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ENTREPRENEUR–INVESTOR INFORMATION DESIGN*

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I consider an environment in which an entrepreneur generates information about the quality of his project prior to contracting with an investor. The investor faces a moral-hazard problem since the entrepreneur may divert the funding for private consumption. I find that the efficient amount of information is generated if and only if the bargaining power of the entrepreneur is high enough. I interpret this result in terms of investors' tightness, competitiveness, and generosity measures. I also show that the investor prefers not to have all the bargaining power when the project costs are high enough.

1. INTRODUCTION

Start-up entrepreneurship financed by venture capital (VC) has been the fuel of economic innovations for several decades, most notably boosting the growth of computer hardware and software innovations.[1] Kortum and Lerner (2001) show that VC-backed firms are more efficient in generating innovations than traditional non-VC corporate research.[2] The VC industry has grown at an impressive rate, from \$610 million to more than \$84 billion within three decades.[3]

The profitability of start-up projects is highly uncertain, and thus they rarely obtain funding from traditional banks. Instead, they turn to VC investors, making the high risk a distinctive feature of the VC industry. Consequently, much of the VC-provided capital is ultimately lost to bad investments across all investment types and stages (Da Rin et al., 2013).

Preinvestment information about the quality of projects could decrease this risk. The decision to generate such information is often at the hands of the entrepreneur. For instance, an entrepreneur can order market research from a consulting agency, and the choice of the agency will determine the informativeness of that research. Developers of software and new technologies can release alpha-/beta-versions or prototypes of their products, which differ in how informative they are. Another example of information generation is a crowdfunding cam-

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[1] For example, VC investors were among the first to finance Apple, Microsoft, and Google (Kaplan and Lerner, 2010).

[2] The estimates of Kortum and Lerner (2001) suggest that, although during the years 1983–92, the VC financed less than 3% of R&D, it accounted for more than 8% of industrial innovations.

[3] https://pitchbook.com/news/articles/the-state-of-the-us-venture-industry-in-15-charts

paign. Observing the number of preordered items, the entrepreneur can learn about the product's underlying demand and future profitability.

This article investigates the amount and the efficiency of information generated about a project before signing the financial agreement between the two agents, the entrepreneur (he) and the investor (she). To focus on the entrepreneur's strategic incentives, I assume that the entrepreneur is flexible in the information structure he generates, publicly commits to his choice, and that information generation is costless. After they observe generated information, the two parties negotiate the contracting terms. I consider a particular conflict of interest: the entrepreneur can secretly divert the funds after contracting with the investor. This moral-hazard problem may distort the entrepreneur's information generation choice.

This article has two main results. First, the entrepreneur generates more information with more bargaining power, and he generates efficient information if his bargaining power is high enough.[4] Second, the investor prefers intermediate bargaining power if the ex ante project quality is not too high.

For some intuition behind the first result, consider two extreme scenarios under binary project quality. Suppose the investor has all the bargaining power. The investor provides the funding to the entrepreneur whenever the precontract information is favorable enough. The entrepreneur's payoff from the contract will be constant because the terms make him indifferent between proper spending and secretly diverting the funds (which always yields a constant payoff). If the information is unfavorable, the investor does not provide the funding. As a result, if the entrepreneur has no bargaining power, he only cares about convincing the investor to fund the project with high probability. Hence, he will provide just enough information to make the investor indifferent between financing the project and not as often as possible. One of the consequences of such information choice is that high-quality projects are pooled together with low-quality ones.

On the other hand, when the entrepreneur has all the bargaining power, he only needs to compensate the investor for the funding cost so that the investor's expected payoff from signing the contract would be zero. The smaller the uncertainty, the smaller the cost of the funding. Thus, the entrepreneur, being the residual claimant to the returns from the project, prefers to implement the project if and only if it is of good quality. He achieves it by generating as much information as possible, which leads to a greater separation of high-quality projects.

With intermediate bargaining power, the entrepreneur faces the trade-off between two forces, the probability of funding the project versus the quality of the project conditional on it being funded. The bargaining power determines the relative importance of each of the forces.

My second result, that the investor prefers intermediate bargaining power, is closely linked with the increasing informativeness result. Given that the entrepreneur chooses more information with more bargaining power, the investor has a trade-off in giving up bargaining power. On the one hand, she loses a share of the pie due to the loss of bargaining power, on the other, she gains through the larger total size of the pie due to more informativeness. This trade-off is resolved at an interior bargaining power. If the bargaining power of the investor is too high, the entrepreneur-preferred information leads to projects being either discarded or making the investor break even, resulting in a zero payoff for her. If the bargaining power of the investor is too low, the information reveals high-quality projects, but all of the corresponding surplus is captured by the entrepreneur. For a range of interior bargaining powers, the information reveals good projects and their surplus is shared between the two players. The exact bargaining power preferred by the investor is within that range. In the binary case, it is the highest investor's bargaining power at which the entrepreneur chooses the efficient information. In the continuous case, it is the bargaining power at which the marginal loss due to a lower share equals the marginal gain due to high-quality projects being revealed more frequently. This result helps explain why investors might

[4] For binary and continuous uniform project qualities, the condition becomes *if and only if*.

have incentives to maintain a reputation for being generous since it limits their bargaining power.

Whereas the investor can often have an informational advantage, as modeled for example, in Yang and Zeng (2019), my article abstracts from these features to focus on the entrepreneur's information. This allows arguing that as long as there is a source of information that the investor does not have control over, and there is a money-diverting motive of the entrepreneur, there will be a potential for informational inefficiency exacerbated by a lack of the entrepreneur's bargaining power. When generating the information, the entrepreneur faces a conflict of interest between the likelihood of the project implementation and ensuring the implementation of the *right* project. This conflict of interest can still be present in settings where the investor can additionally design her own information or when she can interpret the public signal more precisely than the entrepreneur.

Cumming and Dai (2011) have empirically demonstrated a link between the sizes of VC funds and their bargaining powers. They find that VC funds can have diminishing returns from higher bargaining power, with a fund's overall performance having an inverse U-shape with respect to its bargaining power. The results of my article offer inefficient precontract information generation as a plausible source of diminishing returns from bargaining power. Since the entrepreneur has incentives to generate information, I find that the investor prefers a nonabsolute bargaining power for herself when the project costs are high enough. Moreover, I find a setting where the investor's payoff is inverse U-shaped in her bargaining power.

I also interpret my results in terms of the structure of VC-capital markets. A tight investors' side of the market can lead to investors having high bargaining power and inefficient informativeness. There are investment hubs where corporations with VC subsidiaries play dominant roles in regional start-up markets.[5] For sufficiently high investment costs, such entities might benefit from splitting their investing operations between multiple independent subsidiaries. Even though the immediate effect of lowering their bargaining power would be negative, it would also result in higher motivation for start-ups to generate information, making the overall effect for the investor positive.

Another interpretation of bargaining power is the scarcity or abundance of investment capital. It is usually harder to obtain funding during the bust phases of a business cycle. Hence, those few projects that manage to secure financing are likely to have provided less information because of the diminished bargaining power of the entrepreneur. This can lead to a lower success rate in the start-up industry.

Crowdfunding as a way to generate information. Crowdfunding is a modern way for entrepreneurs to raise funds, particularly popular among artists, software designers, and gadget developers. Crowdfunding, especially in its preorder form, allows not only to collect the money for production but also to generate information about the likely profitability of a novel product.

The feedback value of crowdfunding for entrepreneurs in reducing demand uncertainty has been documented empirically (Xu, 2018). Anecdotal evidence also supports the importance of crowdfunding's informational content. There have been multiple cases of venture capitalists approaching entrepreneurs after successful crowdfunding campaigns. A notable example is the Pebble Watch: after the preorder campaign has been completed, its creators have attracted VC funding many times exceeding the amount collected through the crowdfunding campaign itself.

The creators have control over the informational content of a crowdfunding campaign. The extreme choice is not to presell the product through crowdfunding, as there would be no uncertainty reduction. However, the creator can make more nuanced choices, like how detailed the description of product features is or how precise the prototype is. Moreover, adjusting the campaign characteristics, such as its duration, funding target, or the menu of bids and rewards,

[5] For example, Samsung Ventures.

can also lead to different levels of informativeness. For example, failing to achieve a target of \$50,000 within five days could be considered a less unfavorable signal for a project than if the same project failed to reach that same target within 60 days.

My analysis suggests that creators with more bargaining power are likely to design more informative crowdfunding campaigns. The menu of prices, the target sum, and the campaign length will lead to profiles of contributions that will make it more transparent what the demand for the product is likely to be.[6]

Related literature. This work is primarily related to the Bayesian persuasion literature, in which an uninformed sender chooses and commits to the structure of information-revealing experiments, as in Kamenica and Gentzkow (2011).[7] Subsection 2.5 studies the continuous version, similarly to Gentzkow and Kamenica (2016), Kolotilin et al. (2017), Kolotilin (2018), and Dworczak and Martini (2019). This article departs from the standard model by introducing bargaining between the sender and the receiver and the moral hazard. My work shows the importance of the sender's bargaining power for the precision of the experiment.

Boleslavsky and Kim (2020) also study the effect of moral hazard in the Bayesian persuasion setting. There, a third party takes the covert action which influences the distribution over the true states but does not directly influence the outcome. In a similar direction, Bloedel and Segal (2020), Matysková and Montes (2021), and Ely and Szydlowski (2020) study the moral hazard on the receiver's side. Thus, in Bloedel and Segal (2020), the moral hazard takes the form of privately borne cost of attention to process the sender's signals, and in Matysková and Montes (2021)—to process additional external signals. Boleslavsky and Cotton (2018) and Au and Kawai (2020, 2021) study persuasion with multiple senders competing for the receiver's financing. Their results show that the informativeness of *a* sender's experiment increases with the qualities of *other* senders' projects.

Bergemann and Välimäki (2002) study the costly acquisition of private information in mechanism design. Under private values, efficient private information is acquired, whereas information can be under- or overacquired under common values. My results complement and contrast these findings: I show that public information is efficient only if the entrepreneur's payoff is sufficiently coaligned with the investor's payoff.

A related branch of literature is contracting with preceding information acquisition. In Crémer and Khalil (1992) and Crémer et al. (1998a, 1998b), the agent has an opportunity to learn the state of his cost of production before attempting to produce. In Crémer et al. (1998a), where information is productive and is gathered after contracting, it is shown that the principal's payoff is nonmonotonic in the information cost. In Nosal (2006), the principal can gather information about the state of his project. When this choice is observable, there would not be enough incentives for the principal to acquire efficient information; otherwise, there can be either over- or underacquiring of information. Szalay (2009) studies covert information acquisition by the agent with general informational technologies, showing that the agent always values the information whereas the principal might not. Krähmer and Strausz (2011) offer a mechanism design approach to environments with costly private preproject state learning by the agent and moral hazard. They show that optimal contract induces informational distortions. Iossa and Martimort (2015) study private information acquisition by the pessimistic (compared to the principal) agent and derive the optimal menu of contracts in this case. Kessler (1998) allows an agent to exert observable information acquisition with private results *before* being offered a contract. This article is close to mine in terms of results. In a two-state environment, Kessler (1998) shows that the agent never prefers to learn the

[6] Strausz (2017) studies crowdfunding as a mechanism that plays multiple roles—it allows to learn information about the crowd's willingness to pay, collect the seed investment money from that crowd, and incentivize the entrepreneur's proper action by deferring part of the crowd's payment. In my model, crowdfunding is one of the examples of information generation mechanisms. Another relevant article is Chemla and Tinn (2020), in which a potential monopolist uses crowdfunding to sample uncertain demand before entering the market.

[7] In addition, see the survey Kamenica (2019).

state perfectly but rather remains ignorant about the state with some probability. Whereas it is similar to my finding that the entrepreneur might choose to limit the amount of information before contracting, the exact mechanics are different. Unlike the papers in that literature, in my article, not only is the choice to gather information observed, but the information outcome is always public. Information is free, productive, and rich information structures are considered. As a result, distortions do not arise due to the value of private information or to incentivize information revelation. Instead, they are caused by a combination of the entrepreneur's low bargaining power and high willingness to sign a contract (even for low-quality projects). Moreover, this article shows explicitly how informativeness depends on bargaining power.

Of the financial articles, the most closely related is a recent paper by Azarmsa and Cong (2020). They look at the interaction of the three players: the entrepreneur, the insider investor, and the outsider investor. The entrepreneur and the insider observe the experiment outcome deterministically, unlike the outsider, who observes it randomly. When the financial contract offered by the entrepreneur is a simple share, the experiment design and the investment decision are inefficient. When the entrepreneur also designs the financial security contract, the efficiency is restored, with the security contract being a nonlinear function of project payoff. My findings complement the analysis of Azarmsa and Cong (2020), focusing on bargaining power. In my model, to restore efficiency, the entrepreneur does not need the commitment power to design any sophisticated nonlinear security before designing the experiment structure. Instead, it is sufficient that he has high bargaining power. In addition, my model does not rely on the presence of the outsider investor.

Yang and Zeng (2019) study a setting in which the entrepreneur proposes a financial contract to the investor, who has an informational advantage modeled as a costly information acquisition/rational inattention. Their focus is mainly on the security design in the presence of endogenous informativeness. The friction comes from the cost of information and the separation of control over security design and information acquisition. They show that contracts with equity and debt features incentivize information acquisition, with the equity component becoming more attractive to the entrepreneur if the investor gets some bargaining power. The distortion of investor's incentives decreases with her bargaining power. Similar to my article, as the bargaining power of the information-designing party increases, the distortion in the incentives decrease. However, the sources of the distortions are different. Moreover, Yang and Zeng (2019) do not characterize any nonmonotonicity in a parties' payoffs with respect to bargaining powers.

Works by Bergemann and Hege (1998, 2005), Halac et al. (2016), and Drugov and Macchiavello (2014) study entrepreneurial incentives in the presence of moral hazard in a dynamic setting. These are also examples of entrepreneur–investor relationships with endogenously emerging information regarding project quality. My work disentangles the information-related and the effort choices because they take place at different times. Moreover, I allow for arbitrary bargaining power.[8]

The remainder of this article is organized as follows: The version of the model with the two states of the world is introduced in Section 2, where in Subsection 2.2 the entrepreneur has all the bargaining power, in Subsection 2.3 the investor has all the bargaining power, and in Subsection 2.4 the bargaining power is intermediate. Subsection 2.5 expands the analysis to the case of a continuous infinity number of states. Section 4 concludes. The appendices A.1 and A.2 include proofs and technical details.

2. THE MODEL

2.1. *Binary Project Quality: General Description.* There is an entrepreneur with an idea of a project, which costs c to implement. The entrepreneur seeks funding from the investor. The

[8] For further details on the institutional background of VC and corporate finance, see Kaplan and Strömberg (2003), Da Rin et al. (2013), Bottazzi et al. (2016), and Gompers et al. (2020).

state of the world, ω, captures the project quality: $\omega \in \{\text{good}, \text{bad}\}$. Nature chooses the project quality according to

$$\mathbb{P}\{\omega = \text{good}\} = \alpha_0.$$

A good project yields a return of 1, if and only if an amount c is invested into it; otherwise, it yields 0. A bad project always yields 0. Assume $c < 1$.

In the beginning, the entrepreneur chooses the experiment structure, and the investor observes this choice. Then, both players observe the outcome of the experiment, and both form the posterior belief $\hat{\alpha}$.[9] Next, the entrepreneur approaches the investor, and the two negotiate the terms of financing. These terms specify how the project returns will be shared. The entrepreneur gets a share s, and the investor gets a share $1 - s$. Three possible bargaining procedures will be specified in Subsections 2.2, 2.3, and 2.4.

The investor can refuse to finance the project and step out of negotiations. Whenever the entrepreneur and the investor reach an agreement on the contract terms, the investor transfers the sum c to the entrepreneur.

This interaction is affected by moral hazard: the entrepreneur can divert the funds he obtains from the investor to his own private benefit. In that case, the project always yields nothing, but the entrepreneur enjoys the private benefit δc.[10]

After that, the outcome of the project is observed. If the return is positive, it is shared between the parties according to the prespecified contract.

The players' payoffs are:

– if the investor provides funding,

$$V^E(\omega, a, i) = \begin{cases} s, & \text{if the money is spent properly and } \omega = \text{ good}, \\ 0, & \text{if the money is spent properly but } \omega = \text{bad}, \\ \delta c, & \text{if the money is diverted}, \end{cases}$$

$$V^I(\omega, a, i) = \begin{cases} 1 - s - c, & \text{if the money is spent properly} \\ & \quad \text{and } \omega = \text{ good}, \\ -c, & \quad \text{if the money is diverted, or } \omega = \text{ bad}; \end{cases}$$

– if the investor does not provide funding, both players get their reservation payoffs 0.

Efficient experiment. An efficient experiment is any experiment that results in the maximization of the sum of payoffs. In this environment, it is the experiment that would lead to implementing the project of good quality and discarding the project of bad quality.

Except for the experiment design, the above game is relatively familiar.[11] Suppose there is an experiment with two possible outcomes—high and low.[12] The outcome is publicly observed

[9] The experiment choice will be described below in detail.

[10] δ is an exogenously given share of the money that the entrepreneur can recover after diverting. This way, the aggregate welfare loss due to the diverted funds is $(1 - \delta)c$. Assume throughout the article that $\delta < \frac{1-c}{c}$. One way to interpret δ is an inverse measure of the transparency of the accounting system. The higher the transparency, the smaller the amount the entrepreneur would be able to recover. Alternatively, a higher value of δ could mean less trust between economic agents.Instead of in the direct "runaway" interpretation, the entrepreneur might be deciding between exerting costly investment effort and taking a more relaxed approach, resulting in the money being inefficiently spent. δ would then represent a nonpecuniary benefit from working at a start-up. Sometimes, however, hidden action does take the form of outright fraud, as in the infamous case of the Theranos company, https://www.nytimes.com/2018/06/15/health/theranos-elizabeth-holmes-fraud.html.

[11] In particular, a dynamic repeated version of such an environment is studied in Bergemann and Hege (1998).

[12] In a two-state version of the model, it is without loss to consider two outcome experiments. This is in contrast with Boleslavsky and Kim (2020), wherein in the presence of a moral hazard, the optimal number of signals can be

TABLE 1
CONDITIONAL PROBABILITIES OF THE TWO-OUTCOME EXPERIMENT

Outcome/State	Good	Bad
High	x	y
Low	$1-x$	$1-y$

before the negotiations begin. The entrepreneur chooses the probabilities of each outcome, conditional on the underlying state by setting the numbers $(x, y) \in [0,1]^2$, as in Table 1.

If, for instance, the entrepreneur chooses $x = 1$ and $y = 0$, he induces the precise experiment, which allows always to discard the bad projects and invest in the good ones. The precise experiment is an extreme example of the experiment structure. Another extreme is a noninformative experiment, achieved by setting $x = y \in (0, 1)$.

For an arbitrary choice of $(x, y) \in [0,1]^2$, the updated belief $\hat{\alpha}$ follows from the Bayes' Rule:

$$\hat{\alpha} \doteq \mathbb{P}\{\omega = \text{good}|\text{outcome}\} = \begin{cases} \frac{\alpha_0 x}{\alpha_0 x + (1-\alpha_0) y}, & \text{if outcome is high,} \\ \frac{\alpha_0 (1-x)}{\alpha_0 (1-x) + (1-\alpha_0)(1-y)}, & \text{if outcome is low.} \end{cases}$$

Although both parties would like the good projects to be implemented, the entrepreneur, unlike the investor, also wants the contract to be signed as often as possible. Signing the contract puts a lower bound of δc on his payoff, whereas his payoff is zero if the contract is not signed.

The precise experiment maximizes the sum of payoffs, but because of the parties' conflict of interest, the entrepreneur might prefer an experiment different from the precise one. Then, the question is, how informative the entrepreneur-preferred experiment is?

The informativeness depends on the bargaining power, as we show below. When the entrepreneur chooses the experiment structure and proposes the contract, he prefers the precise experiment. When the investor proposes the contract, the precise experiment is suboptimal for the entrepreneur. After the extreme settings, the intermediate case shows how the bargaining power can balance the forces of the two conflicting interests.

2.2. *The Entrepreneur Makes a Take-It-or-Leave-It Offer.* Denote by s^E the take-it-or-leave-it (TIOLI) contract the entrepreneur offers to the investor. The timing is as follows: first, the entrepreneur chooses the experiment design by setting x and y. Next, Nature chooses the experiment outcome according to the conditional probabilities, (x, y) and the probability of the good project:

$$\mathbb{P}\{\text{high}\} = \alpha_0 x + (1-\alpha_0) y.$$

After both players observe the outcome, the entrepreneur proposes the contract s^E to the investor. If she accepts, $a^I = 1$, the game continues, and the entrepreneur receives the investment sum c. He then chooses whether to spend it properly on the project or to divert it. In the end, Nature chooses the project quality according to current belief $\hat{\alpha}$.[13] The return realizes according to project quality, and the entrepreneur's spending decision. That is, the return is equal to 1 if and only if the quality is good *and* the entrepreneur has properly spent the money.

larger than the number of states. In their model, the moral hazard takes place before the experiment choice, whereas in our setting—after. This allows accounting for any moral hazard in the indirect utility of the entrepreneur at the time he chooses the experiment. I am thankful to an anonymous referee for pointing this out.

[13] The actual frequency of good projects must coincide with the ex ante probability of the good project, α_0. In the timeline above, this happens if Nature's eventual choice of the project quality is consistent with the previously realized experiment outcome—that is, it happens according to the posterior beliefs.

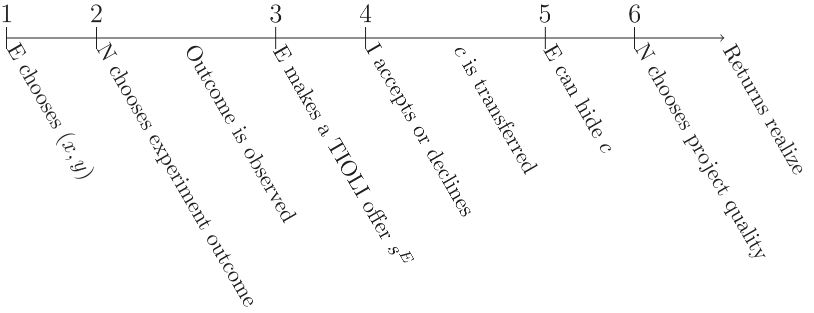


FIGURE 1

TIMELINE

Figure 1 shows the timeline.

Notice that the analysis with the timeline as above is essentially the same as the analysis in the case of Nature covertly choosing the project quality before the start of the play, according to the probability of the project being good α_0.[14]

Analysis. Applying the backward induction, in the subgame-perfect Nash equilibrium, the entrepreneur spends the money properly if his share of the updated expected return from the project is higher than the payoff from diverting the money: $\hat{\alpha}s^E \geq \delta c$; he offers a share contract that makes the investor indifferent $(1 - s^E)\hat{\alpha} = c$; anticipating the possibility of improper money spending, the investor will only fund the project if the posterior belief is high $\hat{\alpha}s^E \geq \delta c$. The latter condition, together with the entrepreneur-preferred contract, implies that a project gets funded if and only if the belief after the experiment outcome is

$$\hat{\alpha} \geq (1 + \delta)c.$$

Write down the entrepreneur's equilibrium payoff from the posterior:

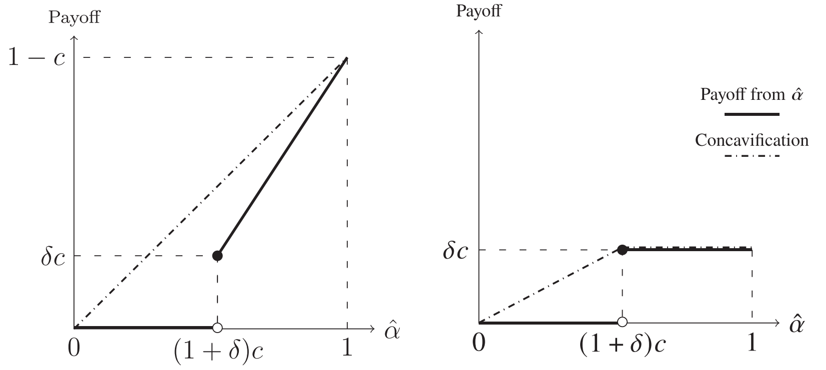
$$V^E(\hat{\alpha}) = \begin{cases} \hat{\alpha} - c, & \text{if } \hat{\alpha} \geq (1 + \delta)c \\ 0, & \text{otherwise.} \end{cases}$$

Result. The reader familiar with the *concavification* technique can see that the experiment, such that the posterior $\hat{\alpha} = 1$ realizes with probability α_0, and the posterior $\hat{\alpha} = 0$ realizes with probability $1 - \alpha_0$, is optimal. This technique implies finding the smallest concave function, which is everywhere weakly greater than the entrepreneur's payoff $V^E(\hat{\alpha})$. The concavification in this case is $\hat{V}^E(\hat{\alpha}) = \hat{\alpha}(1 - c)$. Evaluating this function at $\hat{\alpha} = \alpha_0$ gives the entrepreneur's payoff from the optimal experiment, $\alpha_0(1 - c)$. In terms of conditional probabilities, setting $x = 1$ and $y = 0$ leads to the optimal distribution of posteriors described above. The precise experiment is, therefore, optimal. Figure 2(a) depicts the entrepreneur's payoff function $V^E(\hat{\alpha})$ with its concavification.

PROPOSITION 1. *If the entrepreneur makes a take-it-or-leave-it offer to the investor, he prefers the precise experiment ($x = 1, y = 0$).*

The proof with the reference to the results of Kamenica and Gentzkow (2011) is in the Appendix Subsection A.1.1.

[14] Such a timeline, however, would make the analysis more cumbersome due to the absence of proper subgames and the need to apply a solution concept like the Perfect Bayes equilibrium. The conclusions, nevertheless, would be essentially the same.



(a) Entrepreneur makes TIOLI (b) Investor makes TIOLI

FIGURE 2

ENTREPRENEUR'S PAYOFF FROM $\hat{\alpha}$ AND CONCAVIFICATION

Consider an analogy with corporate finance. In the region of beliefs $\hat{\alpha} \geq (1+\delta)c$, the entrepreneur is effectively the single shareholder of the project, and the investor is the single lender. The effective cost of the project is $(1+\delta)c$—the actual cost of investment, c, plus the cost of the proper incentives, δc. The investor does not lend the money when the posterior belief is below the effective cost of financing. The entrepreneur has a zero payoff when his project is nonprofitable. Thus, over the entire range of beliefs, the entrepreneur acts as the residual claimant. The precise experiment is the efficient choice, which the residual claimant prefers.

2.3. *The Investor Makes a Take-It-or-Leave-It Offer.* Overall, the actions and the timeline are similar to the previous case with the addition of the investor's choice of whether to offer any financing to the entrepreneur. After relabeling, $s^I \in [0,1] \cup \{\emptyset\}$ is the investor's choice of which share contract to offer if any, and $a^E \in \{0,1\}$ is the entrepreneur's choice of whether to accept it.

Analysis. In equilibrium, the entrepreneur accepts any offer by the investor; among the shares that satisfy the entrepreneur's Incentive Compatibility constraint (IC), $s^I \times \hat{\alpha} \geq \delta \times c$, the investor offers the smallest one, $s^I = \delta c/\hat{\alpha}$. As before, the investment is feasible if and only if $\hat{\alpha} \in [(1+\delta)c, 1]$. The investor makes the entrepreneur indifferent between proper spending and diverting the funds when the project is feasible.

The entrepreneur's payoff from posterior $\hat{\alpha}$ is

$$V^E(\hat{\alpha}) = \begin{cases} \delta c, & \text{if } \hat{\alpha} \geq (1+\delta)c, \\ 0, & \text{otherwise.} \end{cases}$$

Result. The entrepreneur's payoff from the precise experiment is $\alpha_0 \delta c$. If the probability of a good project is high, $\alpha_0 \geq (1+\delta)c$, he can attract financing without generating any information, making the precise experiment suboptimal. In fact, generating no information is weakly preferred to *any* informative experiment since the concavification is equal to δc in this region, as shown in Figure 2(b).[15]

[15] Note, however, that there are multiple experiments that are optimal for the entrepreneur. Any experiment that results in the support of posteriors $\subseteq [(1+\delta)c, 1]$ is optimal. In particular, the investor-preferred optimal experiment results in the support of posteriors $\{(1+\delta)c, 1\}$.

If the entrepreneur is unable to attract financing without generating information, $\alpha_0 < (1+\delta)c$, the precise experiment is also suboptimal. The experiment design $x = 1$, $y = \frac{\alpha_0}{1-\alpha_0}(\frac{1}{(1+\delta)c} - 1)$ leads to the belief $\hat{\alpha} = 0$ with probability $\frac{\alpha_0}{(1+\delta)c}$ (in the event of low outcome), and the belief $\hat{\alpha} = (1+\delta)c$ with probability $1 - \frac{\alpha_0}{(1+\delta)c}$ (in the event of high outcome, which allows the investor to exactly recoup the effective cost of financing in expectation). This experiment is the optimal one since it allows the entrepreneur to achieve the ex ante payoff of $\alpha_0 \frac{\delta}{(1+\delta)}$, which lies on the payoff concavification.[16]

PROPOSITION 2. *If the investor makes a take-it-or-leave-it offer,*

- *in the case that the entrepreneur cannot attract financing without an informative experiment ($\alpha_0 < (1+\delta)c$), an experiment with conditional probabilities $x = 1$, $y = \frac{\alpha_0}{1-\alpha_0}(\frac{1}{(1+\delta)c} - 1)$ is optimal;*
- *in the case that the entrepreneur can attract financing without an informative experiment ($\alpha_0 \geq (1+\delta)c$), generating no information is optimal.*

See the details in Appendix A.1.2.

In this case, the investor is the residual claimant. When the investment is feasible, the entrepreneur is effectively an employee working for the constant wage of δc. The investor hires the entrepreneur to carry out the spending effort. The entrepreneur prefers to get hired as often as possible, as he is unable to affect his wage in the events when he is hired. The entrepreneur maximizes his chances of getting hired through a certain level of information obfuscation.

2.4. *Intermediate Bargaining Powers.* The informativeness of the entrepreneur-preferred experiment decreases when the investor has absolute bargaining power. Studying the intermediate bargaining power can facilitate our understanding of the level of bargaining power at which precise experiment is no longer optimal. Moreover, a different experiment design can be optimal for some intermediate bargaining power.

Multiple bargaining protocols allow for interior bargaining powers. Choosing a concrete noncooperative form of bargaining would require additional expositional work and motivation for that particular choice. Instead, the analysis proceeds with the Nash bargaining solution. It allows staying agnostic about how the negotiations between the entrepreneur and the investor take place exactly; it embodies several other bargaining protocols with intermediate bargaining powers; it makes the exposition more straightforward. For example, infinitely repeated random proposer bargaining with players becoming increasingly patient leads to the same results.

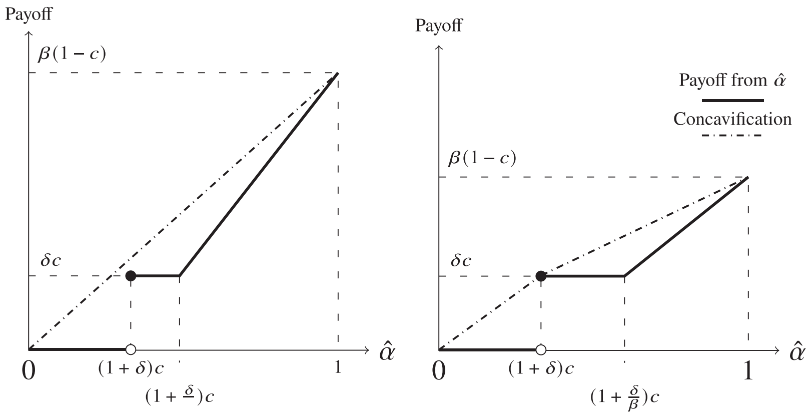
After the players observe the experiment outcome, the surplus they divide is $\hat{\alpha} - c$. The solution must account for the entrepreneur's incentive-compatibility constraint, $\hat{\alpha} \times s \geq \delta \times c$, and the investor's individual rationality constraint, $\hat{\alpha}(1-s) \geq (1+\delta)c$. Then, the space of contracts among which the Nash bargaining solution searches for the optimal contract is $s \in [\delta c/\hat{\alpha}, 1 - c/\hat{\alpha}]$.[17]

As before, the space of acceptable contracts is nonempty if and only if $\hat{\alpha} \geq (1+\delta)c$. Let β denote the entrepreneur's bargaining power. The solution to the Nash bargaining problem is

$$s(\hat{\alpha}) = \arg \max_{\frac{\delta c}{\hat{\alpha}} \leq x \leq 1 - \frac{c}{\hat{\alpha}}} \left\{ (\hat{\alpha} x)^{\beta} (\hat{\alpha}(1-x) - c)^{1-\beta} \right\}.$$

[16] The concavification is given by $\hat{V}^E(\hat{\alpha}) = \min\{\hat{\alpha}\frac{\delta}{(1+\delta)}; \delta c\}$.

[17] The solution to this problem can be called the Nash bargaining solution on the space of incentive-compatible payoffs, or the constrained Nash bargaining solution.



(a) High β (b) Medium β

FIGURE 3

ENTREPRENEUR'S PAYOFF FROM $\hat{\alpha}$ AND CONCAVIFICATION FOR NBS

The interior solution candidate is

$$s(\hat{\alpha}) = \beta(1 - c/\hat{\alpha}).$$

The only corner candidate is at the lower bound, $s = \delta c/\hat{\alpha}$. It *is the* solution when $\hat{\alpha} \in [(1+\delta)c, (1+\delta/\beta)c)$. The Nash bargaining problem is not defined for $\hat{\alpha} \in [0, (1+\delta)c)$. Thus, the solution is

$$s(\hat{\alpha}) = \max\left\{\frac{\delta c}{\hat{\alpha}}, \beta\left(1 - \frac{c}{\hat{\alpha}}\right)\right\}\mathbb{I}_{\{\hat{\alpha}\in[(1+\delta)c,1]\}}.$$

Therefore, the entrepreneur's payoff as a function of posterior belief is

$$V^E(\hat{\alpha}) = \hat{\alpha} \times s(\hat{\alpha}) \times \mathbb{I}_{\{\hat{\alpha}\in[(1+\delta)c,1]\}} = \max\left\{\delta c, \beta(\hat{\alpha} - c)\right\} \times \mathbb{I}_{\{\hat{\alpha}\in[(1+\delta)c,1]\}} =$$

$$= \begin{cases} 0, & \text{if } \hat{\alpha} < (1+\delta/\beta)c, \\ \delta c, & \text{if } (1+\delta)c \le \hat{\alpha} < (1+\delta/\beta)c, \\ \beta(\hat{\alpha} - c), & \text{if } (1+\delta/\beta)c \le \hat{\alpha}. \end{cases}$$

Figure 3 plots the entrepreneur's payoff and concavification for two values of β, high and medium (when the value of β is low, the graph of the payoff is essentially the same as 2(b)).

Three belief regions are distinct. No contract is feasible under low $\hat{\alpha}$ For medium $\hat{\alpha}$, the investment is feasible, and the entrepreneur's payoff is flat with respect to $\hat{\alpha}$. For high $\hat{\alpha}$, the investment is also feasible, and the entrepreneur's payoff increases in $\hat{\alpha}$. Here, the entrepreneur is effectively a shareholder, and his bargaining power determines his share.

The optimal experiment depends on the entrepreneur's bargaining power because the shape of the payoff changes with β. There are three qualitatively different cases. For high β, $\beta \ge \frac{\delta}{(1+\delta)(1-c)}$, the outcome is the same as in the case of the entrepreneur making a take-it-or-leave-it offer: the precise experiment is optimal. The case of low β, $\beta < \frac{\delta c}{1-c}$, and the case that combines medium β and low prior, $\beta \in [\frac{\delta c}{1-c}, \frac{\delta}{(1+\delta)(1-c)})$, $\alpha_0 < (1+\delta)c$, are outcome-equivalent to the investor making a take-it-or-leave-it offer.

A new conclusion emerges for medium β and a high prior belief, $\alpha_0 > (1+\delta)c$. Consider the payoff and its concavification for this case on the Figure 3(b). If the prior belief is high,

$\alpha_0 > (1+\delta)c$, the entrepreneur has strong incentives to conduct an informative experiment: conditionally on being financed, he wants the beliefs about the project to be more optimistic so that it will result in a larger surplus. However, the precise experiment is suboptimal, as he does not want to risk losing his financing by generating too much information. Therefore, he prefers the high outcome of the experiment to result in the belief of 1 and the low outcome to result in the belief $(1+\delta)c$, the lowest under which financing is feasible.

The conditional probabilities that lead to the desired distribution of posteriors are $x = \frac{\alpha_0-(1+\delta)c}{\alpha_0(1-(1+\delta)c)}$ and $y = 0$. This way, after observing a high experiment outcome, the agents are certain that the project is good. After observing a low experiment outcome, the agents understand that there is a mixture of good and bad projects that recoup the effective cost of financing on average. These findings can be summarized as follows:

Proposition 3. *In the case of a medium level of the entrepreneur's bargaining power, $\frac{\delta c}{(1-c)} \leq \beta < \frac{\delta}{(1+\delta)(1-c)}$, the entrepreneur-preferred experiment structure depends on the prior belief about the quality of the project. For $\alpha_0 < (1+\delta)c$, the optimal conditional probabilities are $x = 1$, $y = \frac{\alpha_0}{1-\alpha_0}(\frac{1}{(1+\delta)c} - 1)$. For $\alpha_0 \geq (1+\delta)c$ the optimal conditional probabilities are $x = \frac{\alpha_0-(1+\delta)c}{\alpha_0(1-(1+\delta)c)}$, $y = 0$.*

The details are in the Subsection A.1.3 of Appendix A.1.

An immediate corollary of the above result is the comparative statics of informativeness with respect to δ and c. An experiment A being Blackwell more informative than B is equivalent to the distribution of posteriors in A being Second-Order Stochastically Dominated by that of B. Thus, we can state:

Corollary 1. *For medium (low) bargaining power, if the ex ante expected project quality is low, $\alpha_0 < (1+\delta)c$, the informativeness of the entrepreneur-preferred experiment is increasing in the investment cost, c, and severity of the moral-hazard problem, δ. For a high ex ante expected project quality, $\alpha_0 \geq (1+\delta)c$, the informativeness of the entrepreneur-preferred experiments is decreasing in c and δ.*

Investor-Preferred Bargaining Power. The investor's bargaining power is $1-\beta$. Because the informativeness and the equilibrium surplus increase with β, the investor might benefit from not having absolute bargaining power. If the prior is low, $\alpha_0 < (1+\delta)c$, and the entrepreneur's bargaining power is low (respectively, investor's bargaining power is high), $\beta < \frac{\delta}{(1+\delta)(1-c)}$, the investor gets the expected payoff of zero even if the project gets funded. However, if the investor's bargaining power decreases so that $\beta = \frac{\delta}{(1+\delta)(1-c)}$, her payoff jumps up to $\alpha_0\frac{(1-(1+\delta)c)}{1+\delta}$, as the precise experiment becomes optimal for the entrepreneur.

Even if the prior is above the effective cost of financing, $\alpha_0 \geq (1+\delta)c$, the investor can benefit from a lower bargaining power. Investor's payoff is monotonically decreasing in β if $\beta < \frac{\delta}{(1+\delta)(1-c)}$. Compare the investor's payoff under $\beta = 0$, $V^I = \alpha_0 - (1+\delta)c$, to $V^I = \alpha_0\frac{1-(1+\delta)c}{1+\delta}$, her payoff under $\beta = \frac{\delta}{(1+\delta)(1-c)}$, to conclude that the investor prefers a nonabsolute bargaining power whenever $\alpha_0 \leq \frac{(1+\delta)^2 c}{(2-c)\delta}$. Note also that $\{\alpha_0 \leq \frac{(1+\delta)^2 c}{(2-c)\delta}\} \supset \{\alpha_0 \leq (1+\delta)c\}$

The corollary summarizes these observations:

Corollary 2. *The investor prefers a nonabsolute bargaining power, $\beta = \frac{\delta}{(1+\delta)(1-c)}$, if the ex ante project quality is not too high, $\alpha_0 \leq \frac{(1+\delta)^2 c}{(2-c)\delta}$.*

Consider also the graph of the investor's preferences with respect to the bargaining power in Figure 4.

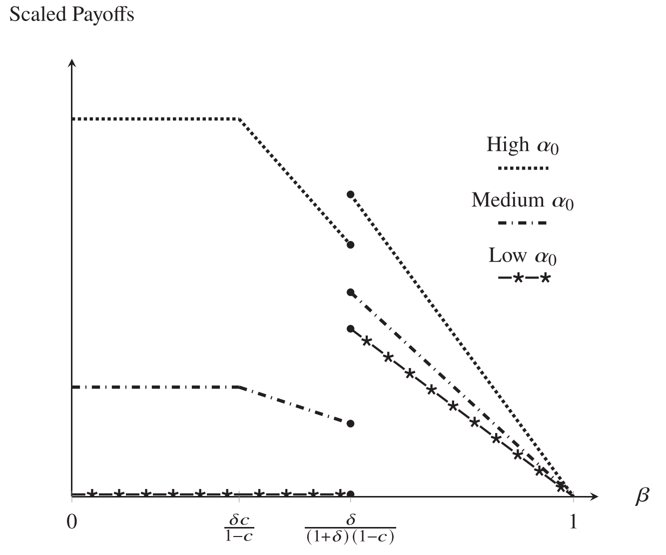


FIGURE 4

INVESTOR'S PREFERENCES OVER BARGAINING POWER, BINARY QUALITY

2.5. *Continuous Project Quality.* To show that our conclusions hold in a richer and, arguably, more robust setting, we extend the analysis to the case of the continuous project quality in Appendix A.2. Here, we summarize its main findings. We allow the project quality ω to be distributed in the interval [0,1] according to an atomless distribution with the Cumulative Distribution Function (CDF)$F_{\omega}()$. The return from the project is the same as its quality. Besides the distributional assumptions on the project quality, the model stays the same.

As a corollary of Lemmas A.5–A.10, the entrepreneur prefers the experiment to divide the project qualities into three intervals:

- low, $\omega \in [0, \kappa]$;
- medium, $\omega \in (\kappa, \tau)$;
- high, $\omega \in [\tau, 1]$.

For projects falling into the medium-quality interval, the entrepreneur prefers the experiment to only reveal that $\omega \in (\kappa, \tau)$. Moreover, κ and τ are chosen so that $\mathbb{E}[\omega|\kappa < \omega < \tau] = (1 + \delta)c$. This way, after observing the medium experiment outcome, the investor is indifferent between investing and not.

For low and high intervals, the entrepreneur-preferred experiment can reveal anything, as long as it reveals that ω is in the respective region, $[0, \kappa]$ or $[\tau, 1]$.[18] The most informative entrepreneur-preferred experiment reveals the quality completely when $\omega \in [0, \kappa] \cup [\tau, 1]$.

Call the pair (κ, τ) *interior*, when $\kappa > 0$ *and* $\tau < 1$. Based on the analysis in the Appendix (Propositions A.1–A.3), we can state the following result:

PROPOSITION 4. *The optimal thresholds κ and τ are interior if and only if the entrepreneur's bargaining power is high enough.*

- *If (κ, τ) are interior, κ is increasing and τ is decreasing in β;*
- *If $\mathbb{E}\omega < (1 + \delta)c$ and (κ, τ) are not interior, then $\tau = 1$ and κ is such that $\mathbb{E}[\omega|\omega > \kappa] = (1 + \delta)c$;*
- *If $\mathbb{E}\omega \geq (1 + \delta)c$ and (κ, τ) are not interior, then $\kappa = 0$ and τ is such that $\mathbb{E}[\omega|\omega < \tau] = (1 + \delta)c$.*

[18] Thus, there are multiple entrepreneur-preferred experiments.

Changes in κ and τ in response to a change in β have straightforward consequences for informativeness. The increase of κ and the decrease of τ mean that the experiment results reveal larger intervals of project qualities if we focus on the most informative entrepreneur-preferred experiment.

COROLLARY 3. *Suppose that β is high enough so κ and τ are interior. Then, the informativeness of the entrepreneur-preferred experiment is strictly increasing in his bargaining power for the most informative experiment.*

κ and τ never coincide and complete information is not attainable as an equilibrium outcome. The efficient outcome can nevertheless be achieved in equilibrium. For efficiency, it is necessary and sufficient that projects with $\omega < c$ are discarded and with $\omega \geq c$ are invested into. Entrepreneur-preferred experiments allow for that under $\kappa = c$.[19]

When the efficiency is not achieved, $\kappa < c$, we can order the equilibrium outcomes with respect to the measure of projects with $\omega < c$ that *do* get implemented, even though they should not. We can then call the equilibrium outcomes with a lower measure of such projects as *more efficient*, with them being closer in order to the efficient outcome. In this sense, the efficiency of the equilibrium increases with the bargaining power of the entrepreneur since κ is increasing in β, lowering the measure of projects being inefficiently invested into. The efficiency is increasing strictly if equilibrium couple (κ, τ) is interior. Note that we do not need to limit the analysis to the most informative experiments to make such kind of comparative efficiency statement.

COROLLARY 4. *The efficiency of the entrepreneur-preferred information structure is increasing in his bargaining power, β. $\beta = 1$ is the necessary condition for efficient information generation in equilibrium.*

The necessity of $\beta = 1$ for efficiency is discussed in Appendix A.2.4.

Finally, the result that the investor might prefer giving up some of her bargaining power also holds in the continuous setting, as shown in A.2.4.

COROLLARY 5. *For continuous project quality, the investor prefers nonabsolute bargaining power, $1 - \beta < 1$, if the project cost c is not too low.*

Uniform example. We conclude the subsection with an example, $\omega \sim \mathcal{U}([0, 1])$. The interior solution is

$$\kappa = \left(1 - \frac{2(1-\beta)}{\beta}\delta\right)c, \ \tau = \left(1 + \tfrac{2\delta}{\beta}\right)c, \ \lambda = \tfrac{(1-\beta)\beta}{2-\beta}.$$

For high ex ante quality, $\mathbb{E}[\omega] = 0.5 \geq (1+\delta)c$, the solution is interior when $\beta \geq \frac{2\delta}{1+2\delta}$; for low ex ante quality—when $\beta \geq \frac{2\delta c}{1-c}$. Note that interior $\kappa = c$ under $\beta = 1$. The corner solutions are $(\kappa, \tau) = (0, 2(1+\delta)c)$, and $(\kappa, \tau) = (2(1+\delta)c - 1, 1)$, for high and low ex ante qualities, respectively.

Figure 5 shows how the project quality intervals look for various levels of β in this example. Besides, Figure 6 depicts the investor's payoffs for this example under various levels of the investment cost c. Note the interior maximum for c not being high.

3. DISCUSSION

Relation to standard Bayesian persuasion. Notice, how our model is not equivalent to the standard Bayesian persuasion example of Kamenica and Gentzkow (2011) with a binary-state,

[19] This holds without restricting the analysis to the most informative experiments.

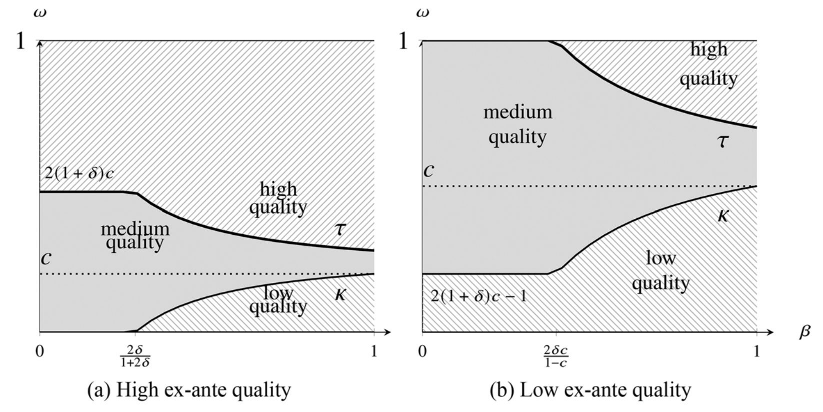


FIGURE 5

PROJECT QUALITY INTERVALS

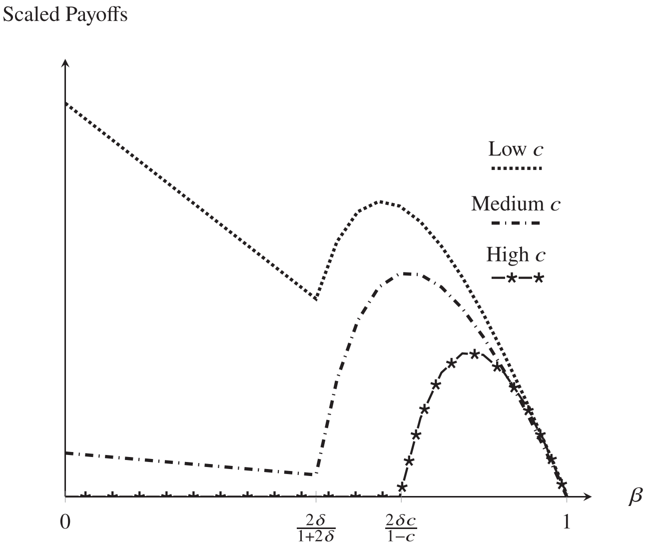


FIGURE 6

INVESTOR'S PREFERENCES OVER BARGAINING POWER, CONTINUOUS QUALITY

binary-action environment augmented with the sender's preferences being a convex combination of state-independent preferences and the preference for matching the state. The starkest difference in outcomes is when the prior belief is high so that in a standard setting the sender would not need to provide further evidence for the receiver to take the desired action. As the weights in the sender's preferences vary, we would get either full information or no information. But in the binary quality entrepreneur–investor setting, as we vary the entrepreneur's bargaining power, we can also get the shaded experiment. The latter is informative, but not fully.

The difference between the two settings is driven by the contracting stage and the moral hazard that follows. Because the investor has to provide the entrepreneur with the incentives to spend the money on the project, there are a flat region and an increasing region of the entrepreneur's payoff when the project gets funding. The increasing portion of payoff creates the incentives for informativeness, whereas the flat portion limits them. The bargaining power balances the relative prevalence of the flat part and the increasing part.

Binary versus Continuous quality. Notice the different effects the full information has in the binary- and the continuous quality settings. In the binary setting, the full information is the only way to achieve the efficient outcome: invest if and only if the project quality is good. In the continuous setting with a single decision maker, full information would be one of the efficient information structures. However, in the game setting, the full information cannot achieve efficient equilibrium due to discrepancies between the entrepreneur's and the investor's incentives. Some opacity is required for parties to agree on funding the projects in $(c, (1+\delta)c)$.

However, the equilibrium source of inefficiency is similar in the two settings: not willing to miss the opportunity of getting funded, the entrepreneur who does not fully internalize the costs of inefficient projects prefers to implement the project with inefficiently high frequency. This results in too many cases of projects receiving funding when they should not have. The higher the entrepreneur's bargaining power, the more he internalizes the funding costs and prefers to implement viable projects, and the smaller the degree of inefficiency.

Related literature. Getting back to the analogies of the results of my article with the results in precontract information gathering, Kessler (1998) shows that the agent always prefers to remain ignorant about the state with some probability. In my article, the entrepreneur might choose to limit the amount of information before contracting when his bargaining power is low. However, the reasons behind such choices are different. If in Kessler (1998) the agent chooses to learn the information perfectly, he cannot claim to be ignorant about the state of the cost: his choice of informativeness is observable. Being ignorant about the state is a form of private information that leads to informational rents. Thus, he loses the advantage of private information when he cannot claim ignorance. My article allows for a more transparent separation of the value of information from rents for private information. Moreover, unlike in, for example, Nosal (2006), where information is still inefficient when the contract proposer gathers information, in my setting, increasing the bargaining power of the information designer allows for the restoration of efficiency.

We can also make parallels to the information design in bilateral trade. Thus, in the corner solution of Proposition 4, when the ex ante quality is insufficient for financing, the information would reveal the bare minimum for the investment to occur with the highest frequency. This is reminiscent of the result in Roesler and Szentes (2017) that the buyer prefers minimal information about her valuation for the trade to occur when facing a take-it-or-leave-it price.

Literature on holdup problems in precontract investing (Grossman and Hart, 1986; Hart and Moore, 1988) is also related because the amount of information in our setup is noncontractible. Thus, in Grout (1984), firms and unions bargain about wages and employment levels after the firms choose the investment in the capital level. In that environment, shareholders are analogous to the entrepreneur and union—to the investor. Similarly to our article, in Grout (1984), shareholders' payoff is increasing in their bargaining power, whereas the negotiated wage of the union is nonmonotonic in the bargaining power.

Comparing the assumptions and the results of my article to Azarmsa and Cong (2020), my analysis complements their findings. First, when the entrepreneur does not design the security contract in their setting, the results of Azarmsa and Cong (2020) show that the information and investment decision is always inefficient. In their model, the outsider learns the experiment outcome with a nonunit probability. They interpret this probability as the measure of the investor's bargaining power. Given this interpretation, in their setting, the informativeness is nonmonotonic in the bargaining power; moreover, no financing can occur for the intermediate levels of bargaining power. In my article, informativeness increases with bargaining power, and financing always occurs with positive probability. Second, to restore efficiency, in my model, the entrepreneur does not need the commitment power to design any sophisticated nonlinear security before designing the experiment structure. Instead, he must have high bargaining power. In the continuous project quality case of my article, the contract is chosen after the experiment outcome. Thus, due to the risk neutrality, it is without loss to consider simple share contracts. In a way, because of the simplicity of the financial contract, the optimal experiment structure is richer: there are two thresholds, such that if the quality is between them, it is only revealed that the quality is medium, whereas if the quality is above the higher threshold, it is completely revealed. Another important difference is that Azarmsa and Cong (2020) assume that the insider investor cannot influence the experiment even though the bond has already been formed in exchange for seed financing. In contrast, in my model, the investor does not influence the experiment design because the parties have not met, which might seem more natural in some settings.

Assumptions. My results complement the analysis of Yang and Zeng (2019), and Strausz (2009), where the investor is allowed to have different forms of informational advantage. My analysis could be augmented to also include the informational advantage on the investor's side, as well as the entrepreneur's. For example, the investor, being an expert in her field, could interpret the results of the entrepreneur's experiment in a more precise way than the entrepreneur would. The investor's signal, modeled as a distribution with the average equal to the updated entrepreneur's belief, would still need to be high enough for the investment to occur. With the entrepreneur having absolute bargaining power, he would still prefer more extreme updated beliefs. In contrast, with the investor having absolute bargaining power, the entrepreneur would prefer to obfuscate the information around the $(1+\delta)c$ threshold, increasing the chances of financing. Another way to introduce an investor's information channel would be to allow her to design an experiment. For example, the returns from the project could be a product of its random 0–1 quality and random continuous cash flows, with the entrepreneur choosing the experiment about the former and the investor—about the latter. Still, with the lack of bargaining power on his side, the entrepreneur could and would try to make the final "estimate" of profitability to concentrate just above $(1+\delta)c$.

Similarly, the mechanics of the article would still carry through if the entrepreneur had an informational advantage on his side in the form of being able to hide unfavorable signals. If the entrepreneur has absolute bargaining power, he is interested in efficiently generating precise information. If he was then to try to hide the negative outcome of the experiment, the investor, knowing that some experiment was conducted and observing no positive results, would deduct that the outcome must have been negative. On the other hand, if the investor has absolute bargaining power and the entrepreneur can obtain financing without new information, he does not have strict incentives to conduct any informative experiment and then hide adversary outcomes. These observations are also consistent with Gentzkow and Kamenica (2017), where the authors show that endogenous privately acquired information is disclosed in equilibrium.

There are several reasons to assume within our model that the entrepreneur conducts the experiment only once, and the investor cannot nudge him to conduct any further precontract information generation. It is not uncommon for start-up entrepreneurs to have offers from several VCs, as documented for instance, in Hsu (2004). Moreover, Gompers and Lerner (2000) show that an inflow of VC funds can increase the prices the investors have to pay because of the competition for a limited number of start-up investment opportunities. Hence, the entrepreneur, being asked to provide further evidence by one investor, might turn to other investors, who do not require any further information before signing the contract. That can motivate the first investor to reconsider asking for more information in the first place.

Another reason why the investor might prefer not to ask for more precontract information is that it can be more beneficial to conduct further experimentation jointly. Then, terms of experimentation would be included in the contract, which in turn would allow for larger-scale experimentation (larger-scale experiments in the start-up environment can achieve economy of scales, as hardware and computational power can be bought, instead of being rented, see Ewens et al., 2018). Another benefit of choosing the experiment jointly is that often high-quality VCs are experienced in their field (as argued in, for example, Hsu (2004) and Ewens et al. (2022)), so together the entrepreneur and the investor can design better experiments. In this interpretation, the entrepreneur having a borderline project quality and signing a contract is like him getting his foot in the door, but with further relation between the two agents not modeled explicitly in this article.

Furthermore, in some settings, it takes time to conduct an informative experiment. If there is discounting, the expected value of a project undergoing an additional precontract experiment will diminish. Sometimes, the nature of the original experiment is one-off. If the product has already been on a crowdfunding platform, it would be hard to attract additional preorder demand with a new campaign but an old product. In this respect, the experience of the Pebble Watch can be relevant. Whereas its creators did conduct preorder campaigns twice, the second campaign was for a new product version and happened after the VC funds were attracted for the first time. We can also think of start-up accelerator programs as an information-generating mechanism, as the teams' projects get evaluated over time by program mentors. Different accelerator programs vary in how they are designed (Cohen et al., 2019) and thus, potentially, can differ in how much information the participants learn about their ideas. It is unusual for the same team of start-up entrepreneurs to go through an accelerator program more than once. Thus, there would be limited opportunities for an entrepreneur, having gone through an accelerator program, to generate additional information of similar nature about his project.

Timing. The timing of signing the contract relative to the entrepreneur's decision about the experiment plays a decisive role in the main results. If the parties were able to sign the contract *before* the entrepreneur's experiment choice, they would internalize the conflict of interest and agree on the efficient choice of information.

There is another alternative, where the parties could negotiate after the experiment choice but before the outcome.[20] The parties would then negotiate the terms contingent on every further continuation. However, the lack of an entrepreneur's bargaining power would still lead to inefficient experiment structures. This happens because even though the parties bargain about their ex ante expected payoffs, the entrepreneur's IC constraints still need to hold ex post.

Consider the following numerical example in the setting of binary quality. Let $\alpha_0 = 1/2$, $\delta = 1/3$, and $c = 1/3$. Suppose the entrepreneur had chosen the precise experiment. The investor transfers the money when the posterior realization is 1 and does not when the posterior realization is 0. The Nash bargaining solution solves $\max_s\{(\alpha_0 s)^\beta((1-\alpha_0)(1-s-c))\}$ subject to $s \geq \delta c$. In this case, $s = (2/3)\beta$, if $\beta \geq 1/6$ and $s = 1/9$, if $\beta < 1/6$. The entrepreneur's payoff from the precise experiment is $V^E = (1/2) \times ((2/3)\beta\mathbb{I}_{\{\beta \geq 1/6\}} + (1/9)\mathbb{I}_{\{\beta<1/6\}})$.

Suppose now the entrepreneur had chosen the shaded experiment, the one that leads to posteriors 1 and $(1+\delta)c$. When the posterior is $(1+\delta)c$, the entrepreneur's payoff is always δc and the investor's – 0. Then, the Nash bargaining solution solves

$$\begin{aligned}
\max_s \quad & \left\{ \left(\frac{\alpha_0 - (1+\delta)c}{1-(1+\delta)c} s + \frac{1-\alpha_0}{1-(1+\delta)c} \delta c \right)^\beta \left(\frac{\alpha_0 - (1+\delta)c}{1-(1+\delta)c} (1-s-c) \right)^{1-\beta} \right\} \\
& \text{s.t.} \\
& s \geq \delta c.
\end{aligned}$$

Then, the solution is $s = \frac{5\beta-3}{3}$, if $\beta \geq 2/3$, and $s = 1/9$ if $\beta < 2/3$, with the entrepreneur's payoff $V^E = ((1/6)\beta\mathbb{I}_{\{\beta \geq 2/3\}} + (1/9)\mathbb{I}_{\{\beta<1/3\}})$. It follows that the entrepreneur prefers the shaded experiment to the precise one when $\beta < 1/3$, which implies that under such a timeline the entrepreneur might still prefer an inefficient experiment structure when his bargaining power is low.

Bargaining power. Bargaining power can be interpreted in several ways. At a microlevel, it is usually assumed that more experienced entrepreneurs have a greater say when the

[20] I am grateful to an anonymous referee for encouraging this discussion.

terms of a contract are negotiated. This means that the more experienced entrepreneurs are more likely to generate the efficient amount of information. Conversely, less experienced entrepreneurs are more likely to generate less information and finance riskier projects. That could lead to a vicious circle at a microlevel: the less experienced entrepreneurs will start risky projects, enjoy success less often, and in the future will have less evidence of success to back up their claims of experience, which will again result in agents undertaking riskier projects.[21]

At a more macrolevel, bargaining power is usually inversely associated with market tightness. For example, there is more competition in the IT industry than there is in healthcare start-ups.[22] Alternatively, entrepreneurs' higher bargaining power can be associated with there being a larger number of investors on the market.

The model results say that in environments rich with investment money and numerous VC investors, only good enough projects are funded. On the other hand, in environments with little money or investor scarcity, riskier projects can also get funded. Consider the following scenario: suppose that a small number of VC investors control a large share of the economy's investment money. They are likely to have a lot of bargaining power. Some of their investment will be in inefficiently risky projects. An inefficiently high amount of money will be lost. Some of the VC firms may have to go out of business due to these losses, resulting in even fewer investors absorbing even more bargaining power.

The two geographical regions that could be juxtaposed with each other, are, for example, Silicon Valley and South Korea. In the former, there are numerous independent investment funds; in the latter, VC investments are controlled by the respective branches of the industrial giants, like Samsung Ventures, and Samsung NEXT.

As has been mentioned, there is empirical evidence in Cumming and Dai (2011) that the higher bargaining power of the VC fund can lead to a lower performance of that fund. My results offer the entrepreneur's inefficient information generation as a plausible source of diseconomy from the bargaining power.

My results also show that the investor prefers nonabsolute bargaining power if the project's cost is not too low. Thus, the investor might have incentives to establish the reputation of being generous: leaving enough "on the table" for the entrepreneur might benefit investment performance. It was documented by Bengtsson and Ravid (2015) that different U.S. states offer different terms of contracting. In particular, California-based investors offer less harsh terms to entrepreneurs. The results of my model might explain this phenomenon.

Crowdfunding. In this article, crowdfunding was mentioned as an instrument to generate public information, thus, neglecting its funds-collecting target. For some projects the money, collected on the crowdfunding stage is negligible, compared to the money collected from outside investors *because* of how successful the preorder campaign was.[23] Crowdfunding, as a means to collect the money and learn the information, is modeled in Strausz (2017), Ellman and Hurkens (2019), and Chemla and Tinn (2020), however, without a possibility of external follow-up investment. It would be interesting to combine in future research the three features: the public informativeness of the crowdfunding campaign; the money-collecting target of crowdfunding; and the external money available for a successful campaign. Then, more concrete informational structures would need to be modeled because of the nature of crowdfunding campaign menus. Would the entrepreneur in such an environment face a nontrivial trade-off of a crowdfunding campaign being more/less informative versus how much money he is likely to collect?

[21] Another documented source of increased bargaining power is the project being at a later stage of development, as shown in Gompers et al. (2020).

[22] See also Gompers et al. (2020).

[23] Consider, for instance, the case of Oculus Rift, which collected $2.4 mln at the crowdfunding stage, but was sold for $2 bln (Stanko and Henard, 2016).

Plausible calibration exercise. The interior solution of the continuous project quality case predicts that the most informative among the entrepreneur-preferred experiments is going to reveal the project state precisely if it is below a certain threshold κ, and also if it is above a different threshold τ, $0 < \kappa < \tau < 1$. There will also be a mass of results pulled together somewhere at (κ, τ).

One could think about the following calibration exercise. Assuming parameterized distributions of qualities and costs would induce the distribution of κ's, τ's, and therefore, distribution of experiment results. Fitting the induced distribution of the results to some observed experiment outcomes data would identify the parameters β and δ. Having a calibrated estimate of β would allow performing welfare analysis, for example, whether investors can increase their payoffs by limiting their bargaining powers by decreasing β. A plausible candidate for experiment results data is some crowdfunding campaign results data.

There is growing empirical evidence that preorder crowdfunding provides informational value beyond the collected money. Xu (2018) shows that Kickstarter campaigns provide feedback value to creators and diminish the demand uncertainty. Mollick and Kuppuswamy (2014) document that a successful campaign helps in providing access to outside funders. There is also evidence that creators can influence the campaign informativeness by influencing the contribution dynamics through updates (Kuppuswamy and Bayus, 2018) and promotions (Lu et al., 2014).

4. CONCLUSION

I have studied the environment in which the entrepreneur can generate information about the investment project without incurring costs prior to obtaining the funding. I have focused on the case of the entrepreneur bargaining with the investor about the financing terms. I characterize the optimal amount of information that the entrepreneur generates depending on his bargaining power. I have shown that informativeness increases with the investor's bargaining power in the presence of a postcontractual moral hazard.

The intuition for such interaction between bargaining power and informativeness is the following. If the new information brings great news about the quality, it results in a contract that makes the entrepreneur effectively a shareholder. If the project is average but can be funded, the entrepreneur effectively acts as a fixed-wage employee. If the entrepreneur's bargaining power is low, the fixed-wage employee region of the beliefs dominates, and if the bargaining power is high, the shareholder region dominates. As an employee, the entrepreneur prefers the project to get funded as often as possible; as a shareholder, he prefers only high-quality enough projects to be funded. These two conflicting interests determine the choice of informativeness.

On the macrolevel, the informational channel has the potential to exacerbate the effects of the business cycle: during the bust phase, when the investment money is scarce, the entrepreneurs' bargaining power is likely to decrease, leading to the projects which are financed being less efficient. This may, in principle, affect the rate of recovery.[24]

On the microlevel, the findings of the article imply that markets, characterized by investors' dominant role, are more likely to result in inefficient investments due to the informational channel. This channel can also create incentives for the investors to commit to slightly decreasing their "greed" during the negotiations since that can lead to a greater size of the "pie" before the negotiations begin. This can lead to a greater payoff.

[24] Increased competition between the entrepreneurs may, of course, present a countervailing force. Boleslavsky and Kim (2020), Au and Kawai (2021), and Au and Kawai (2020) study the environments, which be interpreted as two and more binary quality entrepreneurs competing for the funds of the single investor. However, the individual distributions of posteriors in those works, on the one hand, and the distribution of posteriors in the two-states model of this article cannot be ranked in general.

APPENDIX A

A.1 *Optimal Experiment Structure.*

A.1.1 *The entrepreneur makes a take-it-or-leave-it offer.* Suppose that at the stage preceding contract negotiations, the entrepreneur is facing a problem that is richer than choosing probabilities of observing high and low experiment outcomes. Let him choose a finite space of experiment realizations, S, and for each state of the world, $\omega \in \{\text{bad}, \text{good}\}$, a conditional distribution on the space of experiment realizations: $\{\mathbb{P}\{s|\omega\}\}_{s\in S}$. Note that in the main body of the text for the case of single the entrepreneur, he is only allowed to choose the two families of conditional distributions for a fixed realization space, $S = \{\text{low}, \text{high}\}$.

For each value of the posterior, the consequent payoff of the entrepreneur is unique and known. Denoting the entrepreneur's payoff as a function of the posterior by $V^E(\hat{\alpha})$, write down the entrepreneur's problem at the start of the game as

$$\begin{aligned}
&\max_{S,\{\mathbb{P}\{s|\omega\}\}} \left\{\sum_{\omega}\left(\sum_{s\in S} V^E\left(\frac{\mathbb{P}\{s|\omega\}\times\mathbb{P}\{\omega\}}{\sum_{\omega'}\mathbb{P}\{s|\omega'\}\times\mathbb{P}\{\omega'\}}\right)\mathbb{P}\{s|\omega\}\right)\mathbb{P}\{\omega\}\right\} = \\
&\max_{S,\{\mathbb{P}\{s|\omega\}\}} \left\{(1-\alpha_0)\sum_{s\in S} V^E\left(\frac{(1-\alpha_0)\mathbb{P}\{s|\text{bad}\}}{\alpha_0\mathbb{P}\{s|\text{good}\}+(1-\alpha_0)\mathbb{P}\{s|\text{bad}\}}\right)\right. \\
&\left.+\alpha_0\sum_{s\in S} V^E\left(\frac{\alpha_0\mathbb{P}\{s|\text{good}\}}{\alpha_0\mathbb{P}\{s|\text{good}\}+(1-\alpha_0)\mathbb{P}\{s|\text{bad}\}}\right)\right\}.
\end{aligned}$$

Using the results of Kamenica and Gentzkow (2011), the above problem is equivalent to the one, where the entrepreneur chooses the finite discrete distribution over posterior beliefs, $\mathbf{G} \in \Delta(\Delta(\Omega))$, which is Bayes-plausible, that is, such that $\mathbb{E}_{\mathbf{G}}\hat{\alpha} = \sum_{\hat{\alpha}:\mathbf{g}(\hat{\alpha})>0}\hat{\alpha}\mathbf{g}(\hat{\alpha}) = \alpha_0$, where $\mathbf{g}$ is the correspondent probability mass function. The reformulated problem is

$$\begin{gathered}
\max_{\{\hat{\alpha}|\mathbf{g}(\hat{\alpha})>0\},\mathbf{g}} \sum_{\hat{\alpha}:\mathbf{g}(\hat{\alpha})>0} V^E(\hat{\alpha})\mathbf{g}(\hat{\alpha}) \\
\text{s.t.} \\
\mathbf{g}: [0,1] \to [0,1] \text{ nonnegative} \\
\sum_{\hat{\alpha}:\mathbf{g}(\hat{\alpha})>0} \mathbf{g}(\hat{\alpha}) = 1 \\
\sum_{\hat{\alpha}:\mathbf{g}(\hat{\alpha})>0} \hat{\alpha}\mathbf{g}(\hat{\alpha}) = \alpha_0.
\end{gathered}$$

Denote the value of the entrepreneur's problem as $V^{E*}(\alpha_0)$. Another result from Kamenica and Gentzkow (2011) states that

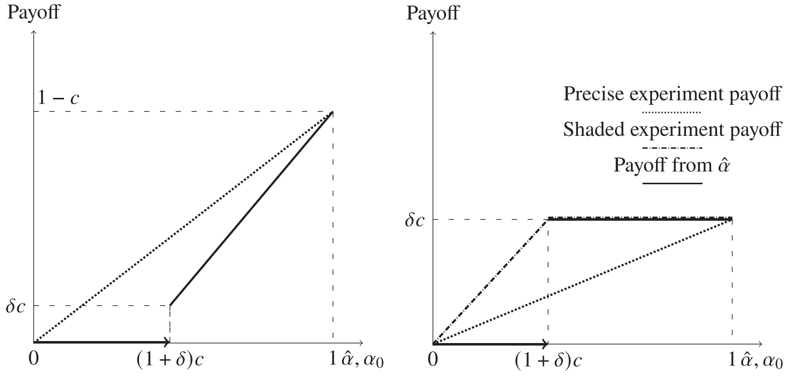
$$V^{E*}(\alpha_0) = \sup\{x|(x,\alpha_0) \in co(V^E)\},$$

where $co(V^E)$ is the convex closure of the graph of the entrepreneur's payoff from the posterior belief. Thus, V^{E*} is the smallest concave function, which is weakly greater than V^E. Aumann et al. (1995) call the result of applying such an operator to a function its *concavification*. So, in order to determine the optimal distribution of posteriors, one can first find the value from this optimal distribution. For that, we would need to find the concavification of $V^E(\hat{\alpha})$.

Since the original function is a piecewise linear function, its concavification is also a piecewise linear function that connects the two points, (0,0) and $(1, \beta(1-c))$. This function is expressed as

$$V^{\text{Linear}}(\hat{\alpha}) = (1-c)\hat{\alpha}.$$

It is relatively simple to check that this is indeed the concavification. Figure A.1(a) provides the graphic illustration.



(a) The entrepreneur makes a TIOLI-offer (b) The investor makes a TIOLI-offer

FIGURE A.1

PAYOFFS WHEN ONE PARTY MAKES A TIOLI-OFFER

An intermediate result can be stated:

LEMMA A.1. *Consider the case of the entrepreneur making a take-it-or-leave-it offer and the correspondent the entrepreneur's payoff function from the realized posterior* $V^E(\hat{\alpha}) = (\hat{\alpha} - c) \times \mathbb{I}_{\{\hat{\alpha} \geq (1+\delta)c\}}$. *Then, the concavification of* $V^E(\hat{\alpha})$ *is a linear function* $V^{Linear}(\hat{\alpha}) = \hat{\alpha}(1-c)$.

Now we can find the support of the optimal distribution over posteriors. The two posteriors, 0 and 1, occurring with respective probabilities of $1-\alpha_0$ and α_0, lead to the ex ante payoff of $\alpha_0 \times V^E(1) + (1-\alpha_0) \times V^E(0) = \alpha_0 \times (1-c)$, which is exactly the value of linear function $V^{\text{Linear}}(x) = (1-c) \times x$ evaluated at the prior $(x = \alpha_0)$.

These observations cab summarized as:

LEMMA A.2. *If the entrepreneur has the ability to choose arbitrary Bayes-plausible distribution of posteriors and makes a take-it-or-leave-it offer to the investor, he chooses the distribution of the posteriors to be* $\begin{cases} 0 \text{ with probability } 1-\alpha_0 \\ 1 \text{ with probability } \alpha_0. \end{cases}$

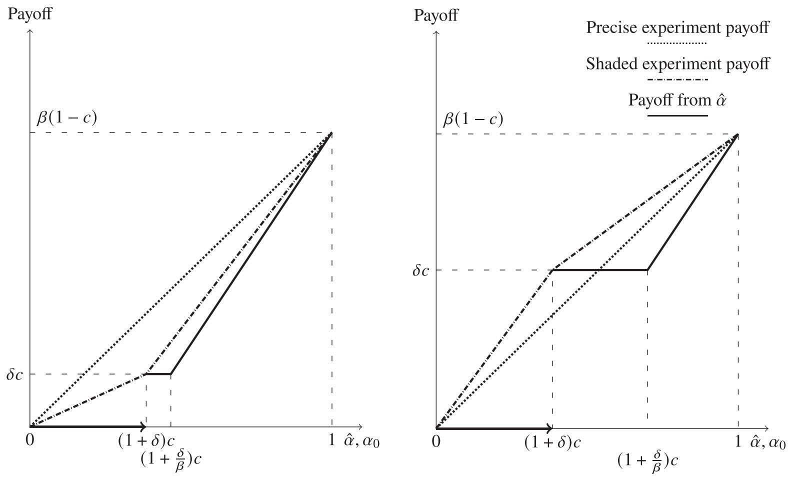
We can also conclude that the two-outcome precise experiment, that is, the one for which the high outcome only happens in the good state of the world and the low outcome only happens in the bad state of the world, leads exactly to the distribution of posteriors described above.

A.1.2 *The investor makes a take-it-or-leave-it offer.* In the case of the investor making a take-it-or-leave-it offer, the entrepreneur's payoff from a posterior is a two-piece linear function consisting of two "flat" parts. It takes the value of 0 for $\hat{\alpha} \in [0, (1+\delta)c)$ and the value of δc for $\hat{\alpha} \in [(1+\delta)c, 1]$. The algebraic expression for the concavification of this payoff is

$$V^{\text{2-part linear}}(\hat{\alpha}) = \frac{\delta}{(1+\delta)}\hat{\alpha} \times \mathbb{I}_{\{\hat{\alpha} < (1+\delta)c\}} + \delta c \times \mathbb{I}_{\{\hat{\alpha} \geq (1+\delta)c\}}.$$

For values of the prior belief α_0 below $(1+\delta)c$, the entrepreneur would like to choose an experiment structure that would induce the support of beliefs to be $\{0, (1+\delta)c\}$.

For values of the prior α_0 above the threshold, $(1+\delta)c$ the entrepreneur is indifferent between any experiment structure, which induces the support of posteriors $\subseteq [(1+\delta)c, 1]$,



(a) The precise experiment is optimal (b) The shaded experiment is optimal

FIGURE A.2

PAYOFFS WITH INTERMEDIATE BARGAINING POWERS

including the uninformative experiment. Any such experiment structure results in the ex ante payoff of δc. The entrepreneur does not have strong incentives to reveal any new information if the prior α_0 is high enough.

Call an experiment structure *shaded* if the induced support of the posterior beliefs consists of two points, one of the points is always $(1+\delta)c$ and the other point is the extreme belief (0 for $\alpha_0 < (1+\delta)c$, 1 for $\alpha_0 \geq (1+\delta)c$).

Figure A.1 shows the payoff from the shaded experiment, as well as from the precise one. The following result holds:

LEMMA A.3. *If the entrepreneur has the ability to choose arbitrary Bayes-plausible distribution of posteriors and but the investor makes a take-it-or-leave-it offer after they observe the posterior realization, the entrepreneur with $\alpha_0 < (1+\delta)c$ prefers the distribution over posteriors to be*

$$\hat{\alpha} = \begin{cases} 0, & \textit{with probability } 1 - \frac{\alpha_0}{(1+\delta)c} \\ (1+\delta)c, & \textit{with probability } \frac{\alpha_0}{(1+\delta)c}, \end{cases}$$

the entrepreneur with $\alpha_0 \geq (1+\delta)c$ is indifferent between Bayes-plausible distribution over posteriors with support $\subseteq [(1+\delta)c, 1]$. He does not have strong incentives to choose any exact one of those distributions.

After establishing the entrepreneur's preferred distribution over posteriors, it is a matter of straightforward computation to see that for $\alpha_0 < (1+\delta)c$ the structure of the two-outcome experiment proposed in Proposition 2, namely, $x = 1, y = \frac{\alpha_0}{1-\alpha_0}(\frac{1}{(1+\delta)c} - 1)$ results in the desired distribution over posteriors, as described above.

A.1.3 *Nash bargaining solution.* Consider first the three Figures A.2(a), A.2(b), and A.3, which help to characterize the qualitatively different results, depending on the value of the entrepreneur's bargaining power, β.

Note that the shape of the entrepreneur's payoff from the realized posterior varies with the changes of β. The only two candidates for the concavification are: the linear function, which

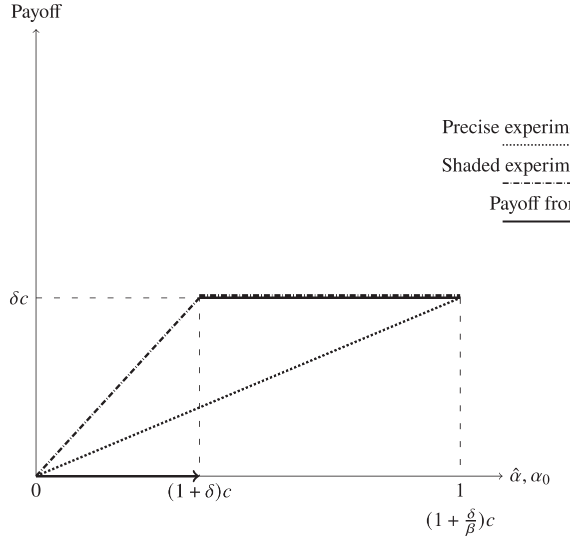


FIGURE A.3

CASE $\beta \leq \frac{\delta c}{1-c}$ IS OUTCOME EQUIVALENT TO INVESTOR MAKING A TAKE-IT-OR-LEAVE-IT OFFER

connects the points (0,0) and $(1, \max\{\beta(1-c), \delta c\})$; and the two-part linear, which connects the three points (0,0), $((1+\delta)c, \delta c)$ and $(1, \max\{\beta(1-c), \delta c\})$. For high values of β, the former function is weakly above the payoff from the realized posteriors, which is sufficient for the concavification; for low values of β, the latter function is concave, which is, in turn, sufficient for this function to be the concavification. The switch happens at $\beta = \frac{\delta}{(1+\delta)(1-c)}$. At this value of β, the slopes of both the linear function and the two-part linear function coincide. Also, for low enough values of β, the two-part linear function is flat for high values of prior. This is because the kink of the positive part of the payoff from realized posterior moves to the right of 1. This leads to the similarity with the case of the investor making a take-it-or-leave-it offer.

Altogether this establishes the following result:

LEMMA A.4.

- *The case of high bargaining power of the entrepreneur,* $\beta \in [\frac{\delta}{(1+\delta)(1-c)}, 1]$, *is equivalent to the case of the entrepreneur making a TIOLI-offer. Hence, the optimal distribution over posteriors is*

$$\begin{cases} 0, \ \textit{with probability}\ 1-\alpha_0 \\ 1, \ \textit{with probability}\ \alpha_0 \end{cases}$$

- *For the case of medium bargaining power of the entrepreneur,* $\beta \in (\frac{\delta c}{1-c}, \frac{\delta}{(1+\delta)(1-c)})$, *the optimal distribution over posterior is:*
  - *If* $\alpha_0 < (1+\delta)c$, $\Big\{ 0, \ \textit{with probability}\ 1 - \frac{\alpha_0}{(1+\delta)c} \$1+\delta)c, \ \textit{with probability}\ \frac{\alpha_0}{(1+\delta)c}$
  - *If* $\alpha_0 \geq (1+\delta)c$, $\begin{cases} (1+\delta)c, \ \textit{with probability}\ \frac{1-\alpha_0}{1-(1+\delta)c} \\ 1, \ \textit{with probability}\ \frac{\alpha_0-(1+\delta)c}{1-(1+\delta)c} \end{cases}$

- *The case of low bargaining power of the entrepreneur, $\beta \in [0, \frac{\delta c}{1-c})$, is equivalent to the case of the investor making a TIOLI-offer. Hence, for $\alpha_0 < (1+\delta)c$ the optimal distribution over posteriors is*

$$\Big\{0,\ \textit{with probability}\ 1-\tfrac{\alpha_0}{(1+\delta)c}\$1+\delta)c,\ \textit{with probability}\ \tfrac{\alpha_0}{(1+\delta)c},$$

and for $\alpha_0 \geq (1+\delta)c$ the entrepreneur is indifferent between Bayes-plausible distributions over posteriors with a support $\subseteq [(1+\delta)c, 1]$.

Note that the distribution of posteriors in the precise experiment is second-order stochastically dominated by the distribution of posteriors in either case of the shaded experiment. This implies that the former experiment is more informative in the Blackwell sense (Blackwell and Girshick, 1979; Borgers, 2009). Also, note that for the lower shaded experiment, as the c and δ parameters increase, the informativeness of the experiment increases, and for the shaded experiment, as those parameters increase, the informativeness of the experiment decreases because exactly the same reasons apply.

A.2 *Continuous Quality.* This subsection of the appendix analyzes the case of continuous project quality more formally and in greater detail than we did in the main text. Assume that the project quality ω is distributed in the interval [0,1] according to an atomless distribution with the CDF $F_\omega()$. The project requires an investment of c, and its return is the same as its quality. Agents do not know the realization of ω in the beginning. Let the entrepreneur choose the experiment and denote the updated distribution as $\hat{F}_\omega()$. After observing the experiment outcome, the two parties negotiate the share contract. In case the contract is signed and the sum c is transferred to the entrepreneur, he has a choice of whether to properly spend it or to divert it and enjoy the payoff of δc.

What kind of information is efficient in this setting? Since there are only two investment levels, 0 and c, the first best is to invest in projects with $\omega \geq c$ and to discard other projects. However, the players' equilibrium incentives need to be taken into account: projects which are known to have $\omega \in [c, (1+\delta)c)$ cannot be agreed upon by the entrepreneur and the investor. So, the efficient information needs to be precise enough to tell apart $\omega \geq c$ from $\omega < c$, but opaque enough so that projects in $[c, (1+\delta)c)$ could still be invested into. As will be shown, this is achievable under some circumstances.

As before, focus on the share contracts determined by the Nash bargaining solution on the space of incentive-compatible payoffs. Given both parties' risk neutrality, it is without loss to look only at the shares s^*, which are constant with respect to ω and depend only on the updated expected quality $\hat{\omega} \doteq \int_0^1 x d\hat{F}_\omega(x)$. To see this, suppose, for example, that there is an optimal contract that is contingent on the actual state, ω. Write down the entrepreneur's payoff, $\int_0^1 s(t, \hat{F}_\omega) d\hat{F}_\omega(t)$. To that contract corresponds the following simple share contract:

$$s^* := \frac{\int_0^1 s(t, \hat{F}_\omega) d\hat{F}_\omega(t)}{\int_0^1 t d\hat{F}_\omega(t)},$$

which gives the same payoff to the entrepreneur:

$$s^* \mathbb{E}\Big[\omega | \omega \sim \hat{F}_\omega\Big] = \int_0^1 s(t, \hat{F}_\omega) d\hat{F}_\omega(t).$$

By risk neutrality, the two contracts are also payoff equivalent for the investor.

The solution to the Nash bargaining problem follows from:

$$s^*(\hat{\omega}) = \arg\max_s \left\{ (s\hat{\omega})^\beta ((1-s)\hat{\omega} - c)^{1-\beta} \right\}$$
$$\text{s.t. } s\hat{\omega} \geq \delta c.$$

Similarly to Subsection 2.4, the solution is

$$s^*(\hat{\omega}) = \max\{\delta c/\hat{\omega}; \beta(1 - c/\hat{\omega})\}\mathbb{I}_{\{\hat{\omega} \geq (1+\delta)c\}},$$

and the entrepreneur's payoff from the updated expected quality is

$$V^E(\hat{\omega}) = \max\{\delta c; \beta(\hat{\omega} - c)\}\mathbb{I}_{\{\hat{\omega} \geq (1+\delta)c\}}.$$

Following the approach of Gentzkow and Kamenica (2016), the problem of choosing the experiment is equivalent to the choice of distribution of the updated expected qualities, $\hat{\omega}$, with the following constraints. First, the distribution of updated expected qualities must be a mean-preserving contraction of the original distribution, written as $\int_0^t \mathbb{P}\{\hat{\omega} \leq x\}dx \in [(t - \int_0^1 x dF_\omega)_+, \int_0^t F_\omega(x)dx], t \in (0, 1)$.[25] Second, if we let $G_{\hat{\omega}}$ denote the CDF of $\hat{\omega}$, $G_{\hat{\omega}}(t) \doteq \int_0^t \mathbb{P}\{\hat{\omega} \leq x\}dx$, it must be nondecreasing, by definition of CDF.[26] The entrepreneur's problem is then

$$\text{(OF)} \qquad V^E = \max_{G_{\hat{\omega}}} \left\{ \int_0^1 \max\{\delta c, \beta(x-c)\}\mathbb{I}_{\{x \geq (1+\delta)c\}} dG_{\hat{\omega}}(x) \right\}$$

$$\text{(MPC)} \qquad \text{s.t. } \int_0^t G_{\hat{\omega}}(x)dx \in \left[(t - \mathbb{E}\omega)_+, \int_0^t F(z)dz \right],$$

$$\text{(ND)} \qquad G_{\hat{\omega}}(t) \text{ is nondecreasing.}$$

The entrepreneur's objective function is linear in $G_{\hat{\omega}}$. Following Proposition 1 of Kleiner et al. (2021), the set of mean-preserving contractions of $F()$ is compact in the norm topology. Denote that set $MPC(F)$. There is a maximizer of the objective function that is an extreme point of $MPC(F)$.

According to Theorem 2 of Kleiner et al. (2021), all extreme points of $MPC(F)$ are functions characterized by countable sets of intervals, such that outside of those intervals, the extreme points coincide with F, and within those intervals the extreme points are constant. Denote the set of intervals, where an extreme point is constant by $\{[\kappa_j, \tau_j), j \in \mathcal{I}\}$.

In the series of lemmata below, we show that in our case, we only need to consider an extreme point of $MPC(F)$ characterized by just one such interval, $[\kappa, \tau)$. Moreover, optimal κ is smaller than $(1+\delta)c$, optimal τ is greater than $(1 + \delta/\beta)c$, and $\mathbb{E}[\omega|\kappa < \omega < \tau] = (1+\delta)c$. After showing these properties, we restate the entrepreneur's problem as a constrained maximization problem with respect to variables κ and τ.

Before proceeding with the properties of an optimal $G_{\hat{\omega}}$, let us transform the objective function:

$$\mathbb{E}V^E(\hat{\omega}) = \int_{(1+\delta)c}^1 \max\{\delta c, \beta(x-c)\}dG_{\hat{\omega}}(x) =$$
$$= \delta c \mathbb{P}\left\{\hat{\omega} \in [(1+\delta)c, (1+\delta/\beta)c)\right\} + \int_{(1+\delta/\beta)c}^1 \beta(x-c)dG_{\hat{\omega}}(x) =$$

[25] That is, the value of the integral of CDF of updated expectations must lie between the integral of the CDF of means in case of no information and the integral of the original CDF F_ω. This constraint is denoted as (MPC).

[26] This constraint is denoted as (ND).

$$= \delta c\left(\lim_{z\downarrow 0} G_{\hat\omega}((1+\delta/\beta)c - z) - \lim_{z\downarrow 0} G_{\hat\omega}((1+\delta)c - z)\right) +$$
$$+ \beta(1-c)G_{\hat\omega}(1) - \lim_{z\downarrow 0}\beta((1+\delta/\beta)c - c - z)G_{\hat\omega}((1+\delta/\beta)c - z)$$
$$- \beta\int_{(1+\delta/\beta)c}^{1} G_{\hat\omega}(x)dx =$$
$$= -\delta c\lim_{z\downarrow 0} G_{\hat\omega}((1+\delta)c - z) + \beta(1-c)G_{\hat\omega}(1) - \beta\int_{(1+\delta/\beta)c}^{1} G_{\hat\omega}(x)dx =$$
$$= \text{const} - \delta c\lim_{z\downarrow 0} G_{\hat\omega}((1+\delta)c - z) + \beta\int_{0}^{(1+\delta/\beta)c} G_{\hat\omega}(x)dx,$$

where the transition from the second to the third line relied on the integration by parts. Besides, the last transition used the facts that $G_{\hat\omega}(1) = 1$, and $\int_{(1+\delta/\beta)c}^{1} G_{\hat\omega}(x)dx = \int_0^1 G_{\hat\omega}(x)dx - \int_0^{(1+\delta/\beta)c} G_{\hat\omega}(x)dx$, and the term $\int_0^1 G_{\hat\omega}(x)dx$ does not depend on $G_{\hat\omega}$ for distributions with equal expectations.

Without constraints (CC) and (MPC), the entrepreneur would like to minimize the value of the left limit of $G_{\hat\omega}()$ at $(1+\delta)c$; and, on the other hand, he would like to maximize the area under $G_{\hat\omega}()$ from 0 to $(1+\delta/\beta)c$.

Following Theorem 2 of Kleiner et al. (2021), we can find an optimal $G_{\hat\omega}$ as a function satisfying the following restrictions:

- there exists a countable collection of intervals $[\kappa_j, \tau_j)$, (possibly empty) subintervals $[\underline{y}_j, \overline{y}_j) \subset [\kappa_j, \tau_j)$, and numbers v_j, $j \in \mathcal{I}$ such that for a.e. $x \in [0,1]$:

$$G_{\hat\omega}(x) = \begin{cases} F(x), & \text{if } x \notin \bigcup_{j\in\mathcal{I}}[\kappa_j, \tau_j), \\ F(\kappa_j), & \text{if } x \in \left[\kappa_j, \underline{y}_j\right), \\ v_j, & \text{if } x \in \left[\underline{y}_j, \overline{y}_j\right), \\ F(\tau_j), & \text{if } x \in \left[\overline{y}_j, \tau_j\right); \end{cases}$$

- $(\overline{y}_j - \underline{y}_j)v_j = \int_{\kappa_j}^{\tau_j} F(x)dx - F(\kappa_j)(\underline{y}_j - \kappa_j) - F(\tau_j)(\tau_j - \overline{y}_j)$
- $F(\kappa_j)(\overline{y}_j - \kappa_j) + F(\tau_j)(\tau_j - \overline{y}_j) \leq \int_{\kappa_j}^{\tau_j} F(x)dx$, $\int_{\kappa_j}^{\tau_j} F(x)dx \leq F(\kappa_j)(\underline{y}_j - \kappa_j) + F(\tau_j)(\tau_j - \underline{y}_j)$
- If $v_j \in (F(\underline{y}_j), F(\overline{y}_j))$ then for m_j such that $F(m_j) = v_j$ it must hold $\int_{m_j}^{\tau_j} F(x)dx \leq v_i(\overline{y}_j - m_j) + F(\tau_j)(\tau_j - \overline{y}_j)$

In the series of lemmas below, we show that the entrepreneur's optimum is achieved by an extreme point of $MPC(F)$ with just one interval, where $G_{\hat\omega}$ is constant. [27]

LEMMA A.5. *For any optimal $G_{\hat\omega}$ that is an extreme point of $MPC(F)$, there exists $j \in \mathcal{I}$ such that $(1+\delta)c \in [\kappa_j, \tau_j)$.*

PROOF. Suppose this is not true. Then we can find a function $\tilde{G}_{\hat\omega} \in MPC(F)$ that increases the entrepreneur's payoff. Pick indices $l, k \in \mathcal{I}$ so that $G_{\hat\omega}$ is constant at $[\kappa_l, \tau_l)$ and $[\kappa_k, \tau_k)$

[27] There is an alternative way to proceed with solving the entrepreneur's problem, namely, using the approach of Dworczak and Martini (2019). Their method, as a substep, would imply finding a "price"-function $p^\star$ which is the solution to $\min_{p()}\{\int p(x)dF_\omega(x)\}$ subject to $p(\hat\omega) \geqslant V^E(\hat\omega)$ and $p()$ being convex. It can be checked, that in our case, $p^\star$ would be a piecewise linear function with at most three pieces, on the intervals $[0,k]$, (k,t), $[t,1]$; coinciding with V^E on $[0,k]$ and $[t,1]$. However, arguably, showing that such $p^\star$ is indeed the "price"-function and characterizing k and t, and how they depend on β and F_ω would imply a similar amount of work, as currently done in the appendix below.

and, moreover, τ_l is largest among $\tau_j < (1+\delta)c$ and κ_k is smallest among $\kappa_j > (1+\delta)c$. If $[\kappa_l, \tau_l)$ is nonexistent, replace τ_l with 0, and if $[\kappa_k, \tau_k)$ is nonexistent, replace κ_k with 1. Note that in an open neighborhood of $(1+\delta)c$, $G_{\hat{\omega}}(x) = F(x)$. By continuity of F, we can find two points ε_1, ε_2, that are close to $(1+\delta)c$, it holds that $\tau_l < \varepsilon_1 < (1+\delta)c < \varepsilon_2 < \min\{(1+\delta/\beta)c, \kappa_k\}$, and for which it holds that

$$\text{(A)} \qquad \int_{\varepsilon_1}^{\varepsilon_2} F(x)dx = F(\varepsilon_1)((1+\delta)c - \varepsilon_1) + F(\varepsilon_2)(\varepsilon_2 - (1+\delta)c).$$

Let $\tilde{G}_{\hat{\omega}}(x) = G_{\hat{\omega}}(x), x \notin [\varepsilon_1, \varepsilon_2)$ and let

$$\tilde{G}_{\hat{\omega}}(x) = \begin{cases} F(\varepsilon_1), & \text{if } x \in [\varepsilon_1, (1+\delta)c), \\ F(\varepsilon_2), & \text{if } x \in [(1+\delta)c, \varepsilon_2). \end{cases}$$

The way we chose ε_1 and ε_2 ensures that $\tilde{G}_{\hat{\omega}}$ is in $MPC(F)$. The values of $\int_0^{(1+\delta/\beta)c} \tilde{G}_{\hat{\omega}}(x)dx$ and $\int_0^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx$ are the same. However, the value of $-\delta c \lim_{z\downarrow 0} \tilde{G}_{\hat{\omega}}((1+\delta)c - z)$ is higher than $-\delta c \lim_{z\downarrow 0} G_{\hat{\omega}}((1+\delta)c - z)$, because $\lim_{z\downarrow 0} \tilde{G}_{\hat{\omega}}((1+\delta)c - z) = F(\varepsilon_1) < F((1+\delta)c) = \lim_{z\downarrow 0} G_{\hat{\omega}}((1+\delta)c - z)$. Thus, $\tilde{G}_{\hat{\omega}}$ gives the entrepreneur a higher payoff than $G_{\hat{\omega}}$. □

Fix the index j, for which $(1+\delta)c \in [\kappa_j, \tau_j)$.

LEMMA A.6. *If for an optimal $G_{\hat{\omega}}$ it holds that $(1+\frac{\delta}{\beta})c > \tau_j$, then it must be that $G_{\hat{\omega}}((1+\frac{\delta}{\beta})c) = F((1+\frac{\delta}{\beta})c)$.*

PROOF. Suppose this does not hold. Then, for $G_{\hat{\omega}}$ there must be an interval $[\kappa_i, \tau_i)$ such that $(1+\delta/\beta)c \in [\kappa_i, \tau_i)$ and

$$G_{\hat{\omega}}(x) = \begin{cases} F(\kappa_i), & \text{if } x \in [\kappa_i, \underline{y}_i), \\ v_i, & \text{if } x \in [\underline{y}_i, \overline{y}_i), \\ F(\tau_i), & \text{if } x \in [\overline{y}_i, \tau_i) \end{cases}$$

for the appropriately specified $[\underline{y}_i, \overline{y}_i) \subset [\kappa_i, \tau_i)$ and v_i. Then, since $G_{\hat{\omega}}$ is an extreme point of $MPC(F)$, it holds that

$$\int_0^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx = \int_0^{\kappa_i} F(x)dx + \int_{\kappa_i}^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx < \int_0^{(1+\delta/\beta)c} F(x)dx.$$

There is, however, an improvement over $G_{\hat{\omega}}$. Let $\tilde{G}\omega$ coincide with $G_{\hat{\omega}}$ except for $x \in [\kappa_i, \tau_i)$, and let $\tilde{G}_{\hat{\omega}}(x) = F(x)$ for $x \in [\kappa_i, \tau_i)$. Such CDF does not decrease $-\delta c\tilde{G}_{\hat{\omega}}((1+\delta)c)$ but it increases $\int_0^{(1+\delta/\beta)c} \tilde{G}_{\hat{\omega}}(x)dx$ and is also in $MPC(F)$. Thus, the initial $G_{\hat{\omega}}$ is not optimal. □

LEMMA A.7. *If $\int_0^{(1+\delta/\beta)c} xdF(x)/F((1+\delta/\beta)c) > (1+\delta)c$, then for an optimal $G_{\hat{\omega}}$, $\kappa_j = 0$, $\tau_j < (1+\delta/\beta)c$, and $\underline{y}_j \geq (1+\delta)c$*

PROOF. Given such F, the described distribution of updated means achieves the entrepreneur's first best, since $\lim_{z\downarrow 0} G_{\hat{\omega}}((1+\delta)c - z) = 0$ and $\int_0^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx = \int_0^{(1+\delta/\beta)c} F_{\hat{\omega}}(x)dx$. One example of an optimal $G_{\hat{\omega}}$ under such F is

$$G_{\hat{\omega}}(x) = \begin{cases} 0, & \text{if } x < (1+\delta)c \\ F(\tau_j), & \text{if } x \in [(1+\delta)c, \tau_j) \\ F(x), & \text{if } x \geq \tau_j, \end{cases}$$

where τ_j is such that $\int_0^{\tau_j} xdF(x)/F(\tau_i) = (1+\delta)c$. Such $G_{\hat{\omega}}$ is the most informative among entrepreneur-preferred, given such F. □

LEMMA A.8. *If $\int_0^{(1+\delta/\beta)c} xdF(x)/F((1+\delta/\beta)c) \leq (1+\delta)c$, then for an optimal $G_{\hat{\omega}}$ it holds that $\underline{y}_j \geqslant (1+\delta)c$.*

PROOF. Suppose this is not the case. If $\overline{y}_j < (1+\delta)c$, then the distribution of posteriors $\tilde{G}_{\hat{\omega}}(x) = F_{\hat{\omega}}(x)$ would be an improvement. If $\underline{y}_j < (1+\delta)c \leqslant \overline{y}_j$, using the equation that enters the definition of the extreme point,

$$(\overline{y}_j - \underline{y}_j)v_j = \int_{\kappa_j}^{\tau_j} F(x)dx - F(\kappa_j)\left(\underline{y}_j - \kappa_j\right) - F(\tau_j)(\tau_j - \overline{y}_j)$$

we can find such $\tilde{G}_{\hat{\omega}}(x)$ for which $\tilde{v}_j < v_j$, $\tilde{\kappa}_j > \kappa_j$, and other values stay the same. $\tilde{G}_{\hat{\omega}}(x)$ would be an improvement because the term $-\delta c \lim_{z\downarrow 0} G_{\hat{\omega}}((1+\delta)c - z)$ of the objective would decrease. □

LEMMA A.9. *If $\int_0^{(1+\delta/\beta)c} xdF(x)/F((1+\delta/\beta)c) \leq (1+\delta)c$, then for an optimal $G_{\hat{\omega}}$ it holds that $\tau_j \geq (1+\delta/\beta)c$.*

PROOF. Suppose this is not the case and $\tau_j < (1+\delta/\beta)c$. Then, we can find an improvement: by slightly increasing τ_j and leaving $\underline{y}_j$, v_j, $\overline{y}_j$ the same as before, κ_j decreases slightly, following Equation (A). This decreases the value of $G_{\hat{\omega}}(\kappa_j)$ and, therefore, the increasing the value of $-\delta c \lim_{z\downarrow 0} G_{\hat{\omega}}((1+\delta)c - z)$, which enters the objective. □

LEMMA A.10. *If $\int_0^{(1+\delta/\beta)c} xdF(x)/F((1+\delta/\beta)c) \leq (1+\delta)c$, then for an optimal $G_{\hat{\omega}}$ it holds that $\underline{y}_i = (1+\delta)c$.*

PROOF. Suppose this is not the case and $\underline{y}_i > (1+\delta)c$. Then, we can find an improvement $\tilde{G}_{\hat{\omega}}$, in which $\tilde{\underline{y}}_j < \underline{y}_j$, $\tilde{\kappa}_j < \kappa_j$, and other parameters $(v, \overline{y}_j, \tau_j)$ are the same. □

LEMMA A.11. *If $\int_0^{(1+\delta/\beta)c} xdF(x)/F((1+\delta/\beta)c) \leq (1+\delta)c$, then for an optimal $G_{\hat{\omega}}$ it holds that $\underline{y}_i = \overline{y}_j$.*

PROOF. Suppose this is not the case and $\underline{y}_i < \overline{y}_i$. Then, we can find an improvement $\tilde{G}_{\hat{\omega}}$, in which $\tilde{\overline{y}}_j < \overline{y}_j$, $\tilde{\tau}_j < \tau_j$, and other parameters $(v, \overline{y}_j, \tau_j)$ are the same. Such $\tilde{G}_{\hat{\omega}}$ leads to a higher value of $\int_0^{(1+\delta/\beta)c} \tilde{G}_{\hat{\omega}}(x)dx$. □

LEMMA A.12. *Among intervals of constant values of any optimal $G_{\hat{\omega}}$, only the interval (κ_i, τ_i) is payoff-relevant.*

If $\mathbb{E}[\omega|\omega < (1+\delta/\beta)c] > (1+\delta)c$, the entrepreneur's problem is trivial, since ex ante quality is so high that he can be an effective shareholder without providing any information. When this is not the case, Lemmas A.5–A.12 show that characterizing the entrepreneur's optimal information policy narrows down to finding two points, κ and τ such that $\kappa \in [0, (1+\delta)c]$, $\tau \in [(1+\delta/\beta)c, 1]$, and $\mathbb{E}[\omega|\kappa < \omega < \tau] = (1+\delta)c$. We can express the objective function in terms of κ and τ. We already know from Lemma A.9 that $-\delta c \lim_{z\downarrow 0} G_{\hat{\omega}}((1+\delta)c - z) = -\delta c F(\kappa)$. Using the results above, there are two ways to reexpress the term $\int_0^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx$. On the one hand,

$$\int_0^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx = \int_0^{\tau} G_{\hat{\omega}}(x)dx - \int_{\tau}^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx =$$

$$= \int_0^\tau F(x)dx - \int_\tau^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx = \int_0^\tau F(x)dx - F(\tau)((1+\delta/\beta)c - \tau),$$

where the second equality uses the fact that for an extreme point $G_{\hat{\omega}}$, $\int_0^\tau F(x)dx = \int_0^\tau G_{\hat{\omega}}(x)dx$, and the third equality uses the fact that $\forall x \in ((1+\delta)c, \tau]$, $G_{\hat{\omega}}(x) = F(\tau)$, following Lemma A.9. On the other hand, rewrite the term $\int_0^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx$ as

$$\begin{aligned} \int_0^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx &= \int_0^\kappa G_{\hat{\omega}}(x)dx + \int_\kappa^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx = \\ = \quad & \int_0^\kappa F(x)dx + \int_\kappa^{(1+\delta)c} G_{\hat{\omega}}(x)dx + \int_{(1+\delta)c}^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx = \\ = & \int_0^\kappa F(x)dx + F(\kappa)((1+\delta)c - \kappa) + F(\tau)((1+\delta/\beta)c - (1+\delta)c), \end{aligned}$$

which again uses the fact that $G_{\hat{\omega}}$ is an extreme point of $MPC(F)$, $[\kappa, (1+\delta)c)$ is the interval where $G_{\hat{\omega}}$ stays constant at $F(\kappa)$, and $[(1+\delta)c, \tau)$ is the interval where $G_{\hat{\omega}}$ stays constant at $F(\tau)$. Using the latter expression for $\int_0^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx$ and the conditions on κ, τ, and how they are linked, write down the entrepreneur's problem as

$$\begin{gathered} \max_{\kappa,\tau} \ \text{const} - \delta c F(\kappa) + \\ \beta\big(\int_0^\kappa F(x)dx + F(\kappa)((1+\delta)c - \kappa) + F(\tau)((1+\delta/\beta)c - (1+\delta)c)\big) \\ \text{s.t.} \\ \kappa \in [0, (1+\delta)c] \\ \tau \in [(1+\delta/\beta)c, 1] \\ \mathbb{E}[\omega|\kappa < \omega < \tau] = (1+\delta)c. \end{gathered}$$

After disposing of the constant term that does not depend on the design of information (and hence, κ and τ), the Lagrangian is

$$\mathcal{L} = -\delta c F_\omega(\kappa) \tag{L}$$

$$+\beta\big(\int_0^\kappa F_\omega(x)dx - F_\omega(\kappa)\kappa + F_\omega(\tau)(1+\delta/\beta)c - (1+\delta)c(F_\omega(\tau) - F_\omega(\kappa))\big) \tag{A.1}$$

$$+\lambda\big(\int_\kappa^\tau F_\omega(x)dx - (1+\delta)c(F_\omega(\kappa) - F_\omega(\tau)) - F_\omega(\tau)\tau + F_\omega(\kappa)\kappa\big)$$

$$+\lambda_\kappa^1 \kappa + \lambda_\kappa^2((1+\delta)c - \kappa) + \lambda_\tau^1(\tau - (1+\delta/\beta)c) + \lambda_\tau^2(1-\tau). \tag{A.2}$$

Noncorner solution. Consider the noncorner solution first, that is, such that $\kappa \notin \{0, (1+\delta)c\}$, $\tau \notin \{(1+\delta/\beta)c, 1\}$. The first-order condition for the noncorner solution rearrange as:

$$\kappa(\lambda) = (1+\delta)c - \tfrac{\delta c}{\beta - \lambda}, \tag{FOC--κ}$$

$$\tau(\lambda) = (1+\delta)c + \tfrac{\delta c(1-\beta)}{\lambda}, \tag{FOC--τ}$$

and λ follows from the constraint equation,

$$\int_{\kappa(\lambda)}^{\tau(\lambda)} F_\omega(x)dx = (1+\delta)c(F_\omega(\kappa(\lambda)) - F_\omega(\tau(\lambda))) \tag{A.3}$$

$$+F_\omega(\tau(\lambda)) \times \tau(\lambda) - F_\omega(\kappa(\lambda)) \times \kappa(\lambda), \tag{λ cond}$$

which can also be written as

$$\mathbb{E}[\omega|\kappa(\lambda) < \omega < \tau(\lambda)] = (1+\delta)c.$$

For Equation (cond), it is straightforward to check that the derivative with respect to λ of the left-hand side of the equation is smaller than the derivative of the right-hand side of the equation. For λ as the solution of that equation to exist, we would need to check that for the smallest possible λ, the left-hand side is greater, and for the greatest possible λ it is smaller.

Call the pair (κ, τ) *corner* when either $\kappa = 0$ or $\tau = 1$. For high ex ante expected quality, the corner solution is such that $\kappa = 0$, and for low ex ante expected quality – $\tau = 1$. We first present the result for a high value of $\mathbb{E}\omega$.

A.2.1 *Conditions for noncorner solution, high ex ante quality.* Suppose that $\mathbb{E}\omega > (1 + \delta)c$. What are the smallest and the greatest possible values of λ? For the solution to be interior, κ needs to be greater than zero. This holds whenever $\lambda \leq \lambda_{\max} = \beta - \frac{\delta}{1+\delta}$. Also, τ needs to be less than 1, which in turn holds whenever $\lambda \geq \lambda_{\min} = \frac{\delta c(1-\beta)}{1-(1+\delta)c}$. The condition, for which the $\lambda_{\max}$ is actually greater than $\lambda_{\min}$ is $\beta \geq \frac{\delta}{(1+\delta)(1-c)}$.

After plugging in the values of $\lambda_{\max}$ and $\lambda_{\min}$ into the constraint equation, we get the conditions on the distribution and the parameters for the solution to be interior:

$$\mathbb{E}\left[\omega|\omega < (1+\delta)c\frac{\beta}{\beta - \delta(1-\beta)}\right] \leq (1+\delta)c$$
$$\mathbb{E}[\omega|\omega > \kappa(\lambda_{\min})] \geq (1+\delta)c.$$

Note that the latter of the two conditions holds trivially since we are studying a case of $\mathbb{E}\omega > (1+\delta)$, which is a stronger restriction. Note also that the former condition implies $\beta \geq \frac{\delta}{(1+\delta)(1-c)}$, that we required above. This is because, by ω having the support [0,1], the condition $\mathbb{E}[\omega|\omega < (1+\delta)c\frac{\beta}{\beta-\delta(1-\beta)}] \leq (1+\delta)c$ together with $\mathbb{E}[\omega] > (1+\delta)c$ implies $(1+\delta)c\frac{\beta}{\beta-\delta(1-\beta)} < 1 \Rightarrow \beta > \frac{\delta}{(1+\delta)(1-c)}$. Since the condition for interior τ is always satisfied, the only corner solution possible in the current case is $\kappa = 0$. These observations allow us to state the following result:

PROPOSITION A.1. *Suppose that $\mathbb{E}\omega \geq (1+\delta)c$. The solution is interior if and only if β is high enough to satisfy*

$$\text{(BP)} \qquad \mathbb{E}\left[\omega|\omega < (1+\delta)c\frac{\beta}{\beta(1+\delta) - \delta}\right] \leq (1+\delta)c.$$

If the condition BP does not hold, the solution is corner: $\kappa = 0$ and τ is such that $\mathbb{E}[\omega|\omega < \tau] = (1+\delta)c$.

Thus, if the entrepreneur's bargaining power is low, the ex ante quality is high, and the solution is corner the entrepreneur-preferred experiment "merges" the low- and medium-quality projects. As a result, the investment is always made, which is an inefficient outcome since projects with $\omega \in [0, c)$ should not be funded.

A.2.2 *Conditions for noncorner solution, low ex ante quality.* Suppose $(1+\delta)c \geq \mathbb{E}\omega$. It can be shown that in this case, there is a positive number $\underline{\kappa} > 0$, such that it is dominated for the entrepreneur to choose $\kappa < \underline{\kappa}$. To see this, recall that the entrepreneur would like to increase the value of the integral of updated means $\psi(t) = \int_0^t G_{\hat{\omega}}(x)dx$ evaluated at $t = (1 + \delta/\beta)c$ on the one hand; and to decrease the value of the CDF of updated means, $G_{\hat{\omega}}(t)$, evaluated at $t = (1+\delta)c$, on the other hand. Because the kink-point of the integral of updated means CDF for the least informative experiment $\underline{\psi}(t) = (t - \mathbb{E}\omega)_+$ is the average quality, $\mathbb{E}\omega$, the points $(1+\delta/\beta)c$ and $(1+\delta)c$ lie above the kink-point. Hence, there is a constant positive value of $\underline{\psi}(1+\delta/\beta)c = (1+\delta/\beta)c - \mathbb{E}\omega$ which is attained for all κ in some range $\kappa \in [0, \underline{\kappa}]$. Moreover, the value of CDF of updated means at $(1+\delta)c$ in this two-variable problem is

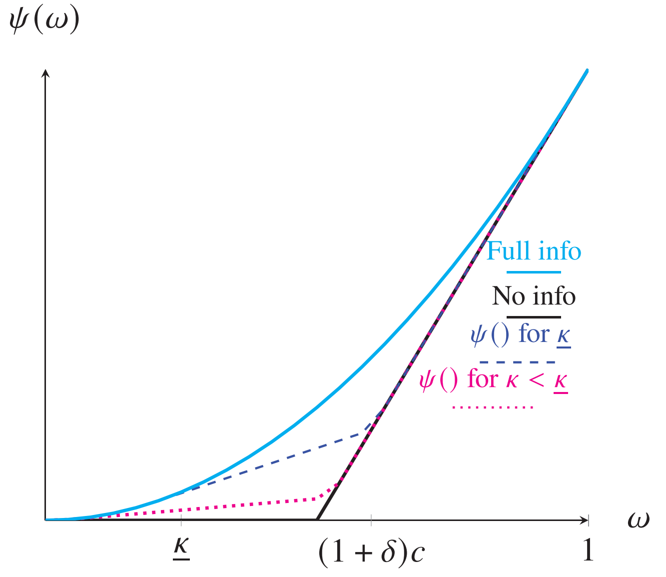


FIGURE A.4

ESTABLISHING $\underline{\kappa}$

equal to $\int_0^{\kappa} F_\omega(x)dx + F_\omega(\kappa)((1+\delta)c-\kappa)$, which is increasing in κ. Therefore, increasing κ as long as it is in the range $[0, \underline{\kappa}]$ increases the value of the CDF of updated means at $(1+\delta)c$, $G_{\hat{\omega}}((1+\delta)c)$ and does not increase the value of the integral of the CDF at $(1+\delta/\beta)c$, $\psi((1+\delta/\beta)c) = \int_0^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx$. So it is suboptimal to set κ to be below $\underline{\kappa}$.

How can we establish the value of $\underline{\kappa}$? It is the smallest κ that satisfies the condition

$$\int_0^{\kappa} F_\omega(x)dx + F_\omega(\kappa)((1+\delta)c-\kappa) \geq (1+\delta)c - \mathbb{E}[\omega].$$

For graphical intuition, please refer to Figure A.4.

Thus the only major thing that changes in the analysis is that now, instead of the constraint $\kappa \geq 0$, κ must be high enough so that $\int_0^{\kappa} F_\omega(x)dx + F_\omega(\kappa)((1+\delta)c-\kappa) \geq (1+\delta)c - \mathbb{E}[\omega]$. Other than replacing one of the constraints and modifying the Lagrangian, the solution remains the same.

We need to define two values, $\lambda_{\max}$ and $\lambda_{\min}$. Let $\lambda_{\max}$ follow from the expression

$$\mathbb{E}[\omega] - \mathbb{E}\left[\omega|\omega < (1+\delta)c - \frac{\delta c}{\beta - \lambda_{\max}}\right] F_\omega\left((1+\delta)c - \frac{\delta c}{\beta - \lambda_{\max}}\right)$$
$$= (1+\delta)c\left(1 - F_\omega\left((1+\delta)c - \frac{\delta c}{\beta - \lambda_{\max}}\right)\right).$$

Define $\lambda_{\min}$ as $\lambda_{\min} = \frac{(1-\beta)\delta c}{1-(1+\delta)c}$. Let $\kappa(\lambda)$ and $\tau(\lambda)$ be, as before, $\kappa(\lambda) = (1+\delta)c - \frac{\delta}{\beta-\lambda}$, and $\tau(\lambda) = (1+\delta)c + \frac{\delta c(1-\beta)}{\lambda}$.

$\lambda_{\max}$ follows from $\kappa(\lambda_{\max}) = \underline{\kappa}$. Thus, for interior solution, λ cannot be greater than $\lambda_{\max}$, since $\kappa(\lambda)$ is decreasing in λ. $\lambda_{\min}$ follows from $\tau(\lambda_{\min}) = 1$. Similarly, for interior solution, λ must be greater than $\lambda_{\min}$, since interior $\tau < 1$ and $\tau(\lambda)$ is decreasing in λ.

Define the following conditions:

Condition 1. $\lambda_{\max} > \lambda_{\min}$.

Condition 2. $\mathbb{E}[\omega|\kappa(\lambda_{\min}) < \omega] > (1+\delta)c$.

Condition 3. $\mathbb{E}[\omega|\kappa(\lambda_{\max}) < \omega < \tau(\lambda_{\max})] < (1+\delta)c$.

Condition 1 makes sure that there is a nonempty interval between $\lambda_{\max}$ and $\lambda_{\min}$ for a non-corner solution to exist. Under Condition 2, it is suboptimal to have $\tau = 1$, as it is possible to decrease κ to have the project financed more often. Under Condition 3, it is suboptimal to have $\kappa = \underline{\kappa}$, as it is possible to increase both κ and τ to, again, have the project financed more often. One can check that each condition is satisfied if the parameter β is high enough.

Overall, we can state the following:

PROPOSITION A.2. *Suppose that $\mathbb{E}\omega < (1+\delta)c$. The solution is interior if and only if the entrepreneur's bargaining power β is high enough to satisfy the Conditions 1, 2, 3 jointly. If the conditions do not hold jointly the solution is corner: κ is such that $\mathbb{E}[\omega|\omega > \kappa] = (1+\delta)c$, and $\tau = 1$.*

The Propositions A.1 and A.2 state that if the bargaining power of the entrepreneur is high enough, any optimal experiment splits the projects into three sets, low, medium, and high, in such way, that it is always possible to tell, which set a project belongs to, based on the outcome of the experiment. Moreover, if the project falls into the medium category, an optimal experiment *must only* reveal this, and nothing more, since that would make middle projects appear exactly at the threshold of implementability. If a project is high or low, an optimal experiment may reveal any additional information.[28] In particular, the most informative optimal experiment reveals the project quality exactly, if the project falls into either a high or a low set.

In terms of the investment decision and the contract, projects below the lower threshold κ are discarded. The medium-quality projects, $\omega \in (\kappa, \tau)$, are funded, and the entrepreneur receives a constant wage δc. High-quality projects $\omega \in [\tau, 1]$ are also funded, and the contract makes both the entrepreneur and the investor shareholders.

The low bargaining power of the entrepreneur leads to the corner solution. If β is low, and $\mathbb{E}\omega$ is high, the low- and medium-quality projects are merged, and the investment is always made. If both β and $\mathbb{E}\omega$ are low-, high- and medium-quality projects are merged so that whenever the project is funded, the entrepreneur receives a constant wage. The intuition behind the above result is similar to the setting with the binary project quality.

A.2.3 *Comparative statics with respect to the bargaining power.* It is a matter of algebra to check that when the optimal κ and τ are interior, the expression for κ is increasing in β, and the expression for τ—decreasing in β.

Applying first the implicit function theorem to the constraint equation, we can get

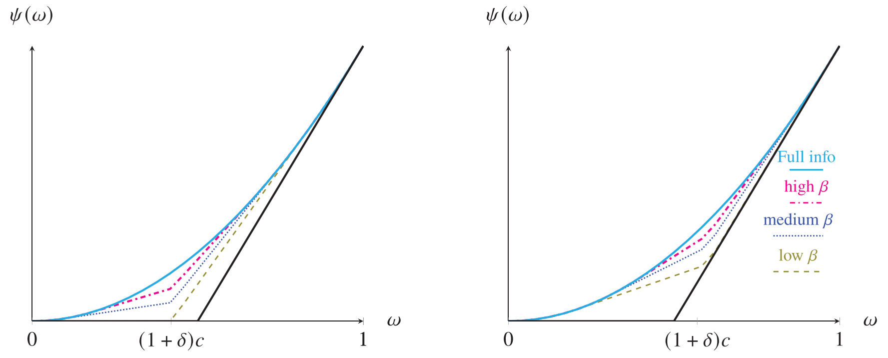
$$\frac{d\lambda}{d\beta} = \frac{f_\omega(\kappa)\frac{\delta c}{(\beta-\lambda)^2}((1+\delta)c-\kappa) + f_\omega(\tau)(-\frac{\delta c}{\lambda})(\tau-(1+\delta)c)}{f_\omega(\kappa)\frac{\delta c}{(\beta-\lambda)^2}((1+\delta)c-\kappa) + f_\omega(\tau)(\frac{\delta c(1-\beta)}{\lambda^2})(\tau-(1+\delta)c)}.$$

It is straightforward to see that this value is less than 1. Moreover, it can be shown that if the value of this expression is negative, the absolute value of this expression is smaller than $\frac{\lambda}{1-\beta}$. Then, differentiating $\kappa()$ and $\tau()$ with respect to parameter β we get:

$$\kappa(\lambda)'_\beta = \frac{\delta c}{(\beta-\lambda)^2}\left(1-\frac{d\lambda}{d\beta}\right) > 0$$

$$\tau(\lambda)'_\beta = \frac{\delta c}{\lambda}\left(-1-\frac{1-\beta}{\lambda}\frac{d\lambda}{d\beta}\right) < 0.$$

[28] This is due to the multiplicity of optimal experiments, which allow for the tangency condition.



(a) Integrals over distributions of posterior means, $\mathbb{E}\omega > (1+\delta)c$ (b) Integrals over distributions of posterior means, $\mathbb{E}\omega < (1+\delta)c$

FIGURE A.5

INTEGRALS OVER DISTRIBUTIONS OF POSTERIOR MEANS

Since with the increase of κ and the decrease of τ the most informative of the functions $\psi()$ gets closer to $\int_0^t F(x)dx$, which corresponds to full information.[29] Note also for the most informative entrepreneur-preferred experiment, such changes mean larger sets of states of the world are revealed. We can state the following result:

PROPOSITION A.3. *Suppose that the bargaining power of the entrepreneur, β, is high enough so that (BP) is satisfied strictly in case of high expected returns, or Conditions 1, 2, 3 hold in case of low expected returns. Then, the optimal amount of information generated by the entrepreneur strictly increases with his bargaining power for the most informative optimal experiment.*

Figures A.5a and A.5b show the result graphically.

A.2.4 *Equilibrium efficiency.* Efficiency is achieved in equilibrium when it is optimal for the entrepreneur to set $\kappa = c$. This way, all the economically viable projects are implemented, and the others—discarded. Recall the expression for κ:

$$\kappa = (1+\delta)c - \delta \times c/(\beta - \lambda).$$

Hence, κ is equal to c if $\beta - \lambda$ is equal to 1. λ is nonnegative because it is a shadow price of a constraint in the Lagrangian. It follows that $\beta \leq 1 + \lambda$, so $\beta = 1$ is a necessary condition for the efficient investment decision. What is also needed is for λ to be equal to 0 in the limit, as β approaches 1. For instance, this holds for the case of uniform distribution, as shown in the example below. For general distribution, however, it can be that $\lambda > 0$ even as β goes to 1.

Investor-preferred bargaining power. The result that the investor might prefer limited bargaining power carries through for the continuous project quality. For low ex ante quality, $\mathbb{E}[\omega] < (1+\delta)c$, if β is low, the entrepreneur-optimal experiment reveals only whether the expected quality is less than the effective financing cost, $(1+\delta)c$, or equal to it. Thus, even when the project is funded, the investor, on average, gets a payoff of 0. On the contrary, if β is high, the experiment outcome reveals when the project quality is high, $\omega > \tau \in ((1+\delta/\beta)c, 1)$, allowing both agents to be effectively shareholders and have economic profit in expectation.

[29] There are multiple optimal $\psi()$ because multiple functions can achieve the same κ and τ, and their behavior below κ and above τ is irrelevant for the entrepreneur's payoff.

For high ex ante quality, consider first the boundary case, $\mathbb{E}[\omega] = (1+\delta)c$. Consider β^* such that if $\beta < \beta^*$, the corner solution is optimal. The condition $\mathbb{E}[\omega|\omega < \tau] = (1+\delta)c$ implies that $\tau = 1$. So, the investor's payoff is zero for $\beta < \beta^*$. On the other hand, for $\beta \geq \beta^*$, the investor's payoff is increasing in β in a neighborhood of β^*. Taking a full derivative of $\tau(\lambda)$ with respect to β, taking into account the constraint $\mathbb{E}[\omega|\kappa(\lambda) < \omega < \tau(\lambda)] = (1+\delta)c$, and evaluating the derivative at $\beta = \beta^*$, we get $\frac{d\tau}{d\beta}|_{\beta=\beta^*} = -\frac{(1+\delta)c(2-\beta)}{1-\beta} < 0$. Hence, for $\beta > \beta^*$, there is a nonempty region of qualities, $\omega \in (\tau, 1)$, that will be revealed and that will lead to the positive payoff of the investor. Overall, for $\mathbb{E}[\omega] = (1+\delta)c$ the investor prefers some $\tilde{\beta} > \beta^*$ to all $\beta < \beta^*$. By continuity, when c is not too low but low enough to satisfy $\mathbb{E}[\omega] \geq (1+\delta)c$, the investor prefers some nonabsolute bargaining power.

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