) is sufficient but not necessary for the distortion pattern in Theorem 3. Hence, we expect the distortion patterns to hold as long as the low-type entrepreneur is given strong enough incentives not to reveal his type to the investor, which helps with the existence of a pooling equilibrium: Assumption 3(a) operationalizes this by having the investor always wish to avoid the low-type entrepreneur. The condition in Proposition A1 about the high-type entrepreneur's reservation payoff generates this incentive by making sure that the high-type would like to pool at a test product with relatively high vertical quality: this incentive exists when the high-type entrepreneur's reservation payoff is low, which makes him care about getting funded. In this case, the low-type entrepreneur is given a strong incentive to mimic the high-type entrepreneur's strategy in that the high vertical quality of the test product improves the low-type entrepreneur's funding probability and equity share relative to when the investor knows his type.

A.3. Distortions in Separating Equilibrium

With the relaxation of Assumption 3(a), there is the possibility of separating equilibria, as the following example shows. Consider the strategy profile where the high-type entrepreneur chooses test product $(0, V-1+\epsilon)$ and the low-type entrepreneur chooses test product $(0, V-\epsilon)$. We show that this strategy profile is a separating equilibrium via the payoffs illustrated in Figure A1. The high-type has no incentive to deviate since being considered as a low-type entrepreneur does not improve his payoff; the low-type entrepreneur has no incentive to deviate since he is already maximizing his payoff when he is considered as a low-type entrepreneur, and deviating to the high-type entrepreneur's test product $(0, V-1+\epsilon)$ leads to a lower payoff.

For our analysis of separating equilibria, we focus on separating equilibria where the high-type entrepreneur gets funded with a positive probability. While the complete characterization of separating equilibria is not tractable, we can nonetheless find intuitive conditions that guarantee the existence of separating equilibria

where the high-type entrepreneur distorts the test product's vertical quality downward to $1-\epsilon$, as the following result shows.

PROPOSITION A2 **(Existence of Separating Equilibrium with High Reservation Payoff)**. *Fix a set of parameters except for u_H. Assume $m(P^{tp}+P^{fp})>2K$. There exists some $\underline{u}_H^*$ and $\underline{m}<1$ such that, for large enough N, if $u_H>\underline{u}_H^*$ and $m>\underline{m}$, then a separating equilibrium where the high-type entrepreneur chooses test product $(0,V-1+\epsilon)$ exists.*

Intuitively, when the high-type entrepreneur's reservation payoff is high, the high-type entrepreneur has an incentive to set the test product's vertical attribute low to ensure a successful product launch, an intuition similar to that in Theorem 3 for the case $u_H>\bar{u}_H$. When m is close to 1, the low-type entrepreneur does not benefit much from being considered as a high-type entrepreneur. Indeed, in the maximum case where $m=1$, when the test product $(0,V-1+\epsilon)$ sells, the investor is indifferent about the entrepreneur's type. Therefore, if the low-type entrepreneur chooses to set the test product's vertical attribute different from $(0,V-1+\epsilon)$, which is the case when $m(P^{tp}+P^{fp})>2K$, then the low-type entrepreneur no incentive to mimic the high-type entrepreneur's strategy, leading to a separating equilibrium.

We further provide conditions under which distortion to the test product's vertical quality by the high-type entrepreneur occurs in a separating equilibrium.

PROPOSITION A3 **(Distortion in Separating Equilibrium)**. *There exists large enough N such that, if there exists a separating equilibrium where the high-type entrepreneur chooses $\lambda=0$ and the investor is indifferent between accepting and rejecting the entrepreneur's equity share offer on every equilibrium path where the entrepreneur gets funded, then the high-type entrepreneur must set the test product's vertical attribute to $\rho>V-\epsilon$.*

The intuition for the necessity of downward distortion to the test product's vertical quality $V-\rho$ is as follows. When $\lambda=0$, if $\rho<V-\epsilon$, then $f^{tp}(\rho)=1$, which means that the high-type entrepreneur becomes certain that $W=1$ after a negative test outcome. In a separating equilibrium, this means that, when the test product does not sell, the test product is launched, and the high-type entrepreneur offers the lowest equity share to the investor across all possible posterior beliefs. In this case, if the low-type entrepreneur chooses the same test product as the high-type entrepreneur, then the low-type entrepreneur will not only get funded but also obtain the maximum possible equity share when the test product does not sell. In the proof of the proposition, we show that launching the final product with a very good equity share after the negative test outcome gives the low-type entrepreneur an incentive to mimic the high-type entrepreneur's strategy, which leads to a contradiction.

In summary, we have shown that while the high-type entrepreneur can use the choice of test product to potentially differentiate from the low-type entrepreneur, the ability to do so is limited by the low-type entrepreneur's desire to get funded when the test product does not sell. This makes pooling equilibria still possible even if Assumption 3(a) is not assumed. The intuition of why the high-type entrepreneur still distorts the vertical test product in this case is the same as that in Theorem 3 when Assumption 3(a) holds. In the case of separating equilibria, the high-type entrepreneur can distort the test product's vertical quality downward from $V-\epsilon$ to make the negative outcome unappealing to the low-type entrepreneur and to lower the low-type entrepreneur's funding probability, which helps constitute a separating equilibrium.