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Entrepreneurial Risk Choice and Credit Market Equilibria*

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Abstract

We analyze under what conditions credit markets are efficient in providing loans to entrepreneurs who can start a new project after previous failure. An entrepreneur of uncertain talent chooses the riskiness of her project. If banks cannot perfectly observe the risk of previous projects, two equilibria may coexist: (1) an inefficient equilibrium in which the entrepreneur undertakes a low-risk project and has no access to finance after failure; and (2) a more efficient equilibrium in which the entrepreneur undertakes high-risk projects and gets financed even after an endogenously determined number of failures.

Keywords: Stigma of Failure, Entrepreneurship, Credit Markets

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1 Introduction

What determines the level of entrepreneurial activity in an economy? One key variable is the extent to which failed entrepreneurs are excluded from further entrepreneurial finance. European and Japanese financiers, for instance, are perceived to be more reluctant to finance a failed entrepreneur's restart than their American counterparts. It therefore has become commonplace to praise the US' lower "stigma of failure" as the source of its higher entrepreneurship rates[1] and consequently of its competitive edge in terms of the ability to innovate, commercialize and grow.[2]

In this paper, we present endogenous risk choice as an explanation for why economies with identical cultural and institutional constraints can experience different levels of the "stigma of failure". If the "stigma of failure" is high and banks provide credit only to those who have never failed, entrepreneurs will choose low-risk projects. In this economy, failure indicates low entrepreneurial talent. If the "stigma of failure" is low and banks provide credit to failed entrepreneurs, new entrepreneurs will be more inclined to experiment with novel (and more risky) business ideas. Failure at the beginning of an entrepreneurial career then indicates bad luck rather than low entrepreneurial talent.

To get an intuition for the model, imagine an entrepreneur who can undertake one of two projects, a low-risk project or a high-risk project. Both projects have no investment costs. The low-risk project yields a safe return of $y_L > 0$. The high-risk project fails with probability $p_H \in (0, 1)$ and then yields a return of 0. It succeeds with probability $1 - p_H$ and then yields a return of $y_H > y_L$. The expected return of the low-risk project is higher than the expected return of the high-risk project, $y_L > (1 - p_H)\, y_H$. If the entrepreneur has only one chance to undertake a project, she should clearly choose the low-risk project. However, assume now that, in the case of success, she works on the project and enjoys its returns; while in the case of failure, she can start a new project and faces the same choice.[3] What project should the entrepreneur now choose? If she chooses the low-risk project, she will earn y_L. If she always chooses the high-risk project, she will succeed for sure after finite time and earn y_H. Therefore, it is optimal to go for the high-risk project.

In our model, there are two complications to this scenario. First, there are investment

[1] GEM (2008) reports that in 2007, 10.8% of adults were engaged in early-stage entrepreneurship in the US as compared to only 5.4% in the EU or 5.4% in Japan.

[2] See Bottazzi et al. (2003), EU Commission (2000), SME Agency (1999) or Wennekers et al. (2006).

[3] For example, both projects could be a business that has no value except for the human capital of the entrepreneur (such as a gourmet restaurant). Returns only materialize if the entrepreneur runs the project during her entire professional life. Another interpretation is that once the entrepreneur has established a successful business, she gets settled such that her costs of starting a new business become prohibitively large.

costs that cannot be financed by the entrepreneur herself. She has to apply for a loan on a competitive credit market. Second, her entrepreneurial talent, which is either high or low, influences her probability of success, but is unknown to her and to banks. Only the distribution of talent is common knowledge. The entrepreneur and banks learn about her talent from the outcome of the project. However, learning depends on the project's risk: failure with a low-risk (high-risk) project implies a relatively low (high) probability of high talent. Given that the ex-ante probability of high talent is sufficiently close to unity, the first-best outcome is as follows. The entrepreneur first undertakes high-risk projects. After continuous failures, she undertakes the low-risk project. Failure with the low-risk project discloses low talent, therefore she stops undertaking projects at all.

Under what circumstances is the first-best outcome an equilibrium outcome and what other equilibria exist? We consider three different informational settings: perfect information (PI), private information of banks (PIB) and imperfect information (IM). Under PI, banks can observe both the entrepreneur's past and present risk choices. In this setting, all parties equally learn about her talent. Hence, only the first-best outcome is a sequential equilibrium. Under PIB, banks only observe the risk of projects in their own loan portfolio. Several equilibria may now co-exist. In the first equilibrium, the entrepreneur undertakes a low-risk project and, if it fails, does not get any more loans. This is due to the fact that only one bank observes the entrepreneur's choice. This bank becomes a monopolistic supplier of finance if all other banks expect that the entrepreneur undertakes a low-risk project. This equilibrium is inefficient since the entrepreneur undertakes the low-risk project too early. In the second equilibrium, the entrepreneur first undertakes high-risk projects and then, after continuous failures, a low-risk project.

Under IM, banks never observe the risk of projects. This causes a moral hazard problem. The entrepreneur chooses the low-risk project only if the expected payoff of the high-risk project is sufficiently small relative to that of the low-risk project. As under PIB, multiple equilibria may again exist. Also the pareto-ranking remains the same. Yet, if the expected payoff of the high-risk project is close to that of the low-risk project, the entrepreneur will only undertake high-risk projects in equilibrium. Thus, if the ex-ante probability of high talent is sufficiently close to unity, multiple rounds of project financing must occur in equilibrium. We may then get a non-monotonic relationship between bank information and potential credit market inefficiency: under PI, the outcome is always efficient, while under PIB, there is always an equilibrium with only one period of project financing. This equilibrium may be strictly dominated by any equilibrium under IM in which the entrepreneur untertakes several high-risk projects.

In addition, we study the equilibrium set in the presence of a credit register that informs all banks about the interest rates of previously chosen loan contracts. Under PIB, such a credit register can ensure the existence of an efficient equilibrium. The reason is that the register transmits the entrepreneur's risk choice to the extent that if the entrepreneur chose a contract with a very low loan rate, this may indicate that she undertook a low-risk project (otherwise, the bank that offered this contract would have made negative expected profits). In this case, banks then stop offering loans. As long as it is unprofitable to undertake a low-risk project that is financed with a loan tailored for high-risk projects, there will be an equilibrium in which the entrepreneur undertakes projects as in the first-best outcome. Under IM, a credit register can have the same effect.

These results yield a number of policy implications. A bank's ability to observe both past and present entrepreneurial risk choices may be crucial in preventing credit market inefficiencies. Detailed credit registers help to accomplish this task because past loan rates may indicate whether a failed business was a high- or low-risk project. Furthermore, we show that with asymmetric information about past risk choices, potential gains from an increase in the population's entrepreneurial talent might not fully be realized.

The remainder of the paper is organized as follows. After a literature review in Section 2, Section 3 introduces the model and characterizes the first-best outcome. Section 4 analyzes the model under different informational settings. Section 5 discusses policy implications. Section 6 concludes. All proofs are in the Appendix.

2 Related Literature

A considerable empirical literature tries to explain cross-country differences in the "stigma of failure" by using persistent institutional or cultural characteristics.[4] Evidence confirms that fresh starts are affected by bankruptcy laws (Armour and Cumming 2008). However, the debate persists over which and how cultural traits shape attitudes towards entrepreneurial failure (see Licht and Siegel 2006, Hayton et al. 2002, Giannetti and Simonov 2004).[5] Our contribution to this literature is to present a model that endogenizes the "stigma of failure".

[4]Most research aims to identify individual characteristics that determine the propensity to entrepreneurship per se, such as family background (Dunn and Holtz-Eakin 2000, Sørensen 2007a), work experience (Sørensen 2007b) or wealth (Hurst and Lusardi 2004).

[5]For instance, Burchell and Hughes (2006) find that GDP growth is not related to failure tolerance, but positively related to second chancing willingness. Surveys, however, show more failure tolerance but less second chancing willingness in the US than in the EU. In the US, the stigma should thus be higher and entrepreneurship rates lower than in the EU, which contradicts empirical evidence.

Several papers study models of entrepreneurial finance with asymmetric information and find multiple equilibria. Gromb and Scharfstein (2002) analyze an occupational choice model in which agents either become entrepreneurs or intrapreneurs. When there are few (many) entrepreneurs, the average quality of failed entrepreneurs is low (high). As a result, the external labor market (that offers jobs to failed entrepreneurs) is poor (good), so that few (many) agents start a venture on their own. In Landier (2006), the capital market cannot distinguish between entrepreneurs who start a new venture because the previous one failed and those who start a new venture to pursue a more promising project. This can generate equilibria in which few (many) entrepreneurs restart because of the latter cause and interest rates are high (low). This, in turn, justifies the entrepreneur's decision. Ghatak et al. (2007) consider a general equilibrium model in which wages for dependent labor are low (high) when there are many (few) untalented entrepreneurs, which implies that many (few) agents become entrepreneurs. In contrast to these papers, we endogenize the number of rounds banks are willing to finance an entrepreneur after failure. The driver of our results is the link between risk choice and bank lending. New entrepreneurs will choose risky (save) projects provided that banks (do not) finance projects after failure. Consequently, the average talent of failed entrepreneurs is high (low), such that multiple rounds of project-financing (do not) occur in equilibrium.

We also contribute to the literature on entrepreneurial risk-taking. A common explanation for why entrepreneurs often bear substantial undiversified risk despite the lack of a positive premium, are (over-) optimistic beliefs (see e.g. Landier and Thesmar 2009). Vereshchagina and Hopenhayn (2009) interpret entrepreneurial risk-taking as a lottery over future wealth that is chosen by borrowing-constrained agents. Limited liability then makes poor and impatient agents (who have not yet saved much) take more risk. Campanale (2010) rationalizes entrepreneurial risk-taking on the grounds that entrepreneurs usually make small personal investments and gain large human capital from starting a business. Risk-taking in our model is determined by the willingness of banks to finance new projects after failure.

3 The Model

We consider an economy populated by an entrepreneur E and banks B_k, $k \in \{1, ..., K\}$ with $K \geq 2$.[6] All agents are risk-neutral. E can undertake a project, which requires an initial investment of 1. She has no wealth on her own. Thus, the project needs to be financed by banks. If E does not undertake a project or banks do not offer any loans, the game is over and all of the agents' payoffs are 0. Otherwise, E chooses a loan contract and

[6] The results easily carry over to a continuum of entrepreneurs.

nature decides on the project's outcome. In case of success, project returns are realized, E pays the loan rate and the game is over. In case of failure, no payments are made, the financing bank loses its investment, and the game starts anew. Time is discrete and denoted by $t \in \{1, 2, ...\}$, where period $t > 1$ is reached if and only if E undertook $t-1$ times projects that failed. There is no discounting between periods.

The Entrepreneur. In period 0, nature decides on E's entrepreneurial talent θ_i, which is high ($i = H$) with probability $\alpha_1 \in (0, 1)$ or low ($i = L$) with probability $1-\alpha_1$. Talent is time-invariant and unobservable to E and banks. Only α_1 is commonly known. E can undertake projects with high ($j = H$) or low ($j = L$) risk of failure p_j. For simplicity, we normalize $0 = p_L < p_H < 1$ and $0 \leq \theta_L < \theta_H = 1$. The project's return is determined by E's talent and choice of risk j: it is y_j with probability $(1-p_j)\theta_i$ and 0 with probability $1-(1-p_j)\theta_i$. The high-risk project yields higher returns, $y_L < y_H$. If E has high (low) talent, projects have positive (negative) value:

$$(1-p_j)y_j > 1 \text{ and } (1-p_j)\theta_L y_j < 1 \text{ for } j \in \{L, H\}. \tag{1}$$

Banks. Banks compete in a Bertrand manner by offering loan contracts. Their refinancing costs are normalized to 0. To apply the concept of sequential equilibrium (SE), we use finite actions sets. Define

$$R(\varepsilon) = \left\{1 + q\varepsilon \,\middle|\, q \in \left\{0, 1, ..., \left[\frac{y_H - 1}{\varepsilon}\right]_+\right\}\right\}, \tag{2}$$

where $[y]_+$ denotes the smallest integer higher than or equal to y. A contract offer of B_k appears as $(k, r, \bar{p})$, where $r \in R(\varepsilon)$ is the loan rate and $\bar{p} \in \{p_L, p_H\}$ the maximum riskiness of the project. If E chooses a contract $(k, r, \bar{p})$ with $\bar{p} = p_L$, then E can only undertake the low-risk project. If $\bar{p} = p_H$, then E can undertake any project. We thereby allow banks to control the project risk (at a later stage, we drop this assumption). Without loss of generality, we assume that each bank offers at most two contracts. Denote by C_t^k (C_t) the set of all contract offers made by B_k (by all banks) in period t. C_t also contains the zero-contract $(0, 0, 0)$. If E chooses this contract, the game is over and payoffs are 0 for every agent in this period. Denote by $\mathbf{C}^k$ ($\mathbf{C}$) the set of all possible C_t^k's (C_t's). In period t, E chooses at most one contract out of C_t and, given its terms, the project risk j. If E has chosen contract $(k, r, \bar{p})$ and risk j, then, in case of success, she earns $\max\{0, y_j - r\}$, while B_k gets $\min\{y_j, r\}$.

Strategies, beliefs and equilibrium. Denote by H_t^k (H_t^E) the history of B_k (E) in period t, i.e. everything B_k (E) has observed up to the beginning of period t. Let $\mathbf{H}_t^k$ ($\mathbf{H}_t^E$) be the set of such histories. We will clarify the details of H_t^k for each informational setting at a later stage. Throughout the paper, we assume that banks never observe their competitors' contract offers and always know how many times the entrepreneur failed. E always recalls her previous choices and contract offers. B_k's strategy $\boldsymbol{\sigma}^k$ is a sequence of action functions σ_t^k for every $t \in \{1, 2, ...\}$, where σ_t^k gives C_t^k as a function of H_t^k:

$$\sigma_t^k : \mathbf{H}_t^k \to \mathbf{C}^k. \tag{3}$$

E's strategy $\boldsymbol{\sigma}^E$ is a sequence of action functions σ_t^E for every $t \in \{1, 2, ...\}$, where σ_t^E gives the contract choice and the project risk as a function of H_t^E and C_t:

$$\sigma_t^E : \mathbf{H}_t^E \times \mathbf{C} \to \{1, ..., K\} \times R(\varepsilon) \times \{p_L, p_H\} \times \{L, H\}. \tag{4}$$

Denote by $\alpha_t^k(H_t^k)$ $(\alpha_t^E(H_t^E))$ the belief of B_k (E) in period t that E has high talent conditional on H_t^k (H_t^E). We will drop the reference to H_t^k (H_t^E) whenever it is clear from the context. Define the expected level of talent for given belief α by $\theta(\alpha) = \alpha + (1-\alpha)\theta_L$. Let $\boldsymbol{\sigma} = (\boldsymbol{\sigma}^E, \boldsymbol{\sigma}^1, ..., \boldsymbol{\sigma}^K)$ be a strategy profile and $\boldsymbol{\alpha} = \left(\boldsymbol{\alpha}^E, \boldsymbol{\alpha}^1, ..., \boldsymbol{\alpha}^K\right)$ a system of beliefs, where $\boldsymbol{\alpha}^E = \left\{\alpha_t^E(\mathbf{H}_t^E)\right\}_{t=1}^{\infty}$ and $\boldsymbol{\alpha}^k = \left\{\alpha_t^k(\mathbf{H}_t^k)\right\}_{t=1}^{\infty}$. The assessment $(\boldsymbol{\sigma}, \boldsymbol{\alpha})$ is a SE if (i) in each period, E and banks maximize expected payoffs for given beliefs and competitors' strategies, and (ii) it is the limit of a sequence $\left\{(\boldsymbol{\sigma}^{[n]}, \boldsymbol{\alpha}^{[n]})\right\}_{n\in\mathbb{N}}$, where $\boldsymbol{\sigma}^{[n]}$ is a totally mixed strategy profile and $\boldsymbol{\alpha}^{[n]}$ is uniquely defined from $\boldsymbol{\sigma}^{[n]}$ by Bayes' rule.

Definition 1. *A SE (assessment), in which E undertakes and banks finance the high-risk project in the first $\tau - 1$ periods and the low-risk project in period τ, is called a $\tau - P$ SE (assessment).*

Projects and the First-Best Outcome. Assume for a moment that $\alpha_1 = 1$ and banks are absent. Instead, E has "deep pockets" and finances all projects by herself. Her expected payoff from always choosing the high-risk project, V^H, amounts to

$$V^H = (1 - p_H)(y_H - 1) + p_H\left(-1 + V^H\right). \tag{5}$$

Solving for V^H yields $V^H = y_H - 1/(1 - p_H)$. Her expected payoff from choosing the low-risk project, V^L, is given by $V^L = y_L - 1$. We make two assumptions. First, if E has only one chance to undertake a project, she will prefer the low-risk project:

Assumption (A1). $y_L > (1 - p_H)\, y_H$.

Second, if she has infinitely many opportunities to undertake a project, she will always choose the high-risk project, i.e. $V^H > V^L$:

Assumption (A2). $y_H - 1/(1-p_H) > y_L - 1$.

In the following, we assume that both (**A1**) and (**A2**) hold.[7] Now imagine that E has "deep pockets" and $\alpha_1 < 1$. In equilibrium, we have $\alpha_1^E = \alpha_1$,

$$\alpha_t^E = \frac{\alpha_1 p_H^{t-1}}{\alpha_1 p_H^{t-1} + (1-\alpha_1)(1-(1-p_H)\,\theta_L)^{t-1}} \tag{6}$$

for each $t > 1$ if E has chosen $j = H$ in all periods $\tau < t$, and $\alpha_t^E = 0$ for $t > 1$ if E has chosen $j = L$ in at least one period $\tau < t$. E's expected payoff from realizing the low-risk project in period t is non-negative if and only if

$$\alpha_t^E \geq \frac{1}{1-\theta_L}\left(\frac{1}{y_L} - \theta_L\right) \equiv \bar{\alpha}(\theta_L, y_L). \tag{7}$$

Given that $\alpha_t^E \notin [\bar{\alpha}(\theta_L, y_L), 1]$, E does not undertake any projects in period t. As $\alpha_1 < 1$, we have $\alpha_t^E \to 0$ for $t \to \infty$. Therefore, she will not undertake high-risk projects in infinitely many periods. We characterize the first-best outcome:

Proposition 1 *There is a function*

$$\bar{t} : [\bar{\alpha}(\theta_L, y_L), 1) \to \mathbb{N}, \alpha_1 \to \bar{t}(\alpha_1)$$

such that E with "deep pockets" maximizes her expected payoff for given α_1 (i) only if she chooses $j = H$ in all periods $t \leq \bar{t}(\alpha_1) - 1$, and (ii) if she chooses $j = H$ in all periods $t \leq \bar{t}(\alpha_1) - 1$ and $j = L$ in period $\bar{t}(\alpha_1)$. For each $t \in \mathbb{N}$, there is a $\hat{\alpha}_1 < 1$, such that $\bar{t}(\alpha_1) > t$ whenever $\alpha_1 > \hat{\alpha}_1$.

Proof. See Appendix. ■

We will refer to this function a number of times. Without loss of generality, we assume in the following that α_1 is high enough such that $\bar{t}(\alpha_1) > 1$. Let $V(\alpha_1)$ be E's expected payoff if she has "deep pockets" and chooses $j = H$ ($j = L$) in all periods $t \leq \bar{t}(\alpha_1) - 1$ (in period $\bar{t}(\alpha_1)$). An equilibrium is efficient if and only if total expected payoffs in this equilibrium equal $V(\alpha_1)$.

4 Equilibria Under Different Informational Settings

4.1 Perfect Information (PI)

We first consider a setting with perfect information (PI), in which banks can observe all of E's risk choices. Note that if ε is sufficiently small, then there is a Nash equilibrium

[7] Note that (**A1**) and (**A2**) can be satisfied at the same time if and only if $y_L > 1$. This is the case as both projects have a positive value as long as E has high skills.

in which banks finance the project in period 1, but never thereafter. Given that E has only one chance to undertake a project, she chooses $j = L$. If she fails with this project, banks know that E has low talent. This information, in turn, justifies the banks' strategy. However, the threat of no offers being made in period 2 if E has chosen $j = H$ in period 1 is not credible. The reason is that all banks observe E's decisions and update their belief via Bayes' rule. If E has chosen the high-risk project, it is still profitable for a bank to finance her after failure. As banks compete in a Bertrand manner, E can undertake projects as if she had "deep pockets". Thus, we can state:

Proposition 2 *If ε is sufficiently small, then under PI, total expected payoffs are $V(\alpha_1)$ in any SE.*

4.2 Private Information of Banks (PIB)

We now relax the assumption that banks can perfectly observe the riskiness of all past projects. Instead, a bank can only observe the risk of projects in its own loan portfolio. The risk of projects in other banks' portfolios remains unknown. Therefore, banks acquire private information about E. We consider an institutional setting with a credit register (PIB^{cr}) and one without (PIB). A credit register informs all banks about the loan rates of E's previously chosen loan contracts. Thus, under PIB^{cr}, if E chooses contract $(k, r, \bar{p})$ in period t, then r becomes publicly known in periods $\tau > t$, while E's risk choice in period t is observed only by B_k. Under PIB, banks only know the loan rates of their own contract offers.[8]

We first study the case with credit registers. Consider an assessment in which E chooses $j = L$ in period 1 and no contract offers are made in period $t \geq 2$. This assessment can be a SE even if α_1 is close to unity. To see why, assume that E deviates and chooses a contract (k, r, p_H) and $j = H$ in period 1 instead of $j = L$. If her project fails, B_k updates its belief about E's type, knowing that she has chosen the high-risk project. All other banks $B_{k'}$, $k' \in \{1, ..., K\} \setminus \{k\}$, do not observe E's deviation and assume that E has chosen $j = L$ in period 1. If they observe a high loan rate r, they may interpret this as a mistake by E. Consequently, these banks will refuse to finance E's project in any period $t > 1$. This makes B_k a monopolistic supplier of finance to E. It can extract almost all rents from E, leaving her with an expected payoff of at most ε. Therefore, it can be optimal for E to undertake the low-risk project in period 1.

In addition, there can be an equilibrium in which E undertakes projects as if she had "deep pockets". Consider a $\bar{t}(\alpha_1) - P$ assessment. If E deviates and chooses a contract

[8] Note that in the US, contract terms are not reported in credit registers, only success or failure.

(k, r, p_L) in period $t \leq \bar{t}(\alpha_1) - 1$, the credit register discloses r. If r is too low (i.e. the bank that offered this contract would make a negative expected profit if E chooses $j = H$ in period t), then banks may infer that E has chosen $j = L$ in t and therefore refuse to finance her in future periods. We only have to rule out that it does not pay off for E to choose a contract (k, r, p_H) and $j = L$, where r is such that the respective bank does not make negative expected profits if E chooses $j = H$. This is implied by (**A2**) if y_L is not too high relative to the risk of failure of a high-risk project.

Proposition 3 *Suppose that $y_L < 2/(1 - p_H)$. If ε is sufficiently small, then under PIB^{cr}, there exists a $\tau - P$ SE for $\tau \in \{1, \bar{t}(\alpha_1)\}$. In any $\tau - P$ SE with $\tau < \bar{t}(\alpha_1)$ ($\tau = \bar{t}(\alpha_1)$), total expected payoffs are less than (equal to) $V(\alpha_1)$.*

Proof. See Appendix. ■

In the absence of credit registers, the inefficient $1 - P$ equilibrium persists. However, this must not be true for a $\bar{t}(\alpha_1) - P$ equilibrium. Note that under PIB, those banks that do not finance E's project in period $t \leq \bar{t}(\alpha) - 1$ have no information about E's risk choice and the contract that E has signed in period t. Thus, it could be profitable for E to undertake a low-risk project in a period $t \leq \bar{t}(\alpha_1) - 1$ and then, in period $t + 1$, switch to another bank that assumes that E has chosen the high-risk project in period t. This cannot happen in equilibrium. Therefore, a $\bar{t}(\alpha_1) - P$ equilibrium might not exist. In the example below, we study a scenario, in which an efficient equilibrium exists under PIB^{cr}, while it does not under PIB.

Consider now a $\bar{t} - P$ assessment for some $\bar{t} > 1$, in which the expected profit of each bank is at most ε. If ε is sufficiently small, E will not deviate to $j = L$ in a period $t < \bar{t}$ whenever she is relatively sure that she has high talent, i.e. if α_t^E is relatively high. Thus, for α_1 sufficiently close to unity, a $\bar{t} - P$ assessment can be an equilibrium under both PIB^{cr} and PIB.

Proposition 4 *Let $\bar{t} \in \mathbb{N}$ be given. If α_1 is sufficiently high and ε is sufficiently small, then under PIB^{cr} and PIB, there exists a $\tau - P$ SE for $\tau \in \{1, \bar{t}\}$ and total expected payoffs in the $1 - P$ SE are smaller than in the $\bar{t} - P$ SE.*

Proof. See Appendix. ■

Example 1. *Let $y_L = 2.5$, $p_H = 0.3$, $\theta_L = 0.3$, $\alpha_1 = 0.95$, $\varepsilon = 0.001$ and $y_H \in \{2.97, 3.1, 3.5\}$. If $y_H = 2.97$, then (**A1**), (**A2**) hold and $\bar{t}(0.95) = 2$. The total expected payoff of a $2 - P$ assessment would be $\approx 1,423$, while the total expected payoff of a $1 - P$ assessment would be $\approx 1,412$. Under PIB, only a $1 - P$ SE exists, while under PIB^{cr},* *also a* $2-P$ *SE exists. If* $y_H = 3.10$*, then* (**A1**), (**A2**) *hold and* $\bar{t}(0.95) = 2$*. The total expected payoff of a* $2-P$ *assessment is now* $\approx 1,511$*. There exist a* $1-P$ *and a* $1-P$ *SE under both* PIB *and* PIB^{cr}*. Finally, if* $y_H = 3.50$*, then* (**A1**), (**A2**) *hold and* $\bar{t}(0.95) = 3$*. For* $\tau \in \{1, 2, 3\}$ *a* $\tau - P$ *SE exists under* PIB *and* PIB^{cr}*. Total expected payoffs in the* $3-P$ *SE (*$2-P$ *SE,* $1-P$ *SE) are* ≈ 1.841 *(*≈ 1.781*,* ≈ 1.412*).*

4.3 Imperfect Information (IM)

We finally turn to a setting with imperfect information, in which no bank can observe E's risk choices. It is no longer possible for banks to restrict E's options in the contract. Therefore, banks can only offer contracts $(., ., p_H)$. Again, we consider a setting with a credit register that informs banks about the loan rates of previous contracts (IM^{cr}) and a setting without such a credit register (IM).

Under imperfect information, banks face a moral hazard problem. E may be inclined to shift risk and undertake the high-risk project whenever banks offer loan contracts that guarantee non-negative profits, only if E chooses the low-risk project. If and only if the following assumption on payoffs holds, can there be equilibria in which E chooses the low-risk project:

Assumption (**A3**). $y_L - 1 > (1 - p_H)(y_H - 1)$.

To see why, consider an assessment in which E chooses $j = L$ in period t and all banks charge a loan rate r^* in this period. E's risk choice does not affect future loan rates. Therefore, she cannot gain by choosing $j = H$ in period t as long as

$$\theta(\alpha_t^E)\,(y_L - r^*) \geq \theta(\alpha_t^E)(1 - p_H)\,(y_H - r^*)\,. \tag{8}$$

Thus, if

$$y_L - (1 - p_H)y_H < p_H r^*, \tag{9}$$

then E always chooses the high-risk project in equilibrium. If (**A3**) does not hold, then

$$y_L - (1 - p_H)y_H \leq p_H. \tag{10}$$

Banks make non-negative profits only if $r^* > 1$. Hence, in equilibrium (10) implies (9). The interpretation of (**A3**) is that the expected return of the low-risk project is sufficiently high relative to the expected return of the high-risk project such that risk-shifting is not profitable. Note that (**A3**) implies (**A1**) and that (**A2**) and (**A3**) can simultaneously hold if $y_H > 2$. Hence, we need to distinguish between two scenarios: one in which (**A3**) does not hold and one in which (**A3**) holds.

Equilibria if (A3) does not hold. A violation of (**A3**) means that E will always choose the high-risk project and banks can make non-negative expected profits in period t if and only if

$$\alpha_t^k \geq \frac{1}{1-\theta_L}\left(\frac{1}{(1-p_H)\,y_H} - \theta_L\right) \equiv \bar{\alpha}(\theta_L, y_H). \tag{11}$$

Define the maximum number of periods banks are willing to offer loan contracts to E by

$$\tilde{t}(\alpha_1) = \max\left\{ t \in \mathbb{N} \,\middle|\, \frac{\alpha_1 p_H^{t-1}}{\alpha_1 p_H^{t-1} + (1-\alpha_1)(1-(1-p_H)\,\theta_L)^{t-1}} \geq \bar{\alpha}(\theta_L, y_H) \right\}.$$

We can state:

Proposition 5 *If* (**A3**) *does not hold,* $\alpha_1 \in [\bar{\alpha}(\theta_L, y_H), 1]$*, and* ε *is sufficiently small, then in each SE under* IM^{cr} *and* IM*,* E *undertakes high-risk projects in at least (at most)* $\tilde{t}(\alpha_1) - 1$ *(*$\tilde{t}(\alpha_1)$*) periods. Furthermore,* E *never undertakes a low-risk project. In each of these SE, total expected payoffs are less than* $V(\alpha_1)$*.*

Clearly these equilibria are not pareto-optimal. In the period before banks stop offering loans, E would prefer to undertake the low-risk project (given that the loan rate is adjusted accordingly). Unable to commit to choose $j = L$, she ends up realizing the hig-risk project. As we will see below, total expected payoffs in this equilibrium can be much higher than in the inefficient $1-P$ SE under PIB^{cr} and PIB, in which the banks' equilibrium strategies force E to undertake the low-risk project in the first period. We therefore obtain a non-monotonic relationship between potential credit market inefficiency and bank information if (**A3**) does not hold.

Equilibria if (A3) does hold. If (**A3**) holds and α_1 is sufficiently large, then again multiple equilibria can occur. On the one hand, there can be a $1-P$ SE. The threat of not providing any further loans is credible since banks do not observe E's risk choice. On the other hand, there can be a $\bar{t}-P$ SE for some $\bar{t} > 1$ if α_1 is sufficiently high. In such an equilibrium, banks correctly anticipate that E chooses $j = H$ in all periods $t < \bar{t}$ and set their loan rates accordingly.

Proposition 6 *Let* $\bar{t} \in \mathbb{N}$ *be given. If* (**A3**) *holds,* α_1 *is sufficiently high and* ε *is sufficiently small, then under* IM^{cr} *and* IM*, there exists a* $\tau - P$ *SE for* $\tau \in \{1, \bar{t}\}$ *and total expected payoffs in the* $1-P$ *SE are smaller than in the* $\bar{t}-P$ *SE.*

Proof. See Appendix. ■

Again, a credit register may help to detect deviations by E. This is the case in the example below. However, without further restrictions on the payoff structure, a credit register per se does not guarantee the existence of an efficient equilibrium. The reason is that in any $\bar{t}(\alpha_1) - P$ assessment, $\alpha^E_{\bar{t}(\alpha_1)}$ may be so small (and therefore the loan rates so high) that E undertakes the high-risk project in period $\bar{t}(\alpha_1)$.

Example 2. *Consider the same values as in Example 1. For* $y_H \in \{2.97, 3.10\}$*,* (**A3**) *holds and the equilibria for* IM (IM^{cr}) *are the same as for* PIB (PIB^{cr}) *in Example 1.*[9] *Credit registers can therefore make a difference under imperfect information. However, if* $y_H = 3.5$*, then* (**A3**) *is violated and the only equilibrium outcome is that* E *chooses the high-risk project in the first three periods and does not get any loans thereafter. The total expected payoff in these equilibria is* $\approx 1,838$ *and therefore exceeds the total expected payoffs of the inefficient equilibria under* PIB *and* PIB^{cr}*.*

5 Policy Implications

Asymmetric Information. Economic theory has well established that asymmetric information can lead to an inefficient allocation of credit. The financial contracting literature has focused on solutions of the moral hazard problem if banks cannot directly observe the entrepreneur's risk choice (via monitoring, collateral or incentive contracts). We have shown that the credit market equilibrium can be inefficient even if the moral hazard problem can be mitigated. In particular, this can happen if entrepreneurs can start a new business after failure and banks cannot observe the entrepreneurs' past risk choices. Policies that aim to change the nature of the equilibrium may not be effective, as both entrepreneurs' actions and banks' expectations would have to be changed simultaneously. Consider, for example, the approach of the European Commission (2000, 2007). It attemps to reduce the "stigma of failure" by advising entrepreneurs to choose higher risk levels. Entrepreneurs, however, will follow such advice only if banks change their policy at the same time.

Credit Registers. Information exchange between banks through credit registers can increase credit market efficiency.[10] In our model, information about the loan rates of previous contracts can be crucial to ensure the existence of more efficient credit market equilibria (in particular, under PIB and IM). This information enables banks to infer E's previous risk choices from loan rates. An unpaid loan with a relatively low loan rate may indicate that the underlying project risk was low (otherwise, the bank would not have offered this loan to the entrepreneur). Failure then discloses low entrepreneurial talent, preventing banks from granting further loans to her. In contrast, an unpaid credit with a high loan rate may indicate that the underlying project's risk was high, suggesting that its failure owes more to bad luck rather than low entrepreneurial talent. In this case, E probably deserves another chance. However, note that the loan rate alone does not reveal

[9] We additionally have to show that risk-shifting does not pay off in the period in which E is supposed to choose $j = L$.

[10] See Jappelli and Pagano (2000) for a literature review.

E's actions. Banks might also infer from a high loan rate that E undertook the low-risk project and–by mistake–has chosen an inappropriate contract. Therefore, the multiplicity of equilibria persists under PIB^{cr} and IM^{cr}.

Improving Entrepreneurial Talent. Another measure to increase entrepreneurial activity is the promotion of education that leads to the formation of relevant skills. Entrepreneurial education plays a substantial role both in economic development (see e.g. Klinger and Schündeln 2010) and the EU's policy to increase entrepreneurship after failure (European Commission 2007). In terms of our model, these policies would increase the probability of having high entrepreneurial talent α_1. If banks have perfect information, then an increase in α_1 has both a direct and an indirect effect on equilibrium welfare. The direct effect is that loan rates decrease in all periods. The indirect effect is that the number $\bar{t}(\alpha_1)$ of periods in which projects are financed (weakly) increases. Yet, if the informational setting is PIB, PIB^{cr} (and in some cases also under IM and IM^{cr}), then the indirect effect might not materialize. There always exists an equilibrium in which the entrepreneur undertakes a low-risk project and does not get financed after failure. Therefore, an increase in α_1 does not necessarily entail a positive effect on entrepreneurial activity among those who fail. Unless the banks' policies and entrepreneurs' risk-taking behaviors become simultaneously coordinated to another equilibrium, only the direct effect unfolds.

6 Conclusion

We have analyzed a model of entrepreneurial finance and risk taking where the extent to which failed entrepreneurs are excluded from further start-up financing is determined endogenously. The driver of our results is the evolution of banks' beliefs about an entrepreneur's talent and the interplay between these beliefs and her risk choices. If banks can perfectly observe the entrepreneur's actions, then the first-best outcome is realized in any equilibrium: she first undertakes a number of high-risk projects and then, after continuous failure, undertakes a low-risk project. The number of trials (weakly) increases in the ex-ante probability of high talent.

This is not the unique equilibrium (eventually, this equilibrium does not exist at all) if banks can only observe the riskiness of projects in their own loan portfolio (PIB). Instead, there also exists an inefficient equilibrium in which the entrepreneur undertakes a low-risk project and becomes excluded from finance after failure. This inefficiency is due to the fact that banks may expect the entrepreneur to undertake the low-risk project. Failure of low-risk projects indicates low talent. Therefore, outside banks may refuse to finance her after failure. The bank that financed the project then becomes a monopolistic supplier of finance to the entrepreneur. Hence, it is rational for the entrepreneur to undertake a low-risk project.

If banks do not observe the riskiness of projects (IM), the equilibrium set depends on the payoff structure. Given that the expected return of the high-risk project is sufficiently close to that of the low-risk project, the entrepreneur always undertakes high-risk projects in equilibrium. This outcome is inefficient. Yet, it may be much better than the one-shot financing equilibrium under PIB. If the expected return of the high-risk project is sufficiently small relative to that of the low-risk project, then multiple equilibria exist as under PIB.

We showed that sharing information about previous loan rates through credit registers can ensure the existence of an efficient equilibrium under PIB (and for some cases also under IM). A low loan rate may indicate that the entrepreneur undertook a low-risk project and therefore should not be financed after failure. Consequently, the entrepreneur cannot gain by realizing the low-risk project too early.

7 Appendix

7.1 Proof of Proposition 1

Take α_1 as given. Whenever E chooses $j = L$ and the project fails, E knows that her talent is low. She then does not undertake any further projects. Consider the set of assessments in which E chooses $j = H$ in periods $t \in \{1, ..., t^* - 1\}$, $j = L$ in period t^*, and no more projects thereafter. Denote by $V_t^{(t^*)}$ the expected payoff of E at the beginning of period $t \in \{1, ..., t^*\}$ under the assessment with t^* periods of project realizations. We have

$$V_{t^*}^{(t^*)} = \theta\left(\alpha_{t^*}^E\right) y_L - 1, \tag{12}$$

and for $t \in \{1, ..., t^* - 1\}$

$$V_t^{(t^*)} = (1 - p_H)\theta\left(\alpha_t^E\right) y_H - 1 + (1 - (1 - p_H)\theta\left(\alpha_t^E\right))V_{t+1}^{(t^*)}, \tag{13}$$

where $\alpha_1^E = \alpha_1$ and α_t^E is given by (6) for each $t \in \{2, ..., t^*\}$. Note that there must be a t^{**} such that $V_1^{(t^*)}$ is positive only if $t^* \in \{1, ..., t^{**}\}$. We therefore find that

$$\bar{t}(\alpha_1) = \min\left\{g \in \{1, ..., t^{**}\} \mid V_1^{(g)} \geq V_1^{(t^*)}, t^* \in \{1, ..., t^{**}\}\right\}. \tag{14}$$

To prove the second claim, observe that

$$\lim_{\alpha_1 \to 1} V_1^{(t^*)} = \left(1 - p_H^{t^*-1}\right)\left(y_H - \frac{1}{1 - p_H}\right) + p_H^{t^*-1}\left(y_L - 1\right). \tag{15}$$

(**A2**) then implies

$$\lim_{\alpha_1 \to 1} V_1^{(t^*)} > \lim_{\alpha_1 \to 1} V_1^{(t)} \tag{16}$$

for all $t < t^*$. Note that $V_1^{(t^*)}$ is continuous in α_1 for all $t^* \in \mathbb{N}$. Thus, for each $t \in \mathbb{N}$ there is a $\hat{\alpha}_1 < 1$, such that $\bar{t}(\alpha_1) > t$ whenever $\alpha_1 > \hat{\alpha}_1$.

7.2 Proof of Proposition 3

$1 - P$ **SE.** Define

$$r(j, \alpha) = \min \left\{ r \in R(\varepsilon) \middle| r \geq \frac{1}{(1 - p_j)\theta(\alpha)} \right\} \tag{17}$$

and consider an assessment $(\boldsymbol{\sigma}, \boldsymbol{\alpha})$ with the following properties:

- In period 1, B_k offers contracts

$$(k, r(L, \alpha_1), p_L) \text{ and } (k, r(H, \alpha_1), p_H). \tag{18}$$

- A bank B_k that did not finance the project in period 1 has beliefs $\alpha_t^k = 0$ in all periods $t \geq 2$ and therefore does not offer any contracts.
- A bank that financed the project in period 1 has a belief in period 2 that is derived from Bayes' rule. As long as it is profitable, this bank offers contracts with loan rates equal to $\max \{r \in R(\varepsilon)\}$.
- E undertakes projects whenever possible.

In this assessment, the expected payoff of E in period 2 is 0 regardless of her choice in period 1. Therefore, it is optimal for her to choose a contract $(k, r(L, \alpha_1), p_L)$ and $j = L$ in period 1 if

$$\theta(\alpha_1)(y_L - r(L, \alpha_1)) \geq (1 - p_H)\theta(\alpha_1)(y_H - r(H, \alpha_1)), \tag{19}$$

which is implied by (**A1**) given that ε is sufficiently small. Facing Bertrand competition, no bank can deviate profitably in period 1. It remains to show that beliefs are consistent. Consider a sequence $\left\{(\boldsymbol{\sigma}^{[n]}, \boldsymbol{\alpha}^{[n]})\right\}_{n \in \mathbb{N}}$ with $(\boldsymbol{\sigma}^{[n]}, \boldsymbol{\alpha}^{[n]}) \to (\boldsymbol{\sigma}, \boldsymbol{\alpha})$ in which $\boldsymbol{\sigma}^{[n]}$ is such that E chooses $j = L$ with probability $(n-1)/n$ and $j = H$ with probability $1/n$ in period 1 whenever she chooses a contract $(.,., p_H)$. Clearly, we have $\left(\alpha_t^k(H_t^k)\right)^{[n]} \to 0$ for any $t > 1$ and H_t^k that does not contain E's actual risk choice in period 1.

$\bar{t}(\alpha_1) - P$ **SE.** Consider a strategy profile with the following properties:

- In period 1, B_k offers the same contracts as in (18).
- In each period $t \in \{2, ..., \bar{t}(\alpha_1) - 1\}$, B_k offers contracts $\left(k, r(L, \alpha_t^k), p_L\right)$ and $\left(k, r(H, \alpha_t^k), p_H\right)$ (where $\alpha_t^k = \alpha_t^E$ and α_t^E is given by (6)) unless it observes that in a period $\tau \in \{1, ..., t-1\}$, E had chosen $j = L$ or had not chosen contracts with loan rates equal to $r(H, \alpha_\tau^E)$ (where α_τ^E is given by (6)). In these cases, it does not offer any contracts.
- In period $t = \bar{t}(\alpha_1)$, B_k offers contract $\left(k, r(L, \alpha_{\bar{t}(\alpha_1)}^k), p_L\right)$ (where $\alpha_{\bar{t}(\alpha_1)}^k = \alpha_{\bar{t}(\alpha_1)}^E$ and $\alpha_{\bar{t}(\alpha_1)}^E$ is given by (6)) unless it observes that in a period $\tau \in \{1, ..., t-1\}$ E had chosen $j = L$ or had not chosen contracts with loan rates equal to $r(H, \alpha_\tau^E)$ (where α_τ^E is given by (6)). In these cases, it does not offer any contracts.
- Banks offer no contracts in any period $t > \bar{t}(\alpha_1)$.
- Whenever banks offer contracts as described above, E undertakes a high-risk project in all periods $t \in \{1, ..., \bar{t}(\alpha_1) - 1\}$ and a low-risk project in period $\bar{t}(\alpha_1)$.

To show that this can be the outcome of a SE, assume that E deviates in period $t^* < \bar{t}(\alpha_1)$ and chooses a contract $\left(k, r(L, \alpha_{t^*}^k), p_L\right)$. Given the banks' strategy, the expected payoff of E in period t^* is

$$\tilde{V}_{t^*}^{(t^*)} = \theta(\alpha_{t^*}^E) \left(y_L - r(L, \alpha_{t^*}^E)\right), \tag{20}$$

and in a period $t \in \{1, ..., t^* - 1\}$ it is

$$\tilde{V}_t^{(t^*)} = (1 - p_H)\theta\left(\alpha_t^E\right)\left(y_H - r(H, \alpha_t^k)\right) + (1 - (1 - p_H)\theta\left(\alpha_t^E\right))\tilde{V}_{t+1}^{(t^*)}. \tag{21}$$

Note that these expressions equal those in (12) and (13) as $\varepsilon \to 0$. It follows from Proposition 1 that E has no incentive to deviate if ε is sufficiently small. Furthermore, it does never pay off for E to choose a contract $\left(., r(H, \alpha_t^E), p_H\right)$ and $j = L$ in any period $t < \bar{t}(\alpha_1)$. If it would pay off, it would also hold for some $V \geq 0$ that

$$\begin{aligned} & \theta\left(\alpha_t^E\right)\left(y_L - r(H, \alpha_t^E)\right) + \left(1 - \theta\left(\alpha_t^E\right)\right)V \\ > \; & \theta\left(\alpha_t^E\right)(1 - p_H)\left(y_H - r(H, \alpha_t^E)\right) + \left(1 - \theta\left(\alpha_t^E\right)(1 - p_H)\right)V \end{aligned} \tag{22}$$

and

$$\theta\left(\alpha_t^E\right)\left(y_L - r(H, \alpha_t^E)\right) + \left(1 - \theta\left(\alpha_t^E\right)\right)V > \theta\left(\alpha_t^E\right)\left(y_L - r(L, \alpha_t^E)\right). \tag{23}$$

We can transform (22) into

$$V < \frac{y_L}{p_H} - \frac{(1 - p_H)\, y_H}{p_H} - r(H, \alpha_t^E) \tag{24}$$

and (23) into

$$V > \frac{\theta\left(\alpha_t^E\right)}{1-\theta\left(\alpha_t^E\right)}\left(r(H,\alpha_t^E) - r(L,\alpha_t^E)\right). \tag{25}$$

Thus, it never pays off it for E to choose a contract $\left(., r(H,\alpha_t^E), p_H\right)$ and $j = L$ in period t if the right-hand side of (25) exceeds the right-hand side of (24). If ε is sufficiently small, then this follows from

$$\frac{p_H}{(1-p_H)} > \frac{y_L}{p_H} - \frac{(1-p_H)\,y_H}{p_H} - \frac{1}{(1-p_H)\theta\left(\alpha_t^E\right)}. \tag{26}$$

Assumption (**A2**) implies

$$y_H > y_L + \frac{p_H}{(1-p_H)}. \tag{27}$$

This can be used to show that (26) follows from $y_L < 2/(1-p_H)$. Due to Bertrand competition, no bank can profitably deviate. The consistency of beliefs can be shown as in the first part of the proof. Finally, the last claim of Proposition 3 directly follows from Proposition 1.

7.3 Proof of Proposition 4

The proof of existence of the $1-P$ SE is straightforward and therefore omitted. Let $r(j,\alpha)$ be given by (17). To show the existence of the $\bar{t}-P$ SE, consider a strategy profile with the following properties:

- In each period $t < \bar{t}$, B^k offers contracts $\left(k, r(L,\alpha_t^k), p_L\right)$ and $\left(k, r(H,\alpha_t^k), p_H\right)$ (where $\alpha_t^k = \alpha_t^E$ and α_t^E is given by (6)) unless it observes that in a period $\tau \in \{1,...,t-1\}$, E had chosen $j = L$. In this case, it does not offer any contracts.
- In period $\bar{t}$, B^k offers contract $\left(r(L,\alpha_{\bar{t}}^k), p_L\right)$ (where $\alpha_{\bar{t}}^k = \alpha_{\bar{t}}^E$ and $\alpha_{\bar{t}}^E$ is given by (6)) unless it observes that in a period $\tau \in \{1,...,\bar{t}-1\}$, E had chosen $j = L$. In this case, it does not offer any contracts.
- Banks offer no contracts in any period $t > \bar{t}$.
- Whenever banks offer contracts as described above, E undertakes a high-risk project in all periods $t \in \{1,...,\bar{t}-1\}$ and a low-risk project in period $\bar{t}$.

To show that this can be the outcome of a SE if α_1 is sufficiently high, assume that E deviates in period $t^* < \bar{t}$ and chooses a contract $\left(., r(L,\alpha_{t^*}^E), p_L\right)$. Given the banks' strategy, E's expected payoff at the beginning of period t^* is less than

$$\theta(\alpha_{t^*}^E)\left(y_L - r(L,\alpha_{t^*}^E)\right) + (1-\theta(\alpha_{t^*}^E))(y_H - 1). \tag{28}$$

For $\alpha_1 \to 1$ and $\varepsilon \to 0$, this term becomes $y_L - 1$, while E's expected payoff at the beginning of period t^* under the original strategy for $\alpha_1 \to 1$ and $\varepsilon \to 0$ becomes

$$\left(1 - p_H^{\bar{t}-t^*}\right)\left(y_H - \frac{1}{1-p_H}\right) + p_H^{\bar{t}-t^*}\left(y_L - 1\right). \tag{29}$$

Thus, (**A2**) ensures that E cannot profitably deviate in any period $t < \bar{t}$ if α_1 is sufficiently high and ε is sufficiently low. (**A1**) ensures that the same is true for period $\bar{t}$. Following the same steps as in the first part of the proof of Proposition 3, we can show that banks' beliefs can be consistent in all periods. Facing Bertrand competition, banks cannot profitably deviate. Finally, if α_1 is sufficiently high and ε is sufficiently low, total expected payoffs in the $1 - P$ SE must be smaller than in the $\bar{t} - P$ SE. Otherwise, it would pay off for E to deviate in period 1 of the considered $\bar{t} - P$ assessment.

7.4 Proof of Proposition 6

$1 - P$ **SE.** The proof is very similar to the one of Proposition 3 and therefore omitted.

$\bar{t} - P$ **SE.** The proof is very similar to the one of Proposition 4 and therefore omitted.

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