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Entrepreneur-Investor Information Design

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Abstract

I consider an environment in which an entrepreneur generates information about the quality of his projects 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 innovations in computer hardware and software.[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]

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[1]For example, venture capital 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 of 1983–1992 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

The profitability of start-up projects is highly uncertain, and thys they rarely obtain funding from traditional banks. Instead, they turn to VC investors, which makes 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, Hellmann and Puri (2013)).

Pre-investment 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 campaign. By observing the number of pre-ordered items, the entrepreneur can learn about the underlying demand and future profitability of the product.

This paper investigates the amount of information generated about a project prior to 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 can choose among all quantities of information to be generated, that he can publicly commit to his choice, and that information generation is costless. Full information about the project quality maximizes total surplus and is therefore efficient. After the generated information is publicly observed, the two parties negotiate the contracting terms. I consider a particular conflict of interest: after contracting with the investor, the entrepreneur can secretly divert the funds. This moral hazard problem may distort the entrepreneur's information generation choice. My main interest is the conditions under which the entrepreneur generates full information about the project quality.

My main result is that when the entrepreneur negotiates the financing terms with the investor, the efficient amount of information is generated if the entrepreneur's bargaining power is high enough.[4] Moreover, the quantity of generated information increases with the bargaining power of the entrepreneur. Full information is not generated when the entrepreneur's bargaining power is low, even though information generation is costless. I also characterize the environments in which the quantity of information is monotonic in the cost of the investment and/or the severity of the moral hazard problem.

I 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 in-

[4]For binary project and for uniformly distributed (on an interval) the condition becomes *if and only if.*

[5]For example, Samsung Ventures.

vestment costs, my findings suggest that such entities might find it beneficial to split 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.

Bargaining power can also be interpreted in terms of the scarcity/abundance of investment capital. During the bust phases of a business cycle, it is usually harder to obtain funding. Hence, those few projects that manage to secure financing are likely to have provided less information because of the diminished entrepreneurs' bargaining power. This can lead to a lower success rate in the start-up industry.

Bargaining power has also been empirically linked to the sizes of VC-funds in Cumming and Dai (2011). Cumming and Dai (2011) find that VC-funds can have diminishing returns from higher bargaining power, with a fund's overall performance being an inverse U-shaped function with respect to its bargaining power. The results of my paper offer inefficient pre-contract information generation as a plausible source of diminishing returns from bargaining power. I find that, since the entrepreneur has incentives to generate information, the investor prefers a non-absolute bargaining power for herself when the project costs are high enough. Moreover, I find a setting in which the investor's payoff with respect to her bargaining power is inverse U-shaped.

My results may also explain why investors have incentives to maintain a reputation for being generous since it limits their bargaining power. Although this decreases their share of the surplus, the size of the surplus for division increases. Hence, the overall effect can be positive.

For some intuition underlying my results, consider two extreme scenarios. First, suppose the investor has all the bargaining power. Recall that both the entrepreneur and the investor are uncertain about the quality of the project and that the information about that quality is observed before the contract negotiation takes place. If this information is favorable enough, the investor will provide the funding to the entrepreneur. If the information is unfavorable, she will not. The investor-preferred financing terms make the entrepreneur indifferent between the proper spending of the funds on the one hand and secretly diverting the funds on the other hand. As long as the realized information is favorable, and the entrepreneur receives the investment money, his payoff from diverting the funds is the same, irrespective of the expected quality of the project. Thus, the payoff from the contract will also be constant. If the information is unfavorable, the investor does not provide the funding to the entrepreneur. As a result, if the entrepreneur has no bargaining power, he only cares about how often news arrives that is favorable enough to convince the investor to fund the project. Hence, the entrepreneur will provide just enough information to make the investor indifferent between funding the project and not funding it.

Now suppose the entrepreneur has all the bargaining power. In this case, when making an offer to the investor, the entrepreneur would only need to compensate her for the funding cost, so the investor's expected payoff from investing in the project 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 a project if and only if it is of good quality. This is achieved by generating as much information as possible.

With intermediate bargaining power, the entrepreneur trades off two forces, the probability of the project being funded versus the quality of the project conditional on being funded. The bargaining power determines the relative importance of each force.

Crowdfunding as a way to generate information Crowdfunding platforms, such as Kickstarter and Indiegogo, provide ways for creators of art, novel products, and gadgets to raise money for their products. Usually, the process is as follows: first, the creators of the crowdfunded product announce their campaign. They specify the period during which contributions will be accepted; the menu of the rewards and contributions;[6] the target amount of money; the promised date of delivery in case of a successful campaign; and the product's features and specifics. Potential contributors, observing the campaign, decide whether to contribute. If the funding goal is met by the time the campaign ends, the money is transferred to the product's creators. Otherwise, the contributions are returned to the contributors.[7]

Crowdfunding is a means of collecting money for entrepreneurial needs, but it also generates information about the likely profitability of a product. For example, when a project creator and outside observers are uncertain about the demand for the product, the amount of funding, and the number of pre-ordered items can decrease that uncertainty. If the project is well funded, it is more likely that the product will be well received in the market.

By adjusting the campaign characteristics, such as its duration, funding target, or the menu of pledges and rewards, the creator can generate different levels of informativeness. For example, a project failing to achieve a goal of $50,000 in five days is less unfavorable than the same project failing to reach the same $50,000 goal in 60 days.

Anecdotal evidence also suggests that the informational content of crowdfunding campaigns is important. There have been multiple cases of entrepreneurs being approached by venture capitalists after successful crowdfunding campaigns. A notable example is the campaign of Pebble watch, a smart watch with an electronic ink display that initially failed to attract external funding. After running a Kickstarter campaign

[6]The rewards are often items or bundles of the crowdfunded product.

[7]In practice, the creators sometimes fail to meet the delivery deadlines, and in some extreme cases, they completely fail to deliver. Such cases are not a subject of this paper.

and dramatically exceeding the funding goal, the creators were able to obtain additional VC funding.

The results of my analysis suggest that creators with more bargaining power are likely to design more informative crowdfunding campaigns. That is, the menu of prices, the target sum, and the campaign length will lead to profiles of contributions that will make it clear what the demand for the product is likely to be.[8]

Related literature This work is largely 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).[9] This paper departs from the standard Bayesian persuasion 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 that he chooses.

The effect of moral hazard in the Bayesian persuasion setting is also studied in Boleslavsky and Kim (2018). There, the hidden action is taken by a third party and influences the distribution over the true states, but does not directly influence the outcome. In my work, it is the sender who takes a hidden action after the experiment outcome has been observed and after the receiver takes action. The hidden action affects the players' payoffs directly.

Boleslavsky and Cotton (2018), Au and Kawai (2019, 2020) study persuasion with multiple senders. Each sender designs an experiment about his project quality and competes for the exclusive financing from a single receiver. Their results show that informativeness of *a* sender's experiment increases with the ex-ante expected qualities of *other* senders' projects.

Gentzkow and Kamenica (2016), Kolotilin, Mylovanov, Zapechelnyuk and Li (2017), and Kolotilin (2018) study Bayesian persuasion under the continuous state. In Section (3) I also study a continuous-state environment, departing from the assumption of a state independent sender's utility (Gentzkow and Kamenica (2016)) and linear-in-state agents' utilities (Kolotilin et al. (2017)). Results of my analysis are similar to the interval revelation results in Kolotilin (2018), which are derived under a set of slightly different assumptions – that the state of the world is two-dimensional and that the utility function of the receiver is linear.

Most closely related is a recent paper by Azarmsa and Cong (2020), who also apply the Bayesian persuasion to study entrepreneurs' financing. They look at the interaction

[8]Strausz (2017) studies crowdfunding as a mechanism that plays multiple roles - it allows to learn information about the crowd's willingness to pay, to collect the seed investment money from that crowd, and to incentivize the proper action by the entrepreneur 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.

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

of the three players: the entrepreneur, the insider investor, and the outsider investor. The entrepreneur and the insider observe the experiment outcome deterministically, whereas the outsider investor observes it with a non-unit probability. 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 non-linear function of project payoff. My findings complement the analysis of Azarmsa and Cong (2020), focusing on bargaining power. In my model, in order to restore efficiency, the entrepreneur does not need the commitment power to design any sophisticated non-linear security before designing the experiment structure. Instead, it is sufficient that he has high enough bargaining power. In addition, my model does not rely on the presence of the outsider investor.

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

Works by Bergemann and Hege (1998, 2005), Halac, Kartik and Liu (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. In my work, the information-related choice and the effort choice are disentangled, taking place at different points in time. Moreover, I allow for arbitrary bargaining power.[10]

The remainder of this paper is organized as follows. The version of the model with the two states of the world is introduced in Section 2, where in subsection Section 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. Section 3 expands the analysis to the case of continuous infinity number of states. Section 5 concludes. The appendices A and B include proofs and technical details.

2 Two states of the world

2.1 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 state of the world, ω, captures the

[10] For further details on the institutional background of VC and corporate finance see Kaplan and Strömberg (2003), Da Rin et al. (2013), Bottazzi, Da Rin and Hellmann (2016), Gompers, Gornall, Kaplan and Strebulaev (2019).

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, both players observe the outcome of the experiment, and both form the posterior belief $\hat{\alpha}$.[11] Next, the entrepreneur approaches the investor, and they negotiate the terms of financing. These terms specify how the project returns will be shared. The entrepreneur gets share s, and the investor – share $1 - s$. Three possible bargaining procedures will be specified in sections 2.2, 2.3, 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.[12]

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

The players' payoffs are:

– if the investor provides funding,

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

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

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

[12] 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 paper 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.

Rather than 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 non-pecuniary 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`

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

Except for the experiment design stage at the beginning of the play, the game described above is relatively familiar.[13] Suppose that there is an experiment with two possible outcomes – high and low.[14] The outcome is publicly observed 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 the following matrix:

outcome \ state	good	bad
high	x	y
low	$1 - x$	$1 - y$

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 to invest in the good ones. The precise experiment is an extreme example of the experiment structure. Another extreme is a non-informative experiment, achieved by setting $x = y \in (0, 1)$.

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

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

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 makes his payoff bounded from below by the payoff from diverting the funds, whereas if the contract is not signed, his payoff is zero.

The precise experiment maximizes the sum of payoffs. Given the conflict of interest between the two parties, there is a questions of whether the entrepreneur will choose the precise experiment. Furthermore, if he does not, how informative will he chose the experiment to be?

The cases of each party making a take-it-or-leave-it offer are shown in the two subsections below. Representing the extreme bargaining powers, these cases show the crucial role that the bargaining power plays in determining the amount of information generated. When the entrepreneur chooses both the experiment structure and the contract, he prefers the precise experiment. When the investor proposes the contract, the precise experiment is suboptimal for the entrepreneur.

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

[14] In a two state version of the model it is without loss to consider two outcome experiments.

These two extreme settings are followed by the case of intermediate bargaining powers. It shows how the bargaining power can balance the forces of the two conflicting interests.

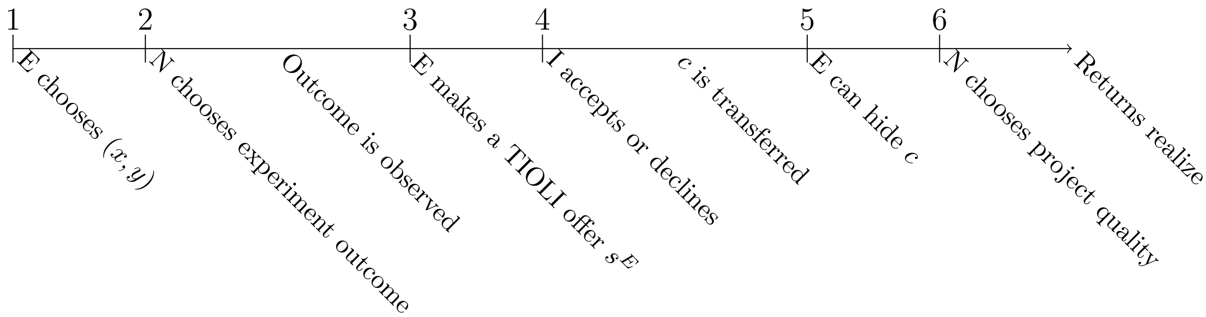
2.2 The entrepreneur makes a take-it-or-leave-it offer

Denote by s^E the take-it-or-leave-it contract offer that the entrepreneur makes 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 project being good:

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

After both players observe the outcome, the entrepreneur proposes the contract s^E to the investor. If the latter accepts the offer, $a^I = 1$, 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 currently held belief, $\hat{\alpha}$, as previously defined.[15] 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.

Below is a stylized depiction of 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.[16]

Analysis It is natural to solve for the Subgame Perfect Nash Equilibrium in this dynamic game of symmetric information. Using backward induction, in the equilibrium,

[15] The actual frequency of good projects must to 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.

[16] 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.

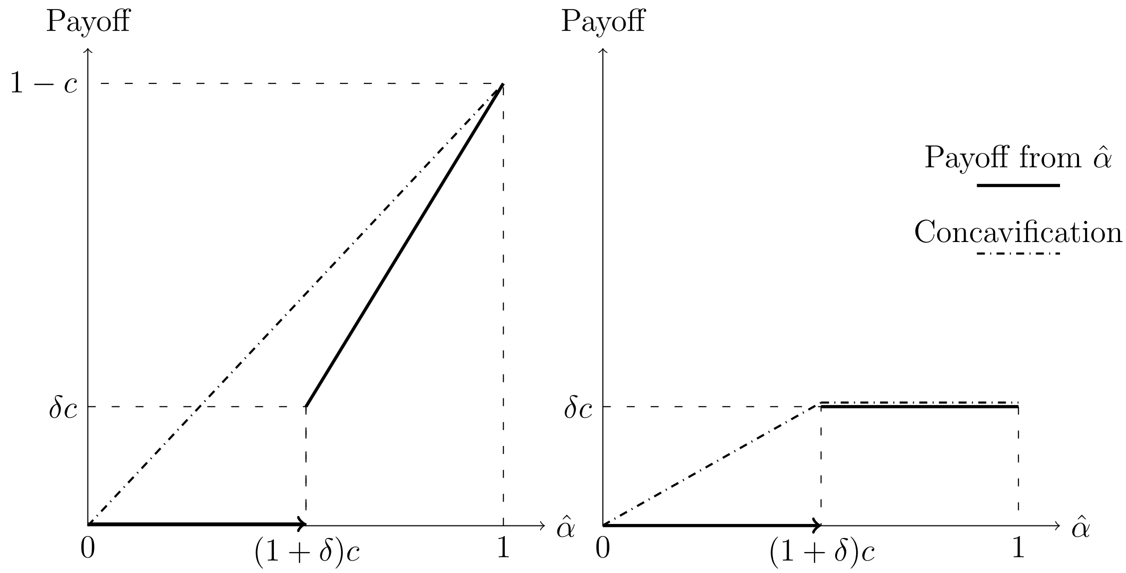
the entrepreneur spends the money properly if his share of the updated expected return from the project is higher than the payoff from diverting the money: $\hat{\alpha} s^E \geqslant \delta c$; he offers a share contract that makes the investor indifferent $(1 - s^E)\hat{\alpha} = c$; anticipating the possibility of improper money spending, the investor will only fund the project if the posterior belief is high $\hat{\alpha} s^E \geqslant \delta c$. 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

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

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

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

Figure (1a) depicts this function, which is a two-piece linear function with a zero-slope for $\hat{\alpha} < (1 + \delta)c$ and with a slope of 1 for $\hat{\alpha} \geqslant (1 + \delta)c$.



(a) Entrepreneur makes TIOLI

(b) Investor makes TIOLI

Figure 1: Entrepreneur's payoff from $\hat{\alpha}$ and concavification

Result The reader familiar with the *concavification* technique can see that the experiment, which results in the posterior $\hat{\alpha} = 1$ with probability α_0, and the posterior $\hat{\alpha} = 0$ 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 design, $\alpha_0(1 - c)$. This payoff is achieved by the distribution of posteriors as described above. In terms of conditional probabilities of the experiment, setting $x = 1$ and $y = 0$ leads to such distribution of posteriors. Thus, the precise experiment is optimal.

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) are in the Subsection A.1 of Appendix A.

An analogy with corporate finance can be drawn. In the region of beliefs $\hat{\alpha} \geqslant (1+\delta)c$, the entrepreneur acts as the single shareholder of this project. In the same region, the investor is the single lender. The effective cost of the project funding is $(1 + \delta)c$ – the actual cost of investment, c, plus the cost of the proper entrepreneurial incentives, δc. There is no lending by the investor when the posterior belief is below the effective cost of financing, which leads to the project not being undertaken. The entrepreneur has a zero payoff when, in expectation, his project is non-profitable. Thus, over the the entire range of beliefs, the entrepreneur acts as the residual claimant. The precise experiment is the efficient choice, and the residual claimant prefers the efficient outcome.

2.3 The investor makes a take-it-or-leave-it offer

Overall the actions and the timeline are similar to the case of the entrepreneur having the absolute bargaining power with the addition of the investor's choice of whether to offer any financing to the entrepreneur. After relabeling, $s^I \in [0, 1] \cup \{\varnothing\}$ 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 The differences with the previous analysis are: the entrepreneur will accept any offer by the investor; the investor will offer the smallest s^I among those that satisfy the entrepreneur's proper spending, $s^I \times \hat{\alpha} \geqslant \delta \times c$; so $s^I = \delta c/\hat{\alpha}$. As before, the investment is feasible if and only if $\hat{\alpha} \in [(1 + \delta)c, 1]$. Otherwise, the investor would not be able to recoup both the cost of the investment and the cost of providing incentives to the entrepreneur. Note that the investor makes the entrepreneur indifferent between the proper spending and diverting the funds whenever the project is implemented.

When making the experiment choice, the entrepreneur computes his equilibrium payoff from a posterior as

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

Result The entrepreneur's payoff from the precise experiment is $\alpha_0 \delta c$. If the probability of a good project is high, $\alpha_0 \geqslant (1 + \delta)c$, he is able to attract financing without generating any information. In this case, the precise experiment is suboptimal for him since generating no information gives a greater payoff of δc. 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 (1b).[17]

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 $x = 1$, $y = \frac{\alpha_0}{1-\alpha_0}\left(\frac{1}{(1+\delta)c} - 1\right)$ 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.[18]

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 $x = 1$, $y = \frac{\alpha_0}{1-\alpha_0}\left(\frac{1}{(1+\delta)c} - 1\right)$ is optimal*
- *in the case that the entrepreneur can attract financing without an informative experiment ($\alpha_0 \geqslant (1+\delta)c$), generating no information is optimal.*

See the details in Appendix A.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 the absolute bargaining power. Studying the case of intermediate bargaining power can facilitate understanding of the level of bargaining power at which precise experiment stops being the optimal one. In addition, it can reveal the level at which experiment described in the Proposition 2 becomes the optimal one. Moreover, a different experiment design can be optimal for some intermediate bargaining power. This section applies the

[17]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 $\{(1+\delta)c, 1\}$.

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

Nash bargaining Solution to the described entrepreneur-investor setting.[19]

After the outcome of the experiment is observed, the surplus for the division is $\hat{\alpha}-c$. The solution must account for the entrepreneur's incentive compatibility constraint, $\hat{\alpha}\times s \geqslant \delta \times c$, and the investor's individual rationality constraint, $\hat{\alpha}(1-s) \geqslant (1+\delta)c$. The space of contracts among which the Nash bargaining solution will search for the optimal contract is, therefore, $s \in [\delta c/\hat{\alpha}, 1 - c/\hat{\alpha}]$.[20]

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

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

When interior, the solution is:

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

The only possible corner solution 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 expressed as

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

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

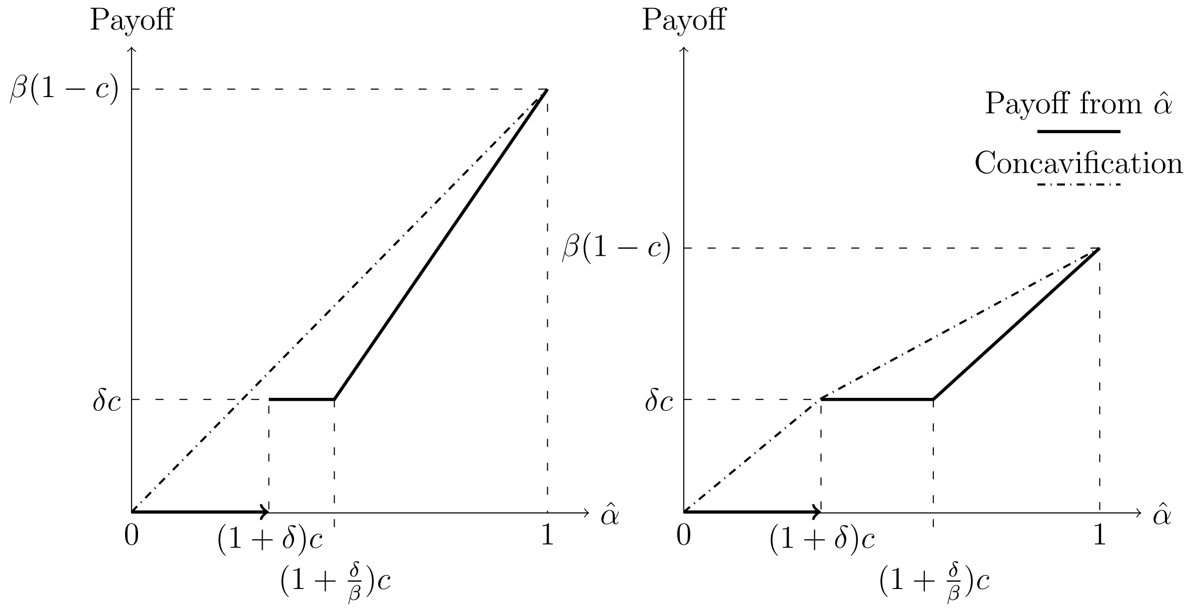
$$V^E(\hat{\alpha}) = \hat{\alpha} \times s(\hat{\alpha}) \times \mathbb{I}_{\{\hat{\alpha}\in[(1+\delta)c,1]\}} = \max\{\delta c, \beta(\hat{\alpha}-c)\} \times \mathbb{I}_{\{\hat{\alpha}\in[(1+\delta)c,1]\}} =$$
$$= \begin{cases} 0, & \text{if } \hat{\alpha} < (1+\delta/\beta)c \\ \delta c, & \text{if } (1+\delta)c \leqslant \hat{\alpha} < (1+\delta/\beta)c \\ \beta(\hat{\alpha}-c), & \text{if } (1+\delta/\beta)c \leqslant \hat{\alpha}. \end{cases}$$

The figure (2) provides a graph of the entrepreneur's payoff and concavification for two values of β, high and medium (when the value of β is low, the graph of payoff is essentially the same as (1b)).

Three regions can be distinguished in this figure. There is no feasible contract for low $\hat{\alpha}$, since the investor anticipates that she will not be able to incentivize the entrepreneur's proper action and recoup the cost of investment at the same time. For medium $\hat{\alpha}$, the

[19] Different bargaining protocols allow for intermediate bargaining powers. One such specific protocol is the Nash bargaining solution. Though it takes a reduced form, it embodies several other bargaining protocols.

[20] 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 2: Entrepreneur's payoff from $\hat{\alpha}$ and concavification for NBS

investment is feasible, and the entrepreneur's payoff is flat with respect to $\hat{\alpha}$. Here, the entrepreneur is effectively an employee with a fixed wage of δc. 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, $\beta \geqslant \frac{\delta}{(1+\delta)(1-c)}$, 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. For low β, $\beta < \frac{\delta c}{1-c}$, and in the case that combines medium β and low prior, $\beta \in \left[\frac{\delta c}{1-c}, \frac{\delta}{(1+\delta)(1-c)}\right)$, $\alpha_0 < (1+\delta)c$, the outcome is the same as that in the case of 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 graph (2b). 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: the low outcome must result in the signed contract. 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, $\frac{\delta c}{(1-c)} \leqslant \beta < \frac{\delta}{(1+\delta)(1-c)}$, 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 $x = 1$, $y = \frac{\alpha_0}{1-\alpha_0}\left(\frac{1}{(1+\delta)c} - 1\right)$. For $\alpha_0 \geqslant (1+\delta)c$ 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.3 of appendix A.

Investor-Preferred Bargaining Power The investor's bargaining power is $1-\beta$. Because the informativeness and the equilibrium surplus increases with β, the investor might benefit from not having the 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, $\alpha_0 \geqslant (1+\delta)c$, the investor can benefit from a lower bargaining power. Suppose that when the entrepreneur is indifferent between either generating no information or the partially informative experiment with the support $\hat{\alpha} \in \{(1+\delta)c, 1\}$, the latter is chosen. Then, among all bargaining powers such that $\beta < \frac{\delta}{(1+\delta)(1-c)}$, the investor prefers $\beta = 0$ – that is, the absolute bargaining power for herself. She gets the expected payoff of $\alpha_0 - (1+\delta)c$.[21] Compare this payoff with that from $\beta = \frac{\delta}{(1+\delta)(1-c)}$ to show that the investor prefers a non-absolute bargaining power whenever $\alpha_0 \leqslant \frac{(1+\delta)^2 c}{(2-c)\delta}$.

The corollary summarizes these observations:

Corollary 1. *The investor prefers a non-absolute bargaining power, $\beta = \frac{\delta}{(1+\delta)(1-c)}$, if the ex-ante project quality is not too high, $\alpha_0 \leqslant \frac{(1+\delta)^2 c}{(2-c)\delta}$. If $\alpha_0 > \frac{(1+\delta)^2 c}{(2-c)\delta}$* and *the investor-preferred equilibrium is played, she prefers the absolute bargaining power, $\beta = 0$.*

Consider also the graph of the investor's preferences with respect to the bargaining power at (3a).

Comparative statics of informativeness Note that for medium and low bargaining power, if the prior is low, $\alpha_0 < (1+\delta)c$, the entrepreneur prefers the support of posteriors to be $\{0, (1+\delta)c\}$. Note also that for the combination of medium bargaining power and

[21]This happens because with probability the $\frac{1-\alpha_0}{1-(1+\delta)c}$, the posterior $\hat{\alpha} = (1+\delta)c$ occurs, bringing the investor the payoff of 0, and, with the complement probability, the posterior $\hat{\alpha} = 1$ occurs, leading to the payoff of $1-(1+\delta)c$.

a high prior, $\alpha_0 \geqslant (1+\delta)c$, he prefers the support to be $\{(1+\delta)c, 1\}$. Call the experiment leading to posteriors $\{0, (1+\delta)c\}$ the *lower shaded experiment* and to posteriors $\{(1+\delta)c, 1\}$ the *higher shaded experiment.*

Apply the Blackwell Informativeness Criterion to compare informativeness of the shaded experiment. In our case, Experiment A is Blackwell more informative than Experiment B if A results in the distribution of posteriors, which is Second-Ordered Stochastically Dominated by the distribution of the posteriors of B. If the two points in the support of posteriors move further away from each other in response to the change of the parameter, the experiment is becoming more informative, and vice versa. Applying this criterion, we see that two points in the support of lower shaded experiment move further away in response to the increase in δ and/or c, and the two points in the support of higher shaded experiment move closer. Thus, the following result can be stated:

Corollary 2. *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, $\alpha_0 \geqslant (1+\delta)c$, the informativeness of the entrepreneur-preferred experiments is decreasing in c and δ.*

3 Continuous Project Quality

This section analyzes the case of continuous project quality. The result that informativeness increases with the entrepreneur's bargaining power is shown to hold in this reacher environment. Moreover, for a range of bargaining powers, the amount of information is strictly continuously increasing, a conclusion that cannot be derived under the assumption of binary project quality.

Assume that the project quality ω be distributed in the interval $[0, 1]$ according to an atomless distribution with the CDF $F_\omega()$. The project requires the 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 after observing the experiment outcome by $\hat{F}_\omega()$. After observing the 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 are the properties of the socially optimal experiments in this setting? Since there are only two investment levels, 0 and c, the first-best is to invest in projects with $\omega \geqslant c$ and to discard other projects. Agents are risk-neutral, so the exact structure of an experiment is irrelevant, as long as it separates the projects with $\omega \geqslant c$ from the projects with $\omega < c$. For instance, an experiment, which reveals the quality exactly, and an experiment, which determines whether or not the actual quality is high enough both lead to the efficient investment decision. Therefore, the set of the efficient experiments includes but is not limited to the perfectly revealing one.

Focus throughout the section on the share contracts determined by Nash bargaining solution on the space of Incentive-Compatible Payoffs. The solution to the bargaining problem is a function $s()$ that maps the updated distribution over qualities $\hat{F}_\omega$ and the actual quality ω into the share of the returns that goes to the entrepreneur. 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 $\hat{\omega} \doteq \int_0^1 x d\hat{F}_\omega(x)$.[22]

The solution to the Nash bargaining problem follows from:

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

Similarly to the section 2.4, the solution is

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

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

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

As before, the entrepreneur's payoff is piecewise linear. There are three regions: for low expected quality, his payoff is zero; for medium expected quality, the payoff is constant and positive; and for high expected quality, the payoff is increasing.

Following the approach of Gentzkow and Kamenica (2016), the entrepreneur's 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 $\hat{\omega}$ must be a mean-preserving spread of the original distributions of project qualities, written as $\int_0^t \mathbb{P}\{\hat{\omega} \leqslant x\}dx \in [(t - \int_0^1 x dF_\omega)_+, \int_0^t F_\omega(x)dx], t \in (0,1)$.[23] Second, since CDFs are non-decreasing, the integral of the CDF of $\hat{\omega}$ must be convex.[24]

Let $G_{\hat{\omega}}$ be the CDF of $\hat{\omega}$, and let $\psi(t)$ denote its integral with the upper limit t –

[22]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: $s^*\mathbb{E}\left[\omega | \omega \sim \hat{F}_\omega\right] = \int_0^1 s(t, \hat{F}_\omega)d\hat{F}_\omega(t)$. By risk neutrality, the two contracts are also payoff equivalent for the investor.

[23]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).

[24]This constraint is denoted as (CC).

that is, $\psi(t) \doteq \int_0^t G_{\hat{\omega}}(x)dx = \int_0^t \mathbb{P}\{\hat{\omega} \leqslant x\}dx$. The entrepreneur's problem is then

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

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

$$\psi(t) \text{ is convex.} \tag{CC}$$

The problem of finding the optimal $G_{\hat{\omega}}$ can be simplified because of the following property:

Lemma 3.1. *The optimal experiments are characterized by two points, $\kappa \in [0, (1+\delta)c)$ and $\tau \in ((1+\delta/\beta)c, 1]$. At those points $\psi()$ must be tangent to the integral of the updated expectations of a fully informative experiment, $\bar{\psi}(t) = \int_0^t F(x)dx$. For qualities between those two points, the optimal experiment reveals only that $\omega \in (\kappa, \tau)$. Moreover, $\mathbb{E}[\omega|\kappa < \omega < \tau] = (1+\delta)c$.*

The lemma above implies that the entrepreneur's problem can be restated in terms of finding the two numbers, κ and τ. However, the lemma does not specify the behavior of $\psi(t)$ outside of the region $[\kappa, \tau]$. This is because there exist multiple experiments that allow for the tangency conditions from the lemma. One particular way is to have $\psi(t) = \bar{\psi}(t)$, $t \notin (\kappa, \tau)$. This is achieved by the experiment, which reveals the quality completely outside of (κ, τ). Such an experiment is the most informative among the optimal experiments. Thus, we can state the following:

Corollary 3. *The most informative optimal experiment reveals the quality completely in the set $[0, \kappa] \cup [\tau, 1]$ and only reveals that $\omega \in (\kappa, \tau)$ otherwise.*

We now need to characterize κ and τ. The following lemma gives the expressions for the optimal κ and τ, when they are *interior*, i.e. $\kappa > 0$ *and* $\tau < 1$.

Lemma 3.2. *The optimal interior κ and τ follow from*

$$\kappa(\lambda) = (1+\delta)c - \frac{\delta c}{\beta - \lambda},$$
$$\tau(\lambda) = (1+\delta)c + \frac{\delta c(1-\beta)}{\lambda},$$

where λ is such that

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

The expressions for κ and τ follow from the first-order condition (FOC) of the associated Lagrangian (L), with the conditions (BP) derived in the appendix B.2.

Call the pair (κ, τ) *corner* when either $\kappa = 0$ or $\tau = 1$. Whenever the optimal (κ, τ)

is not interior, it is corner. For high ex-ante expected quality, the corner solution is such that $\kappa = 0$, and for low ex-ante expected quality – $\tau = 1$. Depending on whether $\mathbb{E}\omega$ is high or low, there are two mutually exclusive sets of conditions for the solution to be interior. These conditions are characterized below.

High expected quality.

Proposition 4. *Suppose that $\mathbb{E}\omega \geqslant (1+\delta)c$. The solution is interior if and only if β is high enough to satisfy*

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

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

Thus, if the entrepreneur's bargaining power is low, and the solution is corner, the entrepreneur-preferred experiment "merges" the low- and the 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.

Low expected quality. For this case several definitions are required. Let $\lambda_{\max}$ follow from the condition

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

Let $\lambda_{\min} = \frac{(1-\beta)\delta c}{1-(1+\delta)c}$. Let $\kappa(\lambda)$ and $\tau(\lambda)$ be as in lemma (3.2). Define also the following conditions:

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

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

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

Then the result is:

Proposition 5. *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 $\tau = 1$.

Consider the most informative of the entrepreneur-preferred experiments. Lemma (3.2) and the two propositions (4), (5) state that if the entrepreneur's bargaining power is high enough, there are two distinct non-trivial thresholds. The optimal experiment perfectly reveals the quality below the lower threshold and above the higher threshold. Between these two thresholds, the experiment "pools" the projects and reports their average quality. The expected quality of the projects in the middle makes the investor indifferent between providing the funds to the entrepreneur and not.

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.

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, the high- and the medium- quality projects are merged. 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. There are two goals that the entrepreneur pursues. On the one hand, as a potential shareholder, he prefers the quality of the funded projects to be above a certain threshold. On the other hand, as a potential employee, he prefers the projects to be funded as often as possible. The first goal is achieved by an experiment that reveals whether the *actual* quality is above the threshold $(1+\delta)c$. The second goal is achieved by an experiment such that with a high probability, the *average* quality, contingent on an outcome, is above the threshold $(1+\delta)c$. There is a conflict between such experiments: the increase in the probability that the average conditional quality is above $(1+\delta)c$ is achieved by pulling together the projects *above and below* $(1+\delta)c$, which is undesirable from the shareholder's point of view. On the other hand, the experiment that tells whether the actual quality is *exactly* above $(1+\delta)c$ decreases the funding probability. The entrepreneur's bargaining power β balances the two forces.

It is a matter of algebra to check that when the optimal κ and τ are internal, the expression for κ is increasing in β, and the expression for τ – decreasing in β. Since for the most informative entrepreneur-preferred experiment, such changes mean larger sets of states of the world being revealed, we can state the following result:

Corollary 4. *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, in the continuous project quality version of the model the optimal amount of information generated by the entrepreneur is strictly increasing in his bargaining power.*

As for the efficiency of the equilibrium outcome, the two thresholds, κ and τ are not equal to each other, even in the case of $\beta = 1$. This means that even as the entrepreneur's bargaining power becomes absolute, there will be a non-empty measure of projects, whose quality will not be revealed exactly.

However, the perfect knowledge of each project quality is not necessary for efficiency, as had been argued before. It is sufficient to know whether $\omega \geqslant c$ or not. Among the entrepreneur-preferred experiments, if there is ever $\kappa = c$, such an experiment would induce efficiency. 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 non-negative because it is a shadow price of a constraint in the Lagrangian. It follows that $\beta \leqslant 1 + \lambda$, 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 a general distribution, however, it can be that $\lambda > 0$ even as β goes to 1. The following corollary summarizes these observations:

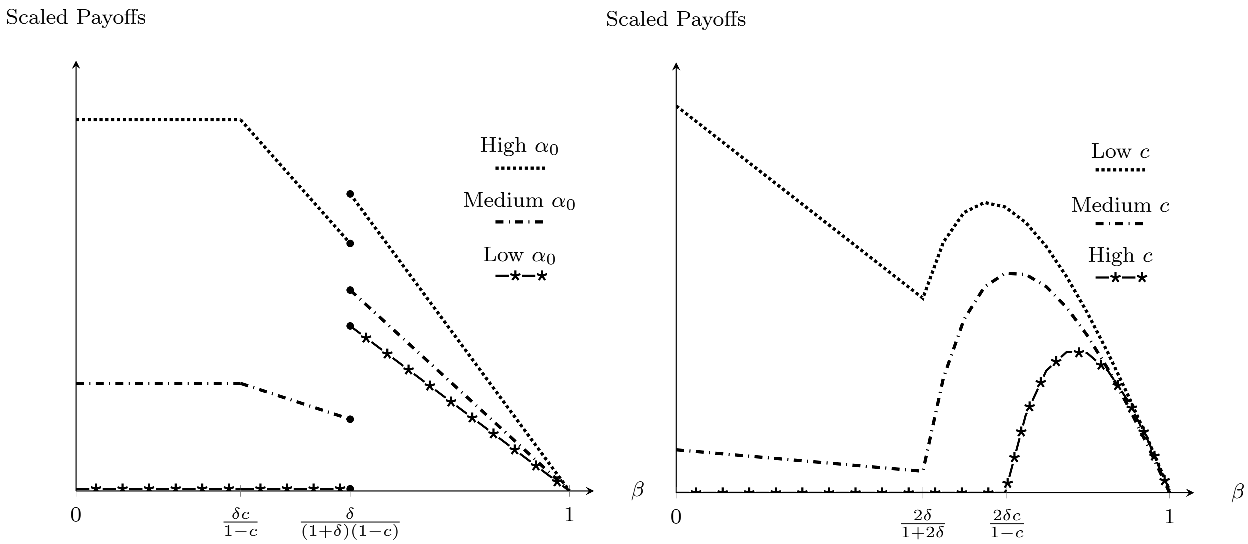
Corollary 5. $\beta = 1$ *is the necessary condition for the efficient information generation in equilibrium.*

Investor-preferred bargaining power The result that the investor might prefer limited bargaining power also holds 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 above or below the effective financing cost, $(1+\delta)c$. 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 the quality above $\tau \in ((1 + \delta/\beta)c, 1)$. Therefore, with a non-zero probability, the investor makes a positive economic profit after accounting for the effective financing cost $(1 + \delta)c$.

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 $\beta < \beta^*$: whenever the project is implemented, it exactly recoups the effective cost of financing. On the other hand, for $\beta \geqslant \beta^*$, the investor's payoff can be shown to increase 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 non-empty 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 $\mathbb{E}[\omega] \geqslant (1 + \delta)c$, the investor prefers some non-absolute bargaining power.

Corollary 6. *For continuous project quality, the investor prefers non-absolute bargaining power, $1-\beta<1$, if the project cost c is not too low.*

Figure (3b) illustrates this corollary for the uniform example by comparing the investor's equilibrium payoff as a function of the bargaining power parameter β for different project cost values, c. For high and medium values of c, the investor prefers non-absolute bargaining power, $\beta > \frac{2\delta}{1+2\delta}$. However, for sufficiently low project cost, she prefers the absolute bargaining power, $\beta = 0$.



(a) binary quality

(b) continuous quality

Figure 3: Investor's preferences over bargaining power

Uniformly distributed project quality Let us apply the results of lemma 3.2 and propositions 4, 5 to the case of uniformly distribute project quality, $\omega \sim \mathcal{U}([0,1])$. From lemma 3.2, the interior solution is

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

In the case of a high ex-ante quality, $\mathbb{E}[\omega] = 0.5 \geqslant (1+\delta)c$, following proposition 4, the solution is interior when

$$\beta \geqslant \frac{2\delta}{1+2\delta}.$$

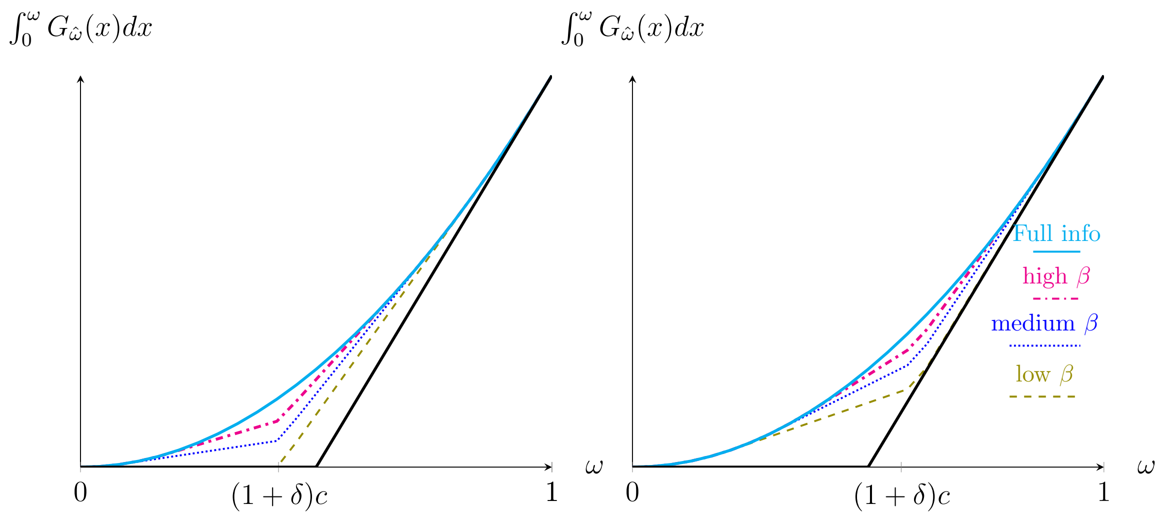
If the entrepreneur's bargaining power is not high enough, the corner solution $\kappa = 0$,

$\tau = 2(1+\delta)c$ is optimal.

In the case of a low ex-ante quality, $\mathbb{E}[\omega] = 0.5 < (1+\delta)c$, determine first that $\lambda_{\max} = \beta - \frac{\delta c}{1-(1+\delta)c}$ and $\lambda_{\min} = \frac{(1-\beta)\delta c}{1-(1+\delta)c}$. Then, each of the conditions 1 – 3 holds for $\beta \geqslant \frac{2\delta c}{1-c}$. If the bargaining power is not high enough, $\beta < \frac{2\delta c}{1-c}$, the corner solution $\kappa = 2(1+\delta)c - 1$, $\tau = 1$ is optimal.

With respect to δ, the informativeness is globally decreasing: for the corner solutions, an increase in δ leads to tighter ranges for β; for the internal solution, an increase in δ leads to a decrease in κ and an increase in τ. As for the comparative statics with respect to c, there is no unequivocal conclusion, since an increase in c causes both the interior κ and τ to increase.

Consider the figures (4a) and (4b). They depict the change of $\psi(t) = \int_0^t G_{\hat{\omega}}(x)dx$ with respect to changes in the bargaining power of the entrepreneur. As the entrepreneur's bargaining power increases, the optimal $\psi(t)$ becomes closer to $\bar{\psi}(t)$, which corresponds to the fully revealing experiment. These graphs are plotted for the uniformly distributed project quality, but a similar behavior holds for a general distribution of the quality.



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

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

4 Discussion

Why do the different levels of the entrepreneur's bargaining power lead to such different qualitative results? Going back to the binary project quality case, if the entrepreneur has no bargaining power, an investor-preferred contract compensates only for the incentives not to divert the money. Whenever the investor is willing to provide the funding, the entrepreneur expects to earn the same amount of money. Thus, being more optimistic about the project quality does not result in a larger payoff for the entrepreneur, when he has no bargaining power. Therefore, the entrepreneur who can attract the funding for his project without generating information does not need to provide any information. The entrepreneur who cannot attract the funding without generating information needs to provide *some* information. This information takes the form of two reports: high and low. The level of optimism from the high report makes the investor exactly indifferent. Levels of optimism higher than that are more costly for the entrepreneur because of the lower probabilities with which they occur. On the other hand, the level of optimism from the low report needs to be as low as possible: lower optimism in the case of a low report increases the frequency of a high report, other things equal.[25]

As for the entrepreneur having all the bargaining power, he cares about the likelihood of being financed in this case, as well. However, in the event that he receives the financing, he would like the level of optimism to be high. This is because he now acts as the residual claimant. In other words, the contract the two agents sign can be viewed as the debt contract. For every value of the posterior belief, the entrepreneur promises to return, on average, exactly the investment cost, keeping the rest for himself. The lower the belief, the higher the riskiness of the project. The entrepreneur needs to promise the investor a higher return in case of success to compensate for the higher risk in case of lower optimism. Thus, whenever the project is feasible, the entrepreneur prefers higher posterior values to the lower ones. When the project is not feasible, the entrepreneur is indifferent between different posteriors: his payoff will be 0 regardless. The entrepreneur would like the highest possible level of optimism to occur as often as possible. To achieve a higher frequency of optimism, the entrepreneur chooses the lowest level of optimism from the low report.

The implication of the above results is that information about the project is efficiently learned and revealed only if the bargaining power of the entrepreneur is high enough. If the bargaining power of the entrepreneur is low, the following form of inefficiency occurs: a project which can be financed without the new information generated might remain as risky as it is ex-ante; a project which cannot attract financing without the new information will result in the entrepreneur generating just enough information to get it financed, which is not the full information. This particular information structure "pools" together good projects and some of the bad projects. This leads to inefficiently risky projects being financed.

Comparing the assumptions and the results of my paper with those of Azarmsa and Cong (2020), my analysis complements their findings in the following way. 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 non-unit

[25] Interestingly, in Strausz (2009), a similar force also limits the information, even though the roles of the agents are reversed: the investor has an informational advantage, whereas the entrepreneur has the bargaining power advantage. There it is optimal for the investor not to reveal everything she knows so that the entrepreneur has incentives to exert the costly effort even in the bad state of the world.

probability. They interpret this probability as the measure of the investor's bargaining power. Given this interpretation, in their setting, the informativeness is non-monotonic in the bargaining power; moreover, no financing can occur for the intermediate levels of bargaining power. In my paper, the informativeness is monotonic in the bargaining power, and the financing occurs for all sets of parameters with positive probability. Second, to restore efficiency, in my model, the entrepreneur does not need the commitment power to design any sophisticated non-linear security before designing the experiment structure. Instead, to restore efficiency in the general continuous quality case, it is necessary that he has a high bargaining power. In the dichotomous and the uniform quality cases, it is also sufficient. In the continuous project quality case of my paper, 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 in some settings might seem more natural.

Bargaining power can be interpreted in several ways. At a micro-level, it is usually assumed that more experienced entrepreneurs have a greater say when the terms of a contract are negotiated. This means that the more experienced entrepreneurs are more likely to generate the efficient amount of information. Conversely, the less experienced entrepreneurs are more likely to generate less information and to try to finance riskier projects. That could lead to a vicious circle at a micro-level: 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 riskier projects being undertaken.[26]

At a more macro level, bargaining power is usually inversely associated with the market tightness. For example, there is more competition in the IT-industry than there is in healthcare start-ups.[27] Alternatively, entrepreneurs' higher bargaining power can be associated with there being a larger number of investors on the market.

What the model results say is 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 with a small number of investors, riskier projects can get funded as well. Consider the following scenario: suppose that a small number of

[26]Another documented source of increased bargaining power is the project being at a later stage of development, as shown in Gompers et al. (2019).

[27]See also Gompers et al. (2019).

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 to each other, are, for example, the 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 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 for dis-economy from the bargaining power.

My results also show that the investor prefers non-absolute bargaining power if the cost of the project 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 be beneficial in terms of 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 offer an explanation for this phenomenon.

Plausible Calibration Exercise Recall that the non-corner solution of the continuous project quality version of the model predicts that the most informative among the entrepreneur-preferred experiments are going to reveal the project state exactly if it is below a certain threshold κ, and also if it is above a different threshold τ, $0 < \kappa < \tau < 1$. There is also going to be a mass of results pulled together somewhere at (κ, τ).

One could think about the following calibration exercise. If we assume parametrized distributions of qualities and costs, it would induce the distribution of κ's, τ's, and therefore, a 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 then allow to perform 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.

5 Conclusion

I have studied the environment in which the entrepreneur can costlessly generate information about the investment project before it gets funded. 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 the informativeness increases in the investor's bargaining power in the presence of a post-contractual moral hazard.

The intuition for such interaction between the bargaining power and the 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 news about the project quality is average but the project can be funded, the entrepreneur effectively becomes 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 the high-quality enough projects to be funded. These two conflicting interests determine the choice of informativeness.

Our findings on the micro-level imply are 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.

On the macro-level, 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.

Appendices

A Optimal experiment structure

A.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 reacher, 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, $S = \{\text{low}, \text{high}\}$.

Recall that for each value of the posterior we know what the consequent payoff of the entrepreneur will be, since the subgame equilibrium outcome is unique. Hence, we can write down the entrepreneur's payoff as a function of the posterior value, denoting it $V^E(\hat{\alpha})$. So the problem that the entrepreneur faces at the beginning of the game is

$$\max_{S,\{\mathbb{P}\{s|\omega\}\}} \left\{ \sum_{\omega} \left(\sum_{s\in S} V^E \left(\frac{\mathbb{P}\{s|\omega\} \times \mathbb{P}\{\omega\}}{\sum_{\omega'} \mathbb{P}\{s|\omega'\} \times \mathbb{P}\{\omega'\}} \right) \mathbb{P}\{s|\omega\} \right) \mathbb{P}\{\omega\} \right\} =$$

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

$$\left. +\alpha_0 \sum_{s\in S} V^E \left(\frac{\alpha_0 \mathbb{P}\{s|\text{good}\}}{\alpha_0 \mathbb{P}\{s|\text{good}\} + (1-\alpha_0)\mathbb{P}\{s|\text{bad}\}} \right) \right\}.$$

Using the results of Kamenica and Gentzkow (2011), the problem described above is equaivalent to the one, where the entrepreneur chooses the finite discrete distribution over posterior beliefs, $\mathbf{G} \in \Delta(\Delta(\Omega))$,‘’ which is Bayes-plausible, i.e. 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:

$$\max_{\{\hat{\alpha}|\mathbf{g}(\hat{\alpha})>0\},\mathbf{g}} \sum_{\hat{\alpha}:\mathbf{g}(\hat{\alpha})>0} V^E(\hat{\alpha})\mathbf{g}(\hat{\alpha})$$

s.t.

$\mathbf{g} : [0,1] \to [0,1]$ non-decreasing

$$\sum_{\hat{\alpha}:\mathbf{g}(\hat{\alpha})>0} \mathbf{g}(\hat{\alpha}) = 1$$

$$\sum_{\hat{\alpha}:\mathbf{g}(\hat{\alpha})>0} \hat{\alpha}\mathbf{g}(\hat{\alpha}) = \alpha_0.$$

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. In other words, V^{E*} is the smallest concave function, which is weakly greater than V^E. Aumann, Maschler and Stearns (1995) call the result of applying such 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. In this particular case of the entrepreneur making a take-it-or-leave-it offer it actually can be seen that the function that we are looking for is the linear function connecting the two points, $(0, 0)$ and $(1, \beta(1 - c))$. This function is expressed as

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

Check that this is indeed the concavification. Being linear, it is concave. The values of this linear function and of the payoff function coincide at the end-points, at $\hat{\alpha} = 0$ and at $\hat{\alpha} = 1$. Thus, any function below this linear function will either fail to be concave, or fail to be weakly above the payoff function. Figure 5 provides the graphic illustration. A

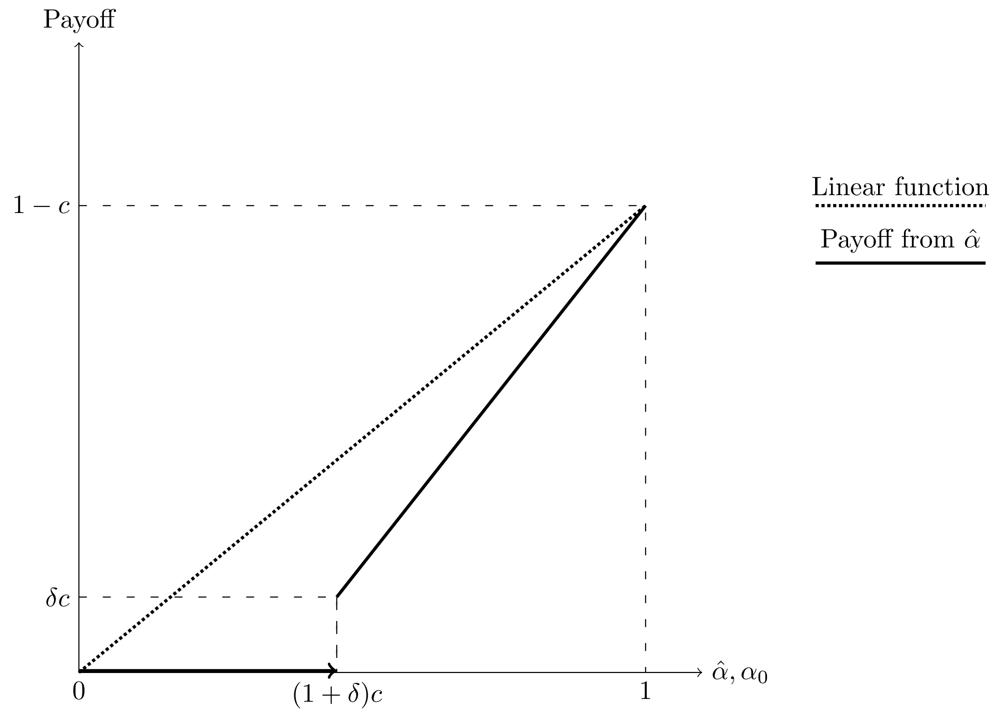


Figure 5: The entrepreneur makes a TIOLI-offer: The straight line is the concavification

simple 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* $V^E(\hat{\alpha}) = (\hat{\alpha} - c) \times \mathbb{I}_{\{\hat{\alpha} \geqslant (1+\delta)c\}}$. *Then the concavification of* $V^E(\hat{\alpha})$ *is a linear function* $V^{Linear}(\hat{\alpha}) = \hat{\alpha}(1-c)$

Once the concavification of $V^E(\hat{\alpha})$ has been established, the support of the optimal distribution over posteriors can be deduced. The support of posteriors which allows for the ex-ante expected value to be on the linear function are the end-points, 0 and 1. Indeed, if only the two beliefs, 0 and 1, are the possible outcomes after observing the results of the experiment, it should hold that the posterior $\hat{\alpha} = 1$ should occur with frequency α_0 and the posterior $\hat{\alpha} = 0$ - with frequency $1 - \alpha_0$, in order for Bayes-plausibility to hold. When the belief is $\hat{\alpha} = 1$ the subgame equilibrium payoff of the entrepreneur is $1 - c$, when belief is $\hat{\alpha} = 0$ the payoff is zero. On average the entrepreneur gets $\alpha_0 \times V^E(1) + (1-\alpha_0) \times V^E(0) = \alpha_0 \times (1-c)$, 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 help to establish the following:

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* $\begin{cases} 0 \text{ with probability } 1-\alpha_0 \\ 1 \text{ with probability } \alpha_0 \end{cases}$

After establishing this, it is easy to see that the two-outcome precise experiment, i.e. 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. Indeed, setting $x = 1$ and $y = 0$, the high outcomes happens with ex-ante probability $\alpha_0 \times x + (1-\alpha_0) \times y = \alpha_0$ and leads to the posterior belief $\mathbb{P}\{\text{good}|\text{high}\} = \frac{\alpha_0 \times x}{\alpha_0 \times x + (1-\alpha_0) \times y} = 1$, whereas the low outcomes happens with probability $\alpha_0 \times (1-x) + (1-\alpha_0) \times (1-y) = 1 - \alpha_0$ and results in the posterior belief of $\mathbb{P}\{\text{good}|\text{low}\} = \frac{\alpha_0 \times (1-x)}{\alpha_0 \times (1-x) + (1-\alpha_0) \times (1-y)} = 0$, exactly as desired by the entrepreneur in this case.

A.2 The investor makes a take-it-or-leave-it offer

It can be seen that in case of the investor making a take-it-or-leave-it offer the subgame[28] equilibrium the entrepreneur's payoff, 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 $\hat{\alpha} \in [(1+\delta)c, 1]$. So the function drawn with the dash-dotted line on the figure is the concavification

[28]to each posterior $\hat{\alpha} \in [0, 1]$ corresponds a subgame

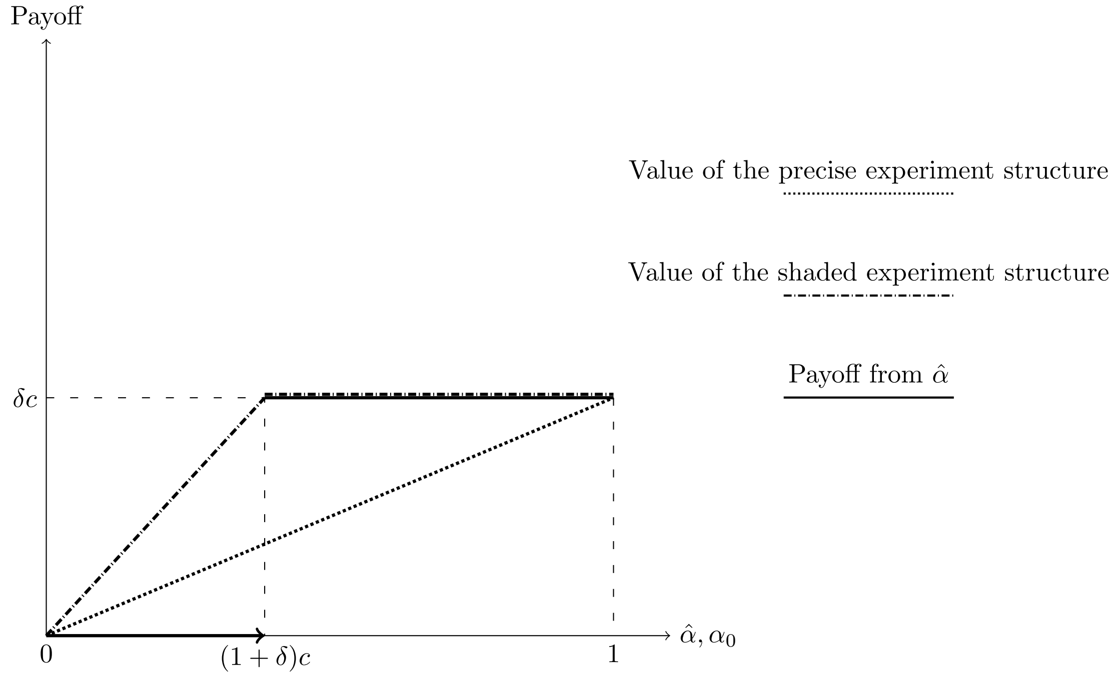


Figure 6: The investor makes a take-it-or-leave-it offer

we are looking for. The algebraic expression for that function is

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

Note that 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 $\{0, (1+\delta)c\}$. Such structure of the experiment would yield an ex-ante expected payoff on dash-dotted line.

For values of the prior α_0 above the threshold $(1+\delta)c$ the entrepreneur is indifferent between any experiment structure, which induce the support of posteriors $\subseteq [(1+\delta)c, 1]$, since any such experiment structure would result in the expected payoff of δc. Note also that an uninformative experiment can also be chosen. So, 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 points is the extreme belief (0 for $\alpha_0 < (1+\delta)c$, 1 for $\alpha_0 \geqslant (1+\delta)c$).

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 distri-*

bution 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 $\alpha_0 \geqslant (1+\delta)c$ *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 the 2, namely, $x = 1, y = \frac{\alpha_0}{1-\alpha_0}\left(\frac{1}{(1+\delta)c} - 1\right)$ results in the desired distribution over posteriors, as described above.

A.3 Nash Bargaining Solution

Consider first the three graphs 7, 8, and 9, which help to characterize the qualitatively different results, depending on the value of the entrepreneur's bargaining power, β. Note

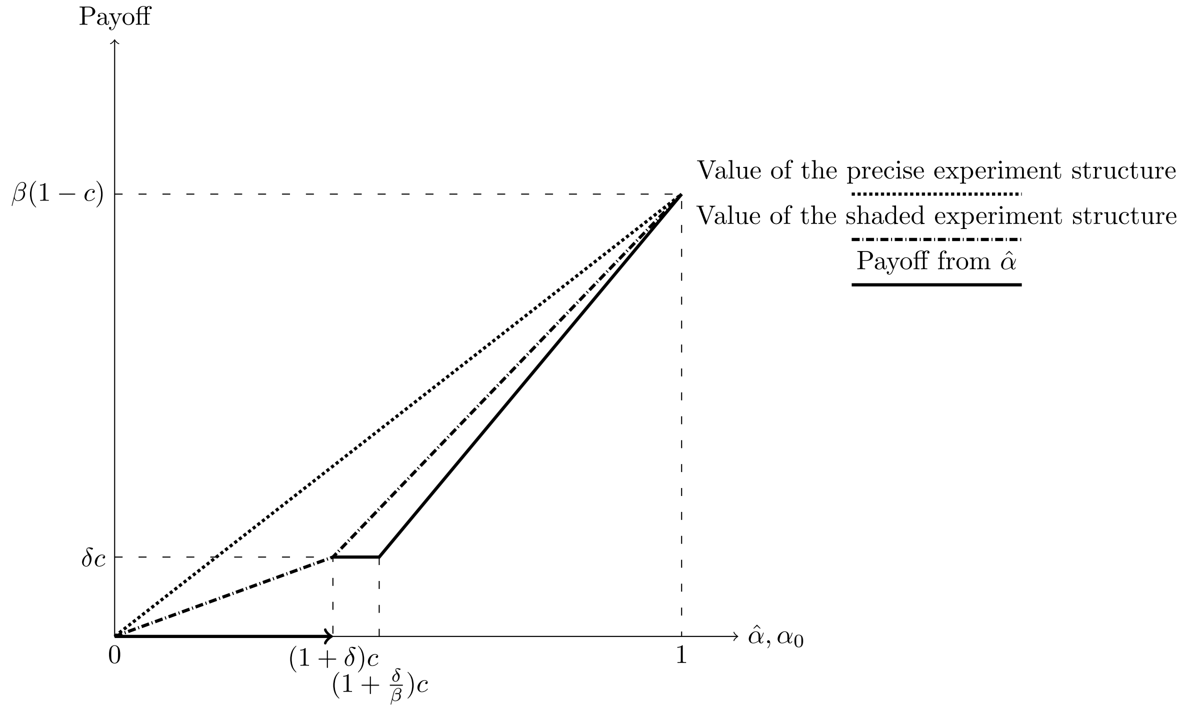


Figure 7: The precise experiment structure is optimal

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 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

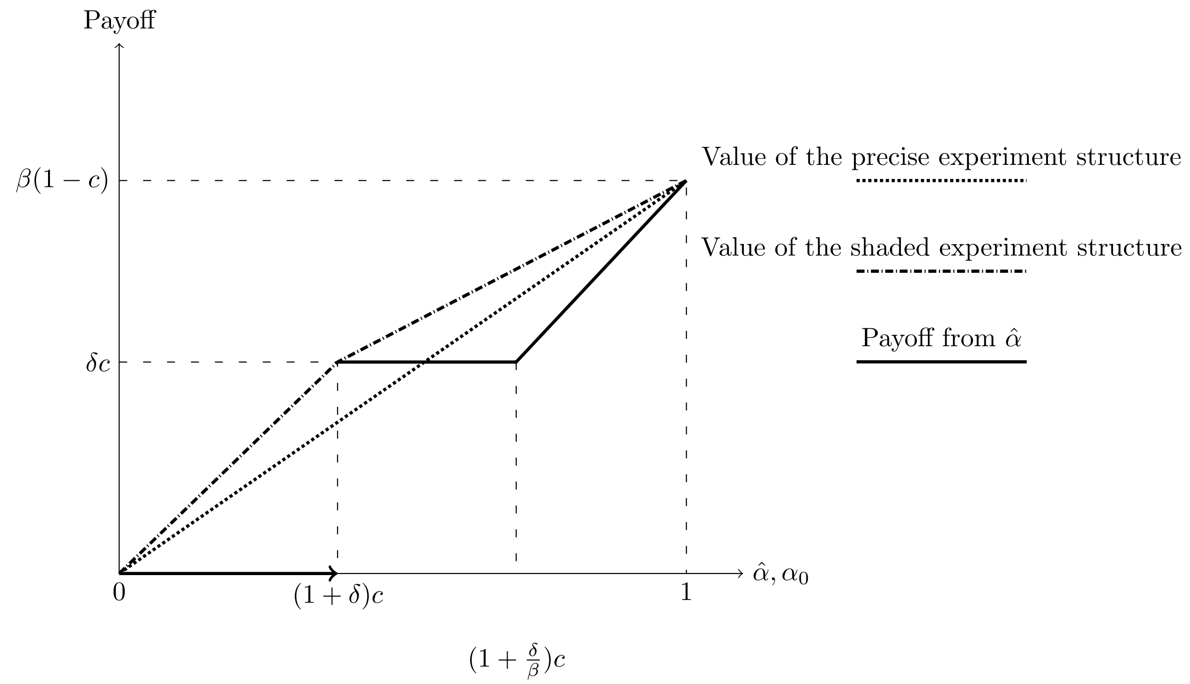


Figure 8: The shaded experiment structure is optimal

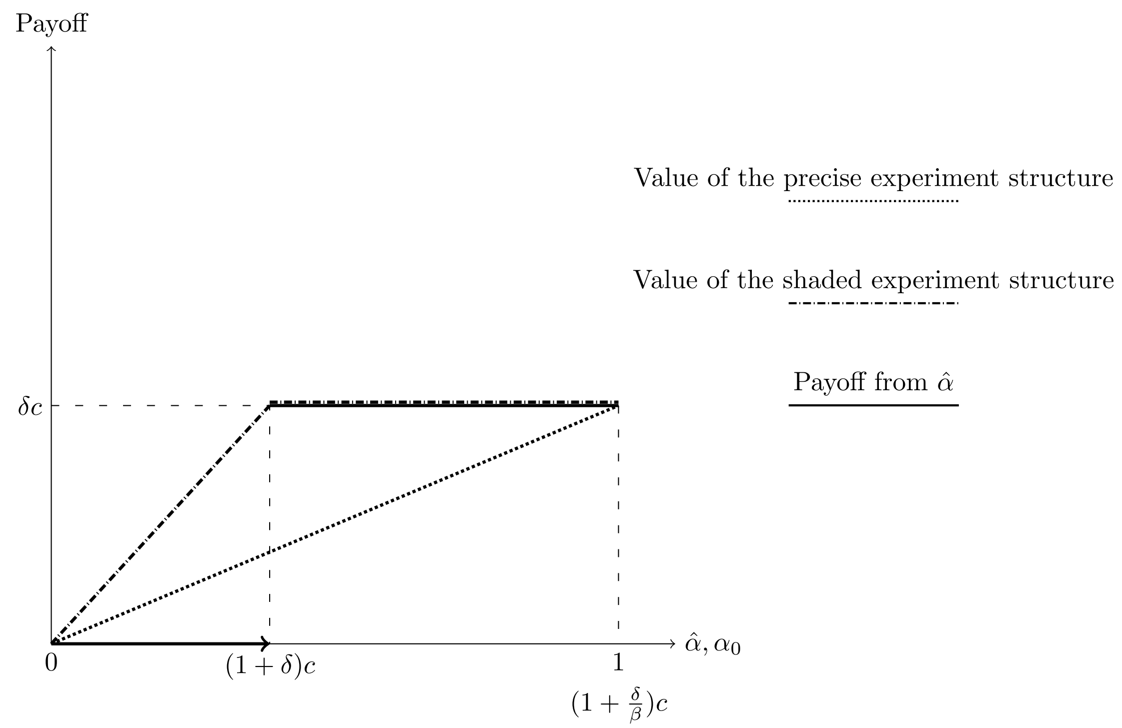


Figure 9: Case $\beta \leqslant \frac{\delta c}{1-c}$ is outcome equivalent to investor making a take-it-or-leave-it offer

sufficient for being 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, $\beta \in \left[\frac{\delta}{(1+\delta)(1-c)}, 1\right]$, 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, $\beta \in \left(\frac{\delta c}{1-c}, \frac{\delta}{(1+\delta)(1-c)}\right)$, the optimal distribution over posterior is:*

  - *If* $\alpha_0 < (1+\delta)c$, $\begin{cases} 0, & \textit{with probability } 1-\frac{\alpha_0}{(1+\delta)c} \\ (1+\delta)c, & \textit{with probability } \frac{\alpha_0}{(1+\delta)c} \end{cases}$
  - *If* $\alpha_0 \geqslant (1+\delta)c$, $\begin{cases} (1+\delta)c, & \textit{with probability } \frac{1-\alpha_0}{1-(1+\delta)c} \\ 1, & \textit{with probability } \frac{\alpha_0-(1+\delta)c}{1-(1+\delta)c} \end{cases}$

- *The case of low bargaining power of the entrepreneur, $\beta \in \left[0, \frac{\delta c}{1-c}\right)$, 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*

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

and for $\alpha_0 \geqslant (1+\delta)c$ 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 of exactly the same reasons.

B Omitted proofs for continuous project returns

B.1 Objective Function Transformation

Note that after a series of transformations the objective function (OF) subject to maximization in the entrepreneur's continuous problem in the section 3 can be rewritten:

$$\begin{aligned}\mathbb{E}_{G_{\hat{\omega}}} V^E(\hat{\omega}) &= \int_0^1 \max\{\delta c, \beta(x-c)\} \mathbb{I}_{\{x \geqslant (1+\delta)c\}} dG_{\hat{\omega}}(x) \\ &= \delta c + \beta(1-c) - \beta \int_0^1 G_{\hat{\omega}}(x)dx \\ &- \delta c \lim_{z \downarrow 0} G_{\hat{\omega}}((1+\delta)c - z) + \beta \int_0^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx.\end{aligned}$$

Note also that the value of $\psi(1) = \int_0^1 G_{\hat{\omega}}(x)dx$ is always equal to $1 - \mathbb{E}\omega$, as it is bound between $t - \mathbb{E}\omega$, and $\int_0^t F(x)dx$, evaluated at $t = 1$. So the expression subject to maximization can be divided into the term which depends on $G_{\hat{\omega}}$ and the term which is constant with respect to $G_{\hat{\omega}}$:

$$\begin{aligned}\mathbb{E}_{G_{\hat{\omega}}} V^E(\hat{\omega}) &= \text{const} - \delta c \lim_{z \downarrow 0} G_{\hat{\omega}}((1+\delta)c - z) + \beta \int_0^{(1+\delta/\beta)c} G_{\hat{\omega}}(x)dx \\ &= \text{const} - \delta c \lim_{z \downarrow 0} \psi'((1+\delta)c - z) + \beta \psi((1+\delta/\beta)c),\end{aligned}$$

where the second equality uses the fact that $\psi(t) = \int_0^t G_{\hat{\omega}}(x)dx$.

Absent of the constraints (CC), and (MPC) the entrepreneur would like to minimize the value of the left derivative of $\psi()$ at point $(1+\delta)c$; and, on the other hand, he would like to maximize the value of $\psi()$ at $(1+\delta/\beta)c$.

B.2 Problem stated as two-variable optimization

Two observations are worth pointing out. First, when the value of $\lim_{z\downarrow} \psi'((1+\delta)c - z)$ is set to its minimum, 0, the maximal possible value for $\psi((1+\delta/\beta)c)$ can be found from the following procedure: find a linear function, tangent to $\int_0^t F_\omega(x)dx$, and which is equal to 0 at $(1+\delta)c$. The value of this linear function evaluated at $(1+\delta/\beta)c$ would yield the maximum possible value for $\psi((1+\delta/\beta)c)$, when the constraints are accounted for. For larger candidate values of $\psi((1+\delta/\beta)c)$ the convexity requirement of ψ will not hold.

Second, when the value of $\psi((1+\delta/\beta)c)$ is set to its maximum, $\int_0^{(1+\delta/\beta)c} F(x)dx$, the minimum possible value for $\lim_{z\downarrow 0} \psi'((1+\delta)c - z)$ is found from the following procedure: find a linear function, tangent to $\int_0^t F_\omega(x)dx$ at $(1+\delta/\beta)c$; evaluate it $(1+\delta)c$; find a second linear function tangent to $\int_0^t F_\omega(x)dx$ at a point below $(1+\delta)c$ such that the value of this second linear function at $(1+\delta)c$ is equal to the value of first linear function at

$(1+\delta)c$. The slope of the second linear function would yield the smallest possible value for the left derivative of $\psi()$ at $(1+\delta)c$. Smaller candidate values for $\lim_{z\downarrow 0}\psi'((1+\delta)c-z)$ will not satisfy the convexity of $\psi()$.

More generically, the following series of lemmas is useful for transforming the entrepreneur's experiment design problem into a two-variable constrained optimization problem:

Lemma B.1. *An optimal function $\psi()$ is such that there is a $\kappa \in (0,(1+\delta)c)$ and $\psi(\kappa)$ is tangent to $\int_0^\kappa F_\omega(x)dx$ and linear with the slope $F_\omega(\kappa)$ in the region $(\kappa,(1+\delta)c)$.*

Proof 1. *Suppose this is not true. Then, $\forall t \in (0,(1+\delta)c)$, $\psi(t) < \int_0^t F_\omega(x)dx$. Then, by convexity of $\psi()$ there is a $t^* < (1+\delta)c$ such that a function $\psi^*()$, which is equal to $\psi()$ everywhere, except $(t^*,(1+\delta)c)$, and is equal to a line segment, connecting $\psi(t^*)$ and $\psi((1+\delta)c)$, is an improvement. The left derivative of this function $\psi^*()$ at $(1+\delta)c$ is smaller than that of $\psi()$.*

Lemma B.2. *An optimal function $\psi()$ is linear in the region $((1+\delta)c,((1+\delta/\beta)c)$.*

Proof 2. *This is because the objective, given a value of left derivative at $(1+\delta)c$, is to maximize the value at of $\psi()$ at $(1+\delta/\beta)c$. Any function with the same value at $(1+\delta/\beta)c$, which is non-linear in the region $((1+\delta)c,(1+\delta/\beta)c)$ would limit the space of continuations of $\psi()$ above $(1+\delta/\beta)c)$, since it would have a higher left derivative at $(1+\delta/\beta)c)$.*

Lemma B.3. *An optimal function $\psi()$ is such that there is a $\tau \in [(1+\delta/\beta)c,1)$ and $\psi(\tau)$ is tangent to $\int_0^\tau F_\omega(x)dx$ and linear with the slope $F_\omega(\tau)$ in the region $((1+\delta/\beta)c,\tau)$.*

Proof 3. *Suppose this is not true. Then, $\forall t \in [(1+\delta/\beta)c,1)$, $\psi(t) < \int_0^t F_\omega(x)dx$. Choose a point $t^* \in ((1+\delta/\beta)c,1)$:$\psi'(t^*) > \lim_{z\downarrow 0}\psi'((1+\delta/\beta)c-z)$ in such a way that a line segment, connecting $\psi((1+\delta)c)$ and $\psi(t^*)$ lies within the constraints. Then, replacing the function $\psi()$ in the region $((1+\delta)c,t^*)$ with the line segment above will be an improvement, since it will yield a higher value at $(1+\delta/\beta)c$.*

If we were to express the value of the left derivative of $\psi()$ at $(1+\delta)c$ it would be equal to $F_\omega(\kappa)$. The value of $\psi()$ at $(1+\delta/\beta)c$, expressed in terms of κ and τ is $\int_0^\kappa F_\omega(x)dx + F_\omega(\kappa)((1+\delta)c-\kappa) + F_\omega(\tau)((1+\delta/\beta)c-(1+\delta)c)$. There are the following constraints on the values of κ and τ: $\kappa \in [0,(1+\delta)c]$;$\tau \in [(1+\delta/\beta)c,1]$; κ and τ are connected by the equation $\int_0^\kappa F_\omega(x)dx + F_\omega(\kappa)((1+\delta)c-\kappa) + F_\omega(\tau)(\tau-(1+\delta)c) =$

$\int_0^\tau F_\omega(x)dx$. After some transformations, the Lagrangian is:

$$\begin{aligned}\mathcal{L} = & -\delta c F_\omega(\kappa) \\ & + \beta\left(\int_0^\kappa F_\omega(x)dx - F_\omega(\kappa)\kappa + F_\omega(\tau)(1+\delta/\beta)c - (1+\delta)c(F_\omega(\tau) - F_\omega(\kappa))\right) \\ & + \lambda\left(\int_\kappa^\tau F_\omega(x)dx - (1+\delta)c(F_\omega(\kappa) - F_\omega(\tau)) - F_\omega(\tau)\tau + F_\omega(\kappa)\kappa\right) \\ & + \lambda_\kappa^1\kappa + \lambda_\kappa^2((1+\delta)c - \kappa) \\ & + \lambda_\tau^1(\tau - (1+\delta/\beta)c) + \lambda_\tau^2(1-\tau).\end{aligned} \tag{L}$$

Non-corner solution The First-Order Condition for the non-corner solution is:

$$\begin{aligned}\kappa(\lambda) &= (1+\delta)c - \frac{\delta c}{\beta - \lambda} \\ \tau(\lambda) &= (1+\delta)c + \frac{\delta c(1-\beta)}{\lambda},\end{aligned} \tag{FOC}$$

and λ follows from the constraint equation[29],

$$\begin{aligned}\int_{\kappa(\lambda)}^{\tau(\lambda)} F_\omega(x)dx = & (1+\delta)c\left(F_\omega(\kappa(\lambda)) - F_\omega(\tau(\lambda))\right) \\ & + F_\omega(\tau(\lambda)) \times \tau(\lambda) - F_\omega(\kappa(\lambda)) \times \kappa(\lambda).\end{aligned}$$

For the equation above it is straightforward to check that the derivative with respect to λ of the left-hand side of the equation is smaller than derivative of the right-hand side of the equation. For the 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.

Conditions for non-corner solution: $\mathbb{E}\omega > (1+\delta)c$ 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 $\lambda \leqslant \lambda_{\max} = \beta - \frac{\delta}{1+\delta}$. Also, τ needs to be less than 1, which in turn holds whenever $\lambda \geqslant \lambda_{\min} = \frac{\delta c(1-\beta)}{1-(1+\delta)c}$. The condition, for which the $\lambda_{\max}$ is actually greater than $\lambda_{\min}$ is $\beta \geqslant \frac{\delta}{(1+\delta)(1-c)}$.

After plugging in the values of $\lambda_{\max}$ and $\lambda_{\min}$ into the constraint equation, we get

[29] This equation is the same as the condition $\mathbb{E}[\omega|\kappa(\lambda) < \omega < \tau(\lambda)] = (1+\delta)c$

the conditions on the distribution and the parameters for the solution to be interior:

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

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 $\beta \geqslant \frac{\delta}{(1+\delta)(1-c)}$, that we required in the previous paragraph. This is because, by ω having the support $[0,1]$, the condition $\mathbb{E}\left[\omega|\omega < (1+\delta)c\frac{\beta}{\beta-\delta(1-\beta)}\right] < (1+\delta)c$ together with $\mathbb{E}[\omega] > (1+\delta)c$ implies $(1+\delta)c\frac{\beta}{\beta-\delta(1-\beta)} < 1 \Rightarrow \beta > \frac{\delta}{(1+\delta)(1-c)}$. This establishes the constraint (BP). Because the condition for interior τ is always satisfied, the only corner solution possible in the current case is $\kappa = 0$.

Conditions for non-corner solution: $(1+\delta)c \geqslant \mathbb{E}\omega$**.** 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 $\psi(1+\delta/\beta)c = (1+\delta/\beta)c - \mathbb{E}\omega$ 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 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 $\int_0^\kappa F_\omega(x)dx + F_\omega(\kappa)((1+\delta)c-\kappa) \geqslant (1+\delta)c - \mathbb{E}[\omega]$. For graphical intuition please refer to the figure 13: Establishing $\underline{\kappa}$. Thus the only major thing that changes in the analysis is that now, instead of the constraint $\kappa \geqslant 0$, κ must be high enough so that $\int_0^\kappa F_\omega(x)dx + F_\omega(\kappa)((1+\delta)c-\kappa) \geqslant (1+\delta)c - \mathbb{E}[\omega]$. Other than replacing one of the constraints and modifying the Lagrangian, the solution remains the same.

Redefine the values $\lambda_{\max}$ and $\lambda_{\min}$ as in the main text. Namely, $\lambda_{\max}$ follows from

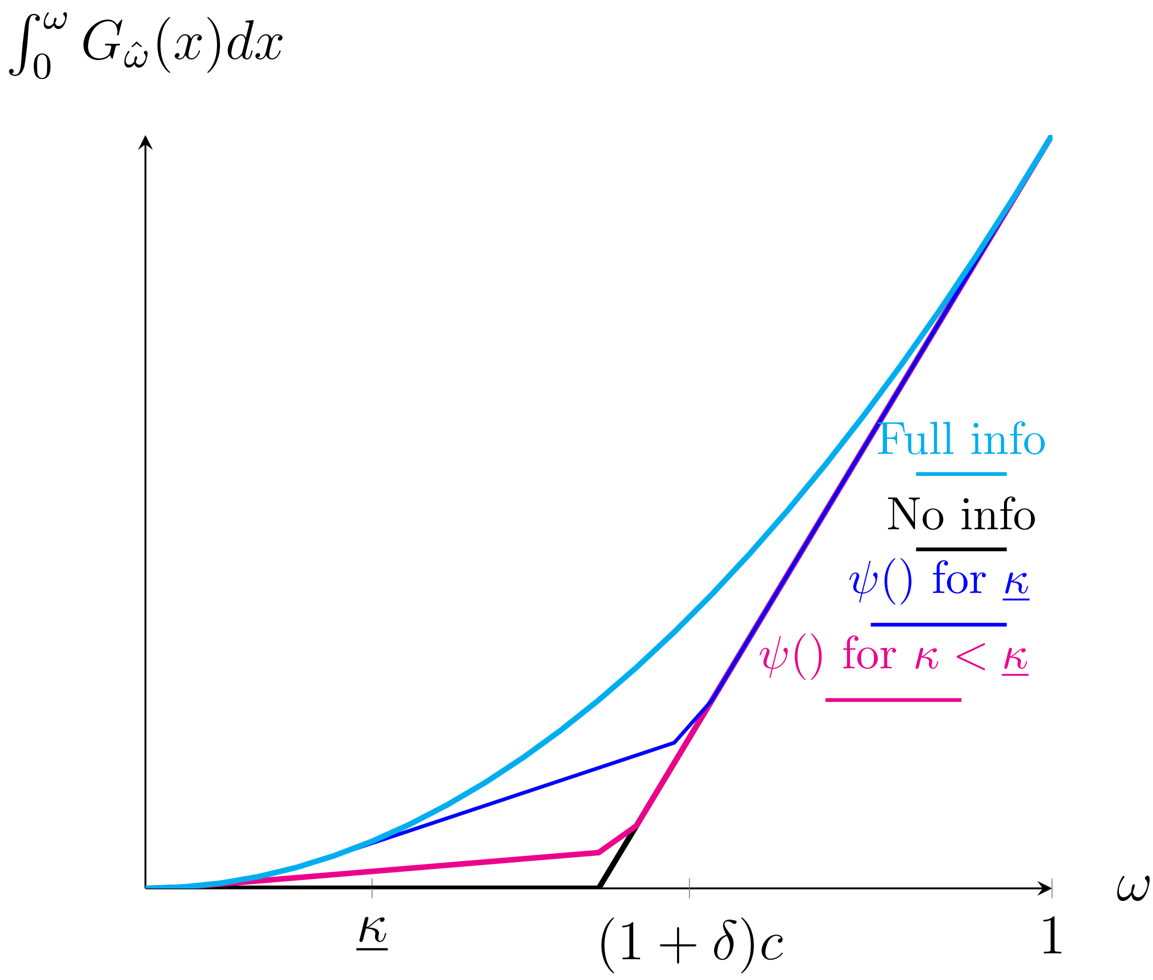


Figure 10: Establishing $\underline{\kappa}$

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 $\tau(\lambda) = (1+\delta)c + \frac{\delta c(1-\beta)}{\lambda}$. Define the following conditions:

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

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

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

Comparative Statics with respect to β Applying 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:

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

Since with the increase of κ and the decrease of τ the most informative of the functions[30] $\psi()$ gets closer to $\int_0^t F(x)dx$, which corresponds to full information.

[30]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

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