Online Appendix

1 Continuous Effort

In our main setting, the effort decision is binary: the entrepreneur either exerts effort or not. We now examine a setting with continuous effort. We use the same setup as that of the main model in our paper, except that we assume the entrepreneur makes effort, e, to improve the outcome, and the cost of the effort is $C(e) \equiv ce^2/2$. The probability of success is increased by e; that is, the probability of success will increase to $p_G + e$ for a good project and $p_B + e$ for a bad project.

We first analyze a benchmark in which the entrepreneur has sufficient funds and thus no financial leverage. In this benchmark the net return from the effort is $eX - ce^2/2$, and therefore the first-best effort level e^o to maximize the net return is $e^o \equiv X/c$. We assume that $X(p_B + e^o) > I + C(e^o)$; that is, at the first-best effort level, e^o, a bad project can be improved to be profitable and yields a positive NPV. It is easy to verify that the entrepreneur always pursues the project and exerts the first-best effort e^o regardless of the project type, and thus information quality plays no role in this benchmark.

When the entrepreneur has financial leverage, by backward induction, we start with the entrepreneur's effort decision on date 3 given the creditor's requested repayment D_S, $S \in \{g, b\}$. The entrepreneur's expected payoff conditional on signal S (denoted by Π_S) is given by

$$\Pi_S = [\theta_S p_G + (1-\theta_S) p_B + e](X - D_S) - ce^2/2 - A.$$

The entrepreneur's equilibrium effort (denoted by e_S, $S \in \{g, b\}$) to maximize Π_S is given by

$$e_S = (X - D_S)/c < e^o.$$

On date 2, given the realized signal S, the creditor decides whether to lend, and if she lends, she also decides the requested repayment D_S in order to break even. As the creditor conjectures the entrepreneur's effort to be $e_S = (X - D_S)/c$, her break-even condition is

$$[\theta_S p_G + (1-\theta_S) p_B + (X - D_S)/c] \cdot D_S = \beta I,$$

and therefore

$$D_S = \frac{1}{2}\left[X + c(\theta_S p_G + (1-\theta_S) p_B) - \sqrt{[X + c(\theta_S p_G + (1-\theta_S) p_B)]^2 - 4c\beta I}\right].$$

Now we consider the entrepreneur's initial investment decision on date 1, given the realized signal S. After substituting e_S into the above equation of Π_S, we have

$$\Pi_S = \left[\theta_S p_G + (1-\theta_S)\, p_B + (X - D_S)/c\right](X - D_S) - \frac{c}{2}\left[(X - D_S)/c\right]^2 - A.$$

The entrepreneur pursues the project and seeks financing only if $\Pi_S > 0$. If $\Pi_S < 0$, the entrepreneur forgoes the project and earns a zero payoff. We find that

$$\frac{d}{d\theta_S}\Pi_S = \underbrace{\frac{\partial}{\partial\theta_S}\Pi_S}_{=(p_G-p_B)(X-D_S)>0} + \underbrace{\frac{\partial}{\partial D_S}\Pi_S}_{=-(X-D_S)/c<0} \cdot \underbrace{\frac{\partial}{\partial\theta_S}D_S}_{<0} > 0.$$

Since Π_S monotonically increases in θ_S, we have $\Pi_S > 0$ if θ_S is sufficiently strong. We summarize our findings of the equilibrium in the following proposition.

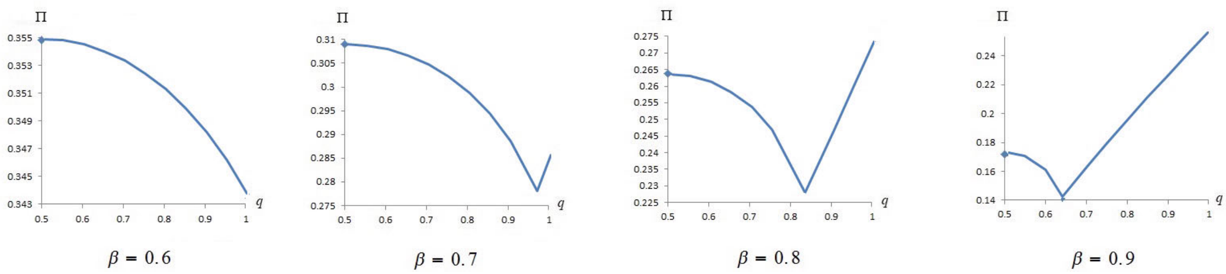
Proposition 1

- In equilibrium, there exists a threshold, θ^*, such that the entrepreneur pursues the project and exerts effort if $\theta_S > \theta^*$, and foregoes the project otherwise. The threshold θ^* increases in β.
- If the entrepreneur pursues the project, his equilibrium effort level $e_S = (X - D_S)/c$ decreases in β, increases in θ_S, and is always lower than e^o.

The result that the entrepreneur pursues the project and exerts effort if θ_S is sufficiently strong and foregoes the project otherwise is consistent with our main setting result that the entrepreneur pursues the project with his effort if $\beta < T(\theta_S)$. Since $T(\theta_S)$ increases in θ_S, the condition, $\beta < T(\theta_S)$, implies that θ_S is sufficiently strong. In addition, the threshold θ^* increases in the leverage β implies that the entrepreneur is more likely to pursue the project with a lower β. The reason is that when the leverage is lower, the requested repayment is lower, which induces a higher level of effort in equilibrium. With a higher effort level, the effort return is higher which encourages the entrepreneur to pursue the project.

If β is sufficiently high and $S = b$, the entrepreneur foregoes the project; a bad signal realization leads to a weak posterior belief θ_b, and a high leverage β implies a higher threshold θ^*, and both result in the entrepreneur's foregoing of the project. This is because the entrepreneur anticipates that even if he undertakes the project, the requested repayment would be so high that his ex-post effort would be discouraged, resulting in a negative NPV.

Figure 1 The optimal information quality given different levels of financial leverage



Notes: $I = 1$, $X = 3$, $P_G = 0.4$, $P_B = 0.25$, $\theta = 0.5$, and $c = 10$.

If the entrepreneur pursues the project, we find his equilibrium effort e_S decreases in leverage and increases in the posterior belief. This is also consistent with our main-setting results that (1) the always-effort case is achieved when β is low, and the never-effort case is achieved when β is high, and (2) the effort threshold $T(\theta_S)$ increases in θ_S, which implies that a higher posterior belief θ_S makes it easier to induce effort in equilibrium.

In this continuous-effort setting, it is difficult to obtain a closed-form solution of the equilibrium threshold θ^*, and thus we do not have a closed-form expression for the entrepreneur's expected payoff (which represents efficiency) to analyze the optimal information quality. Therefore, we resort to numerical analysis and illustrate our findings in Figure 1. We find that with continuous effort, our main results remain the same: When financial leverage is low (high), the optimal information quality is also low (high). Specifically, we find that efficiency decreases in information quality when leverage is low. This is because with low leverage, the entrepreneur retains most of the project's cash flow and is motivated to exert effort regardless of signal realization. As information quality increases, the requested repayment would increase significantly conditional on a bad signal, which discourages the ex-post effort level and reduces efficiency. As a result, low information quality is optimal. We also find that efficiency increases in information quality when leverage is high. With high leverage, the entrepreneur pursues the project only conditional on a good signal. As information quality increases, a good signal of high quality reveals a good-type project, lowers the requested repayment and thus induces a higher level of effort; as a result, the optimal information quality is perfect information quality.

Note that with continuous effort, we do not find an interior optimal information quality in our numerical analysis. This is because with continuous effort, the equilibrium is different from that in the main setting. In particular, in the main setting with binary effort, if the entrepreneur pursues the project, he either exerts no effort ($e = 0$) or exerts effort ($e = 1$). In contrast, in the continuous-effort setting, once the entrepreneur pursues the project, he always exerts a positive level of effort; however, the effort level varies with information quality. With a binary effort decision in the main setting, the determinant of efficiency is whether effort is exerted, whereas with continuous effort, the determinant is the level of effort.

In our binary-effort main setting, as illustrated in Panel (II) of Figure 4, there is an optimal interior information quality when (1) the equilibrium switches from the never-effort case to the effort-only-with-g case as information quality increases, and (2) efficiency decreases in information quality in the effort-only-with-g case. The latter happens with a sufficiently low θ, because effort is exerted ($e = 1$) only when a good signal g is obtained but higher information quality decreases the likelihood of obtaining a good signal. With continuous effort, there is no never-effort case and efficiency increases in information quality in the effort-only-with-g case even with a low θ. Although higher information quality decreases the likelihood of receiving a good signal, it reduces the requested repayment significantly conditional on a high-quality good signal, which induces much higher effort level. In contrast, in the binary-effort main setting there is no change in effort level when $e = 1$. As a result, there is no interior optimal information quality level. Nevertheless, in both settings, our main results remain the same: when financial leverage is low (high), the optimal information quality is also low (high).

2 Continuous Signal

In our main setting, the signal about project types is binary; we now consider a continuous signal, $S \in [\underline{S}, \bar{S}]$. Conditional on a good project, the density function of S is denoted by f_G, and its cumulative distribution function is denoted by F_G; conditional on a bad project, the density function of S is denoted by f_B, and its cumulative distribution function is denoted by F_B. We assume the distribution conditional on a good project dominates the distribution conditional on a bad project in the sense of the monotone likelihood ratio property (MLRP). The posterior probability of a good project conditional on a realized signal is denoted by θ_S, $S \in [\underline{S}, \bar{S}]$, and we have

$$\theta_S = H(S) \equiv \frac{\theta f_G(S)}{\theta f_G(S) + (1-\theta) f_B(S)},$$

where $H(\cdot)$ is a function of the signal realization S. It is easy to see that the posterior belief θ_S monotonically increases in the signal S, given the property of MLRP (i.e., $H'(\cdot) > 0$). In this setting, we do not have q as the measure of information quality. Instead, the information quality of S can be captured by $F_G(S)$ and $F_B(S)$. When information quality is higher, $F_G(S)$ (i.e., the probability that a good type receives a signal lower than S) is lower and

$F_B(S)$ (i.e., the probability that a bad type receives a signal lower than S) is higher. The rest of the model set up remains the same as in the main setting.

Similar to the analysis in our main setting, we find that, given the realized signal S, the entrepreneur exerts effort if $\beta < T(\theta_S) \equiv [\theta_S (p_G - p_B) + p_B + \Delta p] (X - c/\Delta p) / I$. Since $T(\theta_S)$ increases in θ_S and θ_S increases in S, we have that $T(\theta_S)$ increases in S. When financial leverage is low ($\beta < T(\theta_S)$), the entrepreneur always pursues the project and exerts effort. When financial leverage is high ($\beta > T(\theta_S)$), no effort is exerted in equilibrium; the entrepreneur pursues the project and the creditor funds it only when $\theta_S > \theta^u \equiv (I/X - p_B) / (p_G - p_B)$. We characterize the equilibrium decisions as follows:

Proposition 2 *1. **Always-effort case:** When $\beta < T(\theta_{\underline{S}})$, the project is always undertaken and the entrepreneur always exerts effort regardless of the realized signal.*

*2. **Effort-only-with-high-signal case:** When $T(\theta_{\underline{S}}) < \beta < T(\theta_{\bar{S}})$, the project is undertaken and the entrepreneur exerts effort if the signal is high (i.e., $S > \hat{S}$) and no effort is made otherwise. Specifically,*

- *if the signal is high, the project is undertaken and the entrepreneur exerts effort;*
- *if the signal is low, the project is undertaken but the entrepreneur makes no effort if $\theta_S > \theta^u$; otherwise the project is foregone.*
- *$\hat{S} \equiv H^{-1}[T^{-1}(\beta)]$, where $H^{-1}(\cdot)$ ($T^{-1}(\cdot)$) is the inverse function of $H(\cdot)$ ($T(\cdot)$).*

*3. **Never-effort case:** When $\beta > T(\theta_{\bar{S}})$, the entrepreneur makes no effort regardless of the realized signal. The project is undertaken if $\theta_S > \theta^u$; otherwise the project is foregone.*

The three equilibrium cases are very similar to those in the main setting, except that we now have an effort-only-with-high-signal case instead of the effort-only-with-g case. Here in the effort-only-with-high-signal case, there exists a cutoff point denoted by $\hat{S}$, such that the entrepreneur exerts effort if the realized signal is higher than the cutoff ($S > \hat{S}$). When $S > \hat{S}$, the posterior belief θ_S is high enough to induce effort in equilibrium (i.e., $\beta < T(\theta_S)$ is satisfied). The cutoff point $\hat{S}$ is determined by the leverage level β. A higher leverage leads to a higher threshold which reduces the chance of effort in equilibrium.

We find that the impact of information quality on efficiency is similar to that in the main setting with similar intuition. We summarize the results below.

Proposition 3 *(i) In the always-effort case, efficiency is independent of information quality.*

(ii) In the effort-only-with-high-signal case, efficiency increases in information quality when $\theta > \theta_1$, and may decrease in information quality when $\theta < \theta_2$.

(iii) In the never-effort case, efficiency increases in information quality.

The cutoffs θ_1 and θ_2 are defined in the proof.

The results regarding the optimal information quality, given different levels of leverage, are similar to those in the main setting too, as we show below:

Proposition 4

- *When β is low ($\beta < \beta_1$), it is optimal to have low information quality.*
- *When β is intermediate ($\beta_1 < \beta < \beta_2$) and $\theta < \theta_2$, an intermediate level of information quality is optimal.*
- *When β is high ($\beta > \beta_2$, or $\beta > \beta_1$ and $\theta > \theta_1$), the highest information quality is optimal.*

$\beta_1 \equiv [\theta(p_G - p_B) + p_B + \Delta p](X - c/\Delta p)/I < \beta_2 \equiv [p_G + \Delta p](X - c/\Delta p)/I.$

Proofs

Proof of Proposition 1

Proof. Since Π_S monotonically increases in θ_S, it is easy to see that there exists a unique threshold θ^* such that $\Pi_S > 0$ if $\theta_S > \theta^*$. Also, we have

$$\frac{d}{d\beta}\Pi_S = \underbrace{\frac{\partial}{\partial D_S}\Pi_S}_{=-(X-D_S)/c<0} \cdot \underbrace{\frac{\partial}{\partial \beta}D_S}_{>0} < 0.$$

Therefore, it is harder to have $\Pi_S > 0$ if β is higher. That is, the threshold θ^* increases in β. In addition,

$$\frac{d}{d\beta}e_S = \underbrace{\frac{\partial}{\partial D_S}e_S}_{=-1/c<0} \cdot \underbrace{\frac{\partial}{\partial \beta}D_S}_{>0} < 0 \text{ and } \frac{d}{d\theta_S}e_S = \underbrace{\frac{\partial}{\partial D_S}e_S}_{=-1/c<0} \cdot \underbrace{\frac{\partial}{\partial \theta_S}D_S}_{<0} > 0;$$

that is, e_S decreases in β, and increases in θ_S. ■

Proof of Propositions 2 and 3

Proof. In the always-effort case, efficiency is independent of information quality since neither the effort decision nor the investment decision depends on the realized signal. In the effort-only-with-high-signal case, if the realized signal is low ($S < \hat{S}$), the project is still undertaken if $\theta_S > \theta^u$, which can be rewritten as $S > H^{-1}(\theta^u)$. If $\hat{S} > H^{-1}(\theta^u)$ (which implies

$\beta > T(\theta^u)$), the entrepreneur exerts effort when $S > \hat{S}$, the entrepreneur makes no effort but the project is undertaken if $H^{-1}(\theta^u) < S < \hat{S}$, and the project is foregone otherwise. The entrepreneur's expected payoff is as follows:

$$\begin{aligned} \Pi &= \theta\{\left[F_G\left(\hat{S}\right) - F_G\left(H^{-1}(\theta^u)\right)\right][p_G X - I] + \left[1 - F_G\left(\hat{S}\right)\right][(p_G + \Delta p) X - I - c]\} \\ &\quad + (1-\theta)\left\{\left[F_B\left(\hat{S}\right) - F_B\left(H^{-1}(\theta^u)\right)\right][p_B X - I] + \left[1 - F_B\left(\hat{S}\right)\right][(p_B + \Delta p) X - I - c]\right\}. \end{aligned} \tag{1}$$

If $\hat{S} < H^{-1}(\theta^u)$ (which implies $\beta < T(\theta^u)$), the entrepreneur exerts effort when $S > \hat{S}$ and the project is foregone otherwise. The entrepreneur's expected payoff is

$$\Pi = \theta\left[1 - F_G\left(\hat{S}\right)\right][(p_G + \Delta p) X - I - c] + (1-\theta)\left[1 - F_B\left(\hat{S}\right)\right][(p_B + \Delta p) X - I - c]. \tag{2}$$

One can easily see that, in both cases, Π increases in information quality when θ is high. With higher information quality, $F_G(\cdot)$ is lower and $F_B(\cdot)$ is higher. For convenience, given a marginal increase in information quality, the marginal change in $F_G(\cdot)$ is denoted by $F_G'(\cdot) < 0$, and the marginal change in $F_B(\cdot)$ is denoted by $F_B'(\cdot) > 0$. From (1), the marginal change of Π given a marginal increase in information quality is

$$\begin{aligned} &-\theta\left[F_G'\left(H^{-1}(\theta^u)\right)(p_G X - I) + F_G'\left(\hat{S}\right)(\Delta p X - c)\right] \\ &-(1-\theta)\left[F_B'\left(H^{-1}(\theta^u)\right)(p_B X - I) + F_B'\left(\hat{S}\right)(\Delta p X - c)\right]. \end{aligned}$$

From (2), the marginal change of Π given a marginal increase in information quality is

$$-\theta F_G'\left(\hat{S}\right)[(p_G + \Delta p) X - I - c] - (1-\theta) F_B'\left(\hat{S}\right)[(p_B + \Delta p) X - I - c].$$

The marginal change of Π is positive in both cases when $\theta > \theta_1$, where θ_1 is the maximum of

$$\frac{F_B'\left(\hat{S}\right)[(p_B + \Delta p) X - I - c]}{F_B'\left(\hat{S}\right)[(p_B + \Delta p) X - I - c] - F_G'\left(\hat{S}\right)[(p_G + \Delta p) X - I - c]}$$

and

$$\frac{F_B'\left(H^{-1}(\theta^u)\right)(p_B X - I) + F_B'\left(\hat{S}\right)(\Delta p X - c)}{Z},$$

$Z \equiv H^{-1}(\theta^u)\left[F_B'(p_B X - I) - F_G'(p_G X - I)\right] + \left(F_B'\left(\hat{S}\right) - F_G'\left(\hat{S}\right)\right)(\Delta p X - c)$. Conversely, the marginal change of Π is negative in both cases when $\theta < \theta_2$, where θ_2 is the minimum of

$$\frac{F_B'\left(\hat{S}\right)\left[(p_B + \Delta p)X - I - c\right]}{F_B'\left(\hat{S}\right)\left[(p_B + \Delta p)X - I - c\right] - F_G'\left(\hat{S}\right)\left[(p_G + \Delta p)X - I - c\right]}$$

and

$$\frac{F_B'\left(H^{-1}\left(\theta^u\right)\right)\left(p_B X - I\right) + F_B'\left(\hat{S}\right)\left(\Delta p X - c\right)}{Z}.$$

In the never-effort case, information quality only affects the investment decision. The entrepreneur's expected payoff is

$$\Pi = \theta\left[1 - F_G\left(H^{-1}\left(\theta^u\right)\right)\right]\left[p_G X - I\right] + (1-\theta)\left[1 - F_B\left(H^{-1}\left(\theta^u\right)\right)\right]\left[p_B X - I\right].$$

The information quality improves efficiency through the investment decision. With higher information quality, $F_G(\cdot)$ is lower and $F_B(\cdot)$ is higher. Since $p_G X - I > 0$ and $p_B X - I < 0$, the efficiency benefits from both a lower $F_G(\cdot)$ and a higher $F_B(\cdot)$, and Π is higher. ■

Proof of Proposition 4

Proof. The highest $T(\theta_{\underline{S}})$ is achieved when the information quality is the lowest. That is, θ_S stays the same as the prior belief θ regardless of the signal S. We have $\beta_1 \equiv T(\theta) = [\theta(p_G - p_B) + p_B + \Delta p](X - c/\Delta p)/I$. If β is low ($\beta < \beta_1$), the always-effort case can be achieved when the information quality is sufficiently low. Therefore, low information quality is optimal. Specifically, the always-effort case is achieved when $\beta < T(\theta_{\underline{S}})$, which can be written as

$$\theta_{\underline{S}} > \frac{\beta I/(X - c/\Delta p) - (p_B + \Delta p)}{p_G - p_B}.$$

Since $\theta_{\underline{S}} = H(\underline{S}) \equiv \theta f_G(\underline{S}) / [\theta f_G(\underline{S}) + (1-\theta) f_B(\underline{S})]$, we find the condition of always-effort case is

$$\frac{f_G(\underline{S})}{f_B(\underline{S})} > \frac{[\beta I/(X - c/\Delta p) - (p_B + \Delta p)](1-\theta)}{[p_G + \Delta p - \beta I/(X - c/\Delta p)]\theta}.$$

The highest $T(\theta_{\bar{S}})$ is achieved when the information quality is the highest. That is, $\theta_{\bar{S}} = 1$ and $\beta_2 \equiv T(\theta_{\bar{S}} = 1) = [p_G + \Delta p](X - c/\Delta p)/I$. When β is intermediate ($\beta_1 < \beta < \beta_2$), the never-effort case is achieved when information quality is low and then switches to effort-only-with-high-signal case as information quality increases. As efficiency decreases in information quality when $\theta < \theta_2$, efficiency is maximized at the point when the never-effort case switches to the effort-only-with-g case. If $\theta > \theta_1$, efficiency increases in information quality, and thus the highest information quality is optimal. When β is high ($\beta > \beta_2$), the never-effort case is always achieved regardless of q. Since efficiency increases in information quality in the never-effort case, the highest information quality is optimal. ■