Real Effects of Information Processing Costs

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Abstract

Reducing information processing costs is widely seen as a means to improve price informativeness and overall welfare. In this paper, we develop a model to examine the real effects of such cost reductions on corporate investment levels and their welfare implications for capital market participants. We show that corporate investment follows an inverted U-shaped pattern with respect to processing costs. This non-monotonic relation follows from two opposing forces. On one hand, lower processing costs improve price informativeness, which reduces agency frictions and increases entrepreneurs' financing capacity. On the other hand, they increase speculators' trading profits in the secondary market at the expense of initial investors, forcing entrepreneurs to compensate initial investors for future losses and reducing their financing capacity. Moreover, since trading profits are merely transfers among market participants rather than net gains, lowering processing costs does not necessarily benefit entrepreneurs or investors, nor does it always enhance overall welfare.

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1. Introduction

Investors incur costs when acquiring and interpreting information, such as analyzing firm disclosures, parsing financial statements, or understanding regulatory filings. Reducing these information processing costs is commonly regarded as a means to enhance price informativeness and overall welfare. The key argument is that when these costs outweigh the expected gains from trading, investors may ignore disclosures, leaving the information unpriced (see Blankespoor, deHaan, and Marinovic 2020 for a recent review of the literature). To address this issue, the U.S. Securities and Exchange Commission (SEC) introduced EDGAR in 1994 as an electronic repository for regulatory filings and later mandated that companies submit financial reports in a machine-readable format (i.e., XBRL). At the corporate level, Investor Relations (IR) departments play a crucial role in reducing processing costs by organizing investor websites that centralize financial disclosures. Additionally, many companies host earnings conference calls, where executives discuss financial performance and future outlook, often providing transcripts to ensure broader accessibility. Collectively, these efforts help reduce information processing costs, thereby enhancing the accessibility of financial information to investors.

While reducing investors' information processing costs can enhance price informativeness and potentially improve overall welfare, it remains unclear whether this also introduces potential costs, and if so, in what form. Lower processing costs increase trading profits, yet these gains often represent wealth redistribution rather than creation—benefiting informed traders at the expense of those trading for liquidity needs or with informational disadvantages. Murphy, Shleifer, and Vishny (1991) provide historical and cross-country evidence indicating that economies grow more rapidly when talented individuals pursue engineering and entrepreneurship, which drive wealth creation, whereas economies where talent is disproportionately allocated to "rent-seeking" activities, such as law and financial services, often experience stagnation. These findings suggest that lowering information processing costs for investors—who often benefit from wealth redistribution—may not necessarily enhance overall welfare, or even investors' own welfare, if it distorts wealth distribution in ways that discourage entrepreneurial activity and reduce economic growth.

In this paper, we develop a model to examine the real effects of information processing costs and evaluate their welfare implications for investors, entrepreneurs, and overall economic well-being. Our framework features an entrepreneur and two types of investors: initial investors and a speculator. The entrepreneur, who has a project and personal wealth, seeks external financing from initial investors to expand an investment opportunity that yields a positive expected NPV. Initial investors represent a large pool of capital providers (e.g., households or institutions) who, in practice, supply capital through financial intermediaries (e.g., hedge funds or mutual funds) that connect them with entrepreneurs. After investing in the project, the entrepreneur faces a moral hazard problem: he may choose to shirk (e.g., choose low effort) and extract private benefits, rendering the project unprofitable. To prevent shirking, the entrepreneur's compensation is tied to the firm's interim stock price, which serves as a performance measure. The stock price is determined by the trading activity between initial investors, who may have liquidity needs at an interim date, and a speculator, whose ability to acquire information about firm performance depends on the information processing costs.

Reducing information processing costs has two opposing effects on the investment level. On one hand, lower processing costs allow the speculator to acquire more precise information, enhancing the extent to which stock prices reflect the entrepreneur's economic actions. As a result, the interim stock price serves as a more precise performance measure, which reduces the moral hazard problem and enhances the entrepreneur's financing capacity. On the other hand, lower processing costs increase the speculator's trading profits at the expense of initial investors. To raise capital, the entrepreneur must compensate initial investors for the expected liquidity trading losses, which reduces his financing capacity. As a result, the investment level is an inverted U-shaped function of processing costs, reaching its maximum at an interior point.

We find that entrepreneur welfare also follows an inverted U-shaped function of information processing costs, indicating that reducing these costs does not always benefit the entrepreneur. This occurs because the entrepreneur benefits from scaling up a project with positive NPV, and the investment level itself is an inverted U-shaped function of the processing costs. Furthermore, the processing cost level that maximizes entrepreneur welfare exceeds the level that maximizes financing capacity. As information processing costs rise, initial investors face smaller trading losses and require lower compensation from the entrepreneur, which reduces the entrepreneur's financing costs for any given investment level. Consequently, the entrepreneur's optimal processing cost balances the goal of expanding financing capacity with the desire to reduce financing costs.

We also examine the impact of information processing costs on investor welfare. Investor welfare is equivalent to speculator welfare because the entrepreneur compensates initial investors for expected liquidity trading losses. As the investment level influences the size of the speculator's trading profit, investor welfare is also an inverted U-shaped function of processing costs. Thus, investors do not always benefit from lower processing costs. A lower investment leads to a decrease in wealth creation, which, in turn, reduces trading profits. The processing costs that maximize investor welfare lie below those that maximize corporate investment. This follows because, for a given investment level, a decline in processing costs increases the speculator's trading profits. Since entrepreneurs prefer higher processing costs than those that maximize the investment level, investors prefer lower processing costs than entrepreneurs.

Social welfare is maximized at an intermediate level of information processing costs, which falls between the levels that maximize the welfare of entrepreneurs and investors. Consequently, prioritizing either entrepreneur or investor welfare alone does not improve overall social welfare. Unlike entrepreneur and investor welfare, social welfare excludes both the speculator's trading profits and the entrepreneur's costs associated with initial investors' liquidity trading because they are merely transfers between market participants. Lower processing costs increase the entrepreneur's financing costs, but they also increase the speculator's trading profits. As a result, social welfare is less responsive to the negative impact of lower processing costs than entrepreneur welfare and is less responsive to the positive effects of lower processing costs than investor welfare.

Research has shown that information embedded in stock prices can act as a form of market-based monitoring of managerial actions, thereby reducing agency costs (see Tirole 2006, chapter 8).[1] Holmström and Tirole (1993) show that lower ownership concentration increases liquidity trading, which encourages speculators to acquire information, thereby mitigating

[1] For example, informative stock prices facilitate external discipline by takeover threats (Kyle and Vila 1991), internal discipline by large shareholders (Faure-Grimaud and Gromb 2004), improve the effectiveness of managerial compensation (Dow and Gorton 1997), and incentivize managers to pursue profitable projects (Edmans 2009).

managerial agency frictions. In their model, the level of investment is exogenous and firms face no financing constraints, so the capital market's role is limited to generating information about managers' actions through the pricing of secondary market trades. By contrast, our study focuses on how information processing costs shape secondary market trading and influence the investment level in the primary market. Accordingly, we derive novel empirical predictions linking information processing costs to corporate investment. Additionally, we evaluate the welfare implications of changes in information processing costs for all market participants, including project owners and investors, analyzing their impact on social welfare through both wealth creation and distribution.

While the focus of our paper differs, it also relates to accounting research that studies how disclosure and financial reporting influence managerial learning from stock prices in secondary markets. Dye and Sridhar (2002) analyze a setting in which managers announce a change in business strategy and subsequently use the market's price reaction to decide whether to move forward with its implementation. Arya, Mittendorf, and Ramanan (2017) examine the relation between accounting reports and stock prices in affecting firm strategies, showing that backward-looking disclosures enhance the extraction of forward-looking information from market reactions. Langberg and Sivaramakrishnan (2010) and Kumar, Langberg, and Sivaramakrishnan (2012) examine voluntary disclosure decisions in the presence of feedback effects. Several studies examine how market feedback influences firms' disclosure choices, including disclosure quality (Gao and Liang, 2013) and the adoption of conservative accounting rules (Chen et al., 2021). More recently, Chen and Petrov (2024) investigate how market feedback affects earnings management.

Our paper also contributes to the archival literature that examines how increases in information processing costs affect price informativeness and market outcomes (e.g., Hirshleifer, Lim, and Teoh 2009; DeHaan, Shevlin, and Thornock 2015). There is growing interest in understanding the real effects of processing costs. For example, Kempf, Manconi, and Spalt (2017) document that firms are more likely to pursue value-destroying acquisitions when their institutional investors are distracted, suggesting that higher processing costs weaken investor monitoring. More recently, Goldstein, Yang, and Zuo (2023) find empirical evidence that the implementation of EDGAR between 1993 and 1996 led to increased corporate investment among value firms. Our model suggests that the relation between information processing costs and firms' financing capacity is non-monotonic. Reducing these costs boosts financing capacity only up to a critical threshold. Once they fall below this threshold, any further decline in processing costs has a negative effect on the investment level. We derive the precise conditions under which changes in processing costs increase or decrease corporate investment, depending on factors such as the strength of corporate governance. In addition, we assess the welfare implications for capital market participants on both sides of the market.

2. The Model

Consider an economy with an entrepreneur and two types of investors: initial investors and a speculator. Initial investors supply capital and later participate in liquidity trading. The speculator can acquire information about the project outcome to generate trading profits. All parties are risk-neutral and protected by limited liability.

The entrepreneur has an investment project and wealth A. The entrepreneur (he) chooses an investment level I by investing his own wealth and raising additional capital from initial investors. The production technology follows standard components from Holmström and Tirole (1997). Specifically, if capital I is invested, the project will succeed ($x = 1$) with probability p, generating positive cash flows RI. With probability $1 - p$, the project will fail ($x = 0$), generating zero cash flows. Once the project is funded, the entrepreneur privately chooses his effort level. Working results in a success probability of $p = p_H$. Shirking results in a lower success probability of $p = p_L < p_H$ but provides the entrepreneur with private benefits of $BI > 0$. The parameter B reflects the disutility of effort avoided when shirking or private benefits derived from shirking, such as engaging in alternative ventures or pursuing personal interests. The magnitude of B depends on factors such as the strength of corporate governance, which determines the ease with which corporate insiders can extract private benefits. If the entrepreneur works, the project yields a positive NPV per unit invested, $p_H R - 1 > 0$. If he shirks, the project yields a negative NPV per unit invested, $1 > p_L R + B$. We use Δp to denote $p_H - p_L$:

$$\Delta p \equiv p_H - p_L. \tag{1}$$

After the entrepreneur chooses effort $p \in \{p_H, p_L\}$, the speculator (she) privately observes a signal $s \in \{s_H, s_L\}$, which is generated according to the following technology for a given level of precision $\alpha \in [0,1]$:

$$\begin{aligned} \Pr(s = s_H | x = 1) = \Pr(s = s_L | x = 0) = \frac{1+\alpha}{2}; \\ \Pr(s = s_L | x = 1) = \Pr(s = s_H | x = 0) = \frac{1-\alpha}{2}. \end{aligned} \tag{2}$$

A higher α increases the probability that the signal s correctly identifies the project outcome. If $\alpha = 1$, the signal is perfectly informative; if $\alpha = 0$, the signal provides no information. A key feature of the model is that the speculator can choose the signal's precision α at a cost of $I \cdot \frac{c}{2}\alpha^2$. The parameter c reflects the marginal costs associated with extracting private information from publicly available information.[2] We refer to the parameter c as *information processing costs*.[3] To ensure an interior solution with $\alpha < 1$, we assume that information processing costs are sufficiently high:

$$c > p_H(1 - p_H)R\sigma. \tag{3}$$

The game consists of four dates. At date 1, the entrepreneur invests his own wealth and raises additional capital to fund an investment level I. To raise capital, the entrepreneur proposes a financing contract to initial investors that specifies the investment level and the rewards paid to the entrepreneur. We assume that the entrepreneur exits the firm prior to the realization of the project's final cash flow. Consequently, the entrepreneur's compensation is tied to the interim stock price, consistent with the widespread use of stock-based pay to align managerial incentives

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[2] At the 1996 Berkshire Hathaway annual meeting, Warren Buffett emphasized the value of publicly available information in identifying unique investment opportunities. He noted, "It's amazing … how well you can do in investing, really, with what I would call outside information … we've gotten a lot of ideas from annual reports." The transcript of the annual meeting is available at: https://buffett.cnbc.com/video/1996/05/06/morning-session---1996-berkshire-hathaway-annual-meeting.html?&start=8539.66

[3] Blankespoor, deHaan, and Marinovic (2020) outline three costly steps in information processing: awareness (recognizing information exists), acquisition (extracting and quantifying raw information for valuation models), and integration (combining acquired signals into valuation estimates or investment decisions). To the extent that information is publicly available (e.g., annual reports), we interpret information processing costs as reflecting acquisition and integration costs. This interpretation aligns with Blankespoor, deHaan, and Marinovic's (2020 p.6-7) observation that prior rational expectation models tend to incorporate either acquisition or integration costs.

with firm value (e.g., Murphy 1999).[4] In Section 3, we derive the interim stock prices that arise in equilibrium and the optimal reward for the entrepreneur contingent on the stock price. The optimal compensation for the entrepreneur can be implemented via stock options or equity with performance-based vesting.

The capital market is competitive, and initial investors supply capital if they break even, with an interest rate normalized to zero. These initial investors represent a large pool of capital providers (e.g., households or institutions) who, in practice, supply capital through financial intermediaries (e.g., hedge funds or mutual funds) that promise the market rate of return. Once the project is funded, the entrepreneur chooses to work ($p = p_H$) or shirk ($p = p_L$). At date 2, the speculator incurs a cost of $I \cdot \frac{c}{2}\alpha^2$ to choose the precision $\alpha \in [0,1]$ of her private signal. In our setting, initial investors do not incur costs to acquire information about the project's outcome. This assumption can be motivated in two ways. First, as discussed below, their trading is driven by reasons unrelated to the project's fundamentals (they face liquidity shocks). Second, as initial investors (e.g., households) typically lack the time, expertise, or other resources to process complex information or utilize technological tools, improvements in information-processing systems (e.g., EDGAR or XBRL) may have little impact on their information acquisition decisions. This notion is consistent with findings from Blankespoor, Miller, and White (2014) and Gomez (2024).

At date 3, the secondary stock market opens, and trading takes place among the speculator, initial investors, and a market maker within a Kyle-type setting, similar to Goldstein and Guembel (2008) and Gao and Liang (2013). Initial investors who contributed funds at date 1 experience liquidity shocks and trade their shares. We normalize the total number of shares to one. The initial investors' aggregate liquidity trade is denoted by $n \in \{\sigma, -\sigma\}$, where $n = \sigma$ and $n = -\sigma$ are equally likely.[5] The speculator trades in the secondary stock market by submitting an

[4] Kanodia and Sapra (2016, p. 629) argue that "the rewards to ownership in the firm are determined by short-term price movements in the capital market, rather than by the terminal accumulations of cash in the firm." They justify this based on the observation that "joint ventures of limited duration and scope were increasingly replaced by publicly traded firms with indefinite duration and scope." See also Feltham and Xie (1994), Fischer and Verrecchia (2000), Ewert and Wagenhofer (2005), and Laux (2010) for similar assumptions.

[5] Liquidity sales ($n = -\sigma$) may arise when investors experience negative shocks and need cash to fund consumption, emergencies, or other obligations. Liquidity purchases ($n = \sigma$) may occur when investors receive unexpected inflows of cash and seek to store it to smooth consumption over time.

Date 1	Date 2	Date 3	Date 4
A financing contract is signed to fund a project; the entrepreneur either works or shirks.	The speculator acquires a private signal.	Liquidity shocks are realized; trading occurs in the secondary stock market; the entrepreneur is rewarded and exits the firm.	The project generates cash flows, which are distributed to shareholders.

Figure 1. Timeline

order d. The market maker observes the net order flow $n + d$ but cannot distinguish between the liquidity trade n and the speculator's trade d. Thus, the market maker sets the stock price P_{n+d} based on the net order flow $n + d$ to clear the market and break even in expectation:

$$P_{n+d} = E[x|n + d]RI. \tag{4}$$

The entrepreneur receives a reward $R_{n+d} \geq 0$ based on the interim stock price P_{n+d} and subsequently exits the firm. At date 4, the outcome of the project is realized, and cash flows are distributed to shareholders. The timeline of the model is summarized in Figure 1.

We make the following assumptions on the model's parameter space. First, we assume that the speculator's expected trading profits per unit of investment, denoted by Π, and the agency costs per unit of investment, denoted by $\mathcal{L}B$, satisfy:

$$1 > p_H R - \Pi - \mathcal{L}B. \tag{5}$$

The functional forms of Π and $\mathcal{L}B$ are derived in Section 3. Here, $p_H R - \Pi - \mathcal{L}B$ represents the maximum return that the entrepreneur can pledge to initial investors per unit of investment, which is referred to as the *pledgeable income.* This assumption implies that the pledgeable income is less than the unit cost of capital. Consequently, the entrepreneur must use his own funds to cover the difference. If this assumption does not hold, the entrepreneur can raise unlimited capital to expand investment indefinitely. Second, the expected trading profits Π satisfy $p_H R - \Pi - 1 > 0$. This implies that the entrepreneur's rent per unit of investment—net of both the speculator's profits and the unit cost of capital—is positive, giving the entrepreneur an incentive to implement the project. The parameter space consistent with both assumptions is characterized in Appendix B.

Before turning to the analysis, we motivate our focus on external financing constraints as a central impediment to wealth creation. These constraints are widely regarded as a key friction that hinders entrepreneurial activity and economic growth. In his review of the finance-growth literature, Levine (2005, p. 868) emphasizes that "better functioning financial systems ease the external financing constraints that impede firm and industrial expansion, suggesting that this is one mechanism through which financial development matters for growth." In our model, the primary friction in external financing stems from ex post moral hazard. We abstract away from ex ante screening, which involves costly efforts to distinguish profitable projects from unprofitable ones.[6] The role of moral hazard in affecting financing constraints has been studied in the context of economic growth (e.g., Aghion, Banerjee, and Piketty 1999), entrepreneurial activities (Tirole 2006), and macroeconomic impact (e.g., Holmström and Tirole 2011).

3. Equilibrium

In this section, we start by deriving the equilibrium stock prices and trading strategies at date 3 and the speculator's optimal precision choice α^* at date 2. We then derive the entrepreneur's optimal reward scheme and the optimal investment level I^*. We use backward induction to solve the model. At date 3, initial investors experience liquidity shocks, and the speculator receives signal $s \in \{s_H, s_L\}$, which is informative about the project's success, $x \in \{1,0\}$. Subsequently, trading occurs in the secondary stock market. Assuming the entrepreneur worked ($p = p_H$) and the speculator chose $\alpha = \alpha^*$ at date 2, the expected project outcome conditional on $s = s_H$ and $s = s_L$ is given by:

$$\begin{aligned} \mathrm{E}[x|s_H] &= \frac{p_H \frac{1+\alpha^*}{2}}{p_H \frac{1+\alpha^*}{2} + (1-p_H)\frac{1-\alpha^*}{2}} = \frac{p_H(1+\alpha^*)}{1+(2p_H-1)\alpha^*} > \mathrm{E}[x] = p_H; \\ \mathrm{E}[x|s_L] &= \frac{p_H \frac{1-\alpha^*}{2}}{p_H \frac{1-\alpha^*}{2} + (1-p_H)\frac{1+\alpha^*}{2}} = \frac{p_H(1-\alpha^*)}{1-(2p_H-1)\alpha^*} < \mathrm{E}[x] = p_H. \end{aligned} \tag{6}$$

[6] The role of ex ante screening in shaping financing constraints has been investigated in various settings, including economic growth (e.g., King and Levine 1993) and entrepreneurial activities (see chapter 6 of Tirole 2006).

	$d = \sigma$ with $s = s_H$	$d = -\sigma$ with $s = s_L$
$n = \sigma$	Net order: $n + d = 2\sigma$ Price: $P_{2\sigma} = \mathrm{E}[x \vert s_H]RI$	Net order: $n + d = 0$ Price: $P_0 = p_H RI$
$n = -\sigma$	Net order: $n + d = 0$ Price: $P_0 = p_H RI$	Net order: $n + d = -2\sigma$ Price: $P_{-2\sigma} = \mathrm{E}[x \vert s_L]RI$

Table 1. Equilibrium Share Prices

If $s = s_H$, the speculator knows the project is likely undervalued ($\mathrm{E}[x|s_H] > \mathrm{E}[x] = p_H$) and seeks to purchase shares. However, the speculator must protect her private information. If the information is revealed, the stock price will be adjusted to reflect the positive signal, eliminating any potential trading profits. Since the market maker observes only the net order $n + d$, the speculator can conceal her purchase order by buying σ shares ($d = \sigma$), which offsets potential liquidity sales from initial investors ($n = -\sigma$). Conversely, if $s = s_L$, the speculator learns that the project is likely overvalued and takes a short position by choosing $d = -\sigma$. Table 1 describes the stock price P_{n+d} at date 3 as a function of the net order $n + d$.

When the net order is 2σ, the market maker infers that the speculator ordered $d = \sigma$, indicating that he observed $s = s_H$. The market maker then sets the stock price to reflect the positive signal: $P_{2\sigma} = E[x|s_H]RI$. Conversely, when the net order is -2σ, the market maker infers that the speculator observed $s = s_L$, resulting in a stock price of $P_{-2\sigma} = E[x|s_L]RI$. In both cases, the speculator earns no trading profits.

When the net order is zero ($n + d = 0$), the market maker cannot determine which signal the speculator received.[7] A zero net order arises in two cases: when the speculator purchases σ shares ($d = \sigma$) due to $s = s_H$ and there are liquidity sales ($n = -\sigma$), which occur with probability $\Pr(s = s_H, n = -\sigma) = \frac{1}{2}\left(p_H \frac{1+\alpha^*}{2} + (1 - p_H)\frac{1-\alpha^*}{2}\right)$; or when the speculator takes a short position ($d = -\sigma$) due to $s = s_L$ and there are liquidity purchases ($n = \sigma$), which occur

[7] Our results remain unchanged when initial investors face only negative liquidity shocks (i.e., $n \in \{-\sigma, 0\}$), as discussed in Tirole (2006, chapter 8.3). In this case, a zero net order can result either from the absence of liquidity-driven sales or from negative liquidity sales offset by the speculator's purchase orders. For informed trading to occur, stock prices must respond imperfectly to the speculator's order flow, as in Grossman and Stiglitz (1980) or Kyle (1985). Otherwise, were prices fully revealing, the speculator could not earn profits, which would lead to the "no-trade equilibrium" of Milgrom and Stokey (1982).

with probability $\Pr(s = s_L, n = \sigma) = \frac{1}{2}\left(p_H \frac{1-\alpha^*}{2} + (1 - p_H)\frac{1+\alpha^*}{2}\right)$. Applying Bayes' rule and noting that the stock price equals the expected payoff, we obtain:

$$P_0 = \frac{\Pr(s = s_H, n = -\sigma)\,\mathrm{E}[x|s_H] + \Pr(s = s_L, n = \sigma)\,\mathrm{E}[x|s_L]}{\Pr(s = s_H, n = -\sigma) + \Pr(s = s_L, n = \sigma)} RI = p_H RI. \tag{7}$$

At date 2, the speculator chooses the precision of her private signal, α, assuming the entrepreneur worked ($p = p_H$). With probability $\Pr(s = s_H, n = -\sigma)$, the speculator observes $s = s_H$, and liquidity sales ($n = -\sigma$) occur. The liquidity sales enable the speculator to disguise her buying order ($d = \sigma$), thereby preserving some undervaluation in the market (i.e., $P_0 = p_H RI$). The degree of undervaluation is $E[x|s_H]RI - p_H RI$. With probability $\Pr(s = s_L, n = \sigma)$, liquidity purchases ($n = \sigma$) occur, and the speculator observes $s = s_L$ and chooses $d = -\sigma$. In this case, $n = \sigma$ preserves some overvaluation, and the degree of overvaluation is $p_H RI - E[x|s_L]RI$. The speculator's expected profit from trading is given by:

$$\Pr(s = s_H, n = -\sigma)\,(E[x|s_H] - p_H)RI\sigma + \Pr(s = s_L, n = \sigma)\,(p_H - E[x|s_L])RI\sigma, \tag{8}$$

which simplifies to $p_H(1 - p_H)\alpha RI\sigma$. The speculator's expected profit per unit of investment and ex ante utility are given by:

$$\Pi \equiv p_H(1 - p_H)\alpha R\sigma, \tag{9}$$

$$U_I \equiv \underbrace{p_H(1 - p_H)\alpha R\sigma}_{=\Pi} \cdot I - I\frac{c}{2}\alpha^2. \tag{10}$$

Taking the first-order condition of (10) with respect to α yields the speculator's precision choice:

$$\alpha^* = \frac{p_H(1 - p_H)R\sigma}{c}. \tag{11}$$

The following lemma summarizes the date-3 and date-2 equilibrium outcomes.

Lemma 1. *The date-3 and date-2 equilibrium outcomes are as follows:*

(i) *At date 3, the speculator chooses $d = \sigma$ if $s = s_H$ and $d = -\sigma$ if $s = s_L$.*

(ii) *The date-3 stock prices are: $P_{2\sigma} = E[x|s_H]RI$, $P_{-2\sigma} = E[x|s_L]RI$, and $P_0 = p_H RI$.*

(iii) *At date 2, the speculator chooses* $\alpha^* = \frac{p_H(1-p_H)R\sigma}{c}$.

At date 1, the entrepreneur invests his personal wealth A and raises additional capital $I - A$ from initial investors to finance a project of size I. We show below that it is indeed optimal for the entrepreneur to invest all his wealth. The financing contract specifies the reward $R_{n+d} \geq 0$ for the entrepreneur contingent on the date-3 stock price P_{n+d}, with initial investors receiving the firm's equity, and the size of the investment I to maximize the entrepreneur's utility:

$$U_E = E[R_{n+d}|p_H] - A, \tag{12}$$

subject to $\alpha^* = p_H(1 - p_H)R\sigma/c$ from (11), his incentive compatibility constraint,

$$E[R_{n+d}|p_H] \geq E[R_{n+d}|p_L] + BI, \tag{13}$$

and initial investors' participation constraint:

$$p_H RI - E[R_{n+d}|p_H] - \Pi \cdot I \geq I - A. \tag{14}$$

The term $E[R_{n+d}|p_H]$ represents the entrepreneur's expected payoff. The term $\Pi \cdot I$ reflects the expected liquidity trading loss for initial investors since their trading loss corresponds to the speculator's trading profit. We refer to $\Pi \cdot I$ as the *liquidity premium* because the entrepreneur must compensate initial investors for this loss to secure funding. The next proposition shows the solution to this problem.

Proposition 1. *The entrepreneur invests his entire wealth A and chooses the following reward scheme and investment level:* $R_{2\sigma} = \frac{2BI^*}{\alpha^* \Delta p}$, $R_0 = 0$, $R_{-2\sigma} = 0$, *and* $I^* = \frac{A}{1-(p_H R - \Pi - \mathcal{L}B)}$, *where:*

$$\mathcal{L} \equiv \frac{\Pr(P_{2\sigma}|p_H)}{\Pr(P_{2\sigma}|p_H) - \Pr(P_{2\sigma}|p_L)}. \tag{15}$$

Since initial investors break even in equilibrium, we use the binding participation constraint in (14) to rewrite the entrepreneur's utility U_E in (12) as:

$$U_E = (p_H R - \Pi - 1)I, \tag{16}$$

which is the net surplus of the project, $(p_H R - 1)I$, less the speculator's trading profit $\Pi \cdot I$. Note that U_E increases with a larger investment level I because the project exhibits constant returns to scale. Thus, the entrepreneur's goal is to invest as much as possible.

The entrepreneur's financing capacity is determined by the initial investors' participation constraint in (14) and the entrepreneur's incentive compatibility constraint in (13), which simplifies to:

$$R_{2\sigma} - R_{-2\sigma} \geq \frac{BI}{\Pr(P_{2\sigma}|p_H) - \Pr(P_{2\sigma}|p_L)}. \tag{17}$$

To maximize financing capacity, the entrepreneur pledges as much income as possible to investors, without violating the incentive compatibility constraint. This is achieved by setting $R_{2\sigma} = BI/[\Pr(P_{2\sigma}|p_H) - \Pr(P_{2\sigma}|p_L)]$ and $R_0 = R_{-2\sigma} = 0$, which implies the entrepreneur is rewarded only for the highest stock price $P_{2\sigma}$. This reward scheme can be implemented either through stock options or equity grants with performance-based vesting. By tying the entrepreneur's reward to high performance, the pay plan reduces agency costs, thereby enhancing the entrepreneur's financing capacity.

Substituting the entrepreneur's optimal payments into the initial investors' participation constraint in (14) and rearranging terms, we obtain the entrepreneur's upper bound on investment (financing capacity):

$$I \leq \frac{A}{1 - (p_H R - \Pi - \mathcal{L}B)}. \tag{18}$$

The pledgeable income per unit of investment is $p_H R - \Pi - \mathcal{L}B$, which is the maximum return that the entrepreneur can pledge to initial investors. It consists of the expected cash flow from the project, $p_H R$, minus the liquidity premium Π and the agency cost $\mathcal{L}B$, all per unit of investment. As established in condition (5), the pledgeable income is less than the unit cost of investment, $p_H R - \Pi - \mathcal{L}B < 1$, which ensures that the upper bound in (18) is positive. The gap $1 - (p_H R - \Pi - \mathcal{L}B) > 0$ represents the portion of the investment that cannot be financed externally and must be covered by the entrepreneur's own funds. For a given investment level I, the total shortfall is $[1 - (p_H R - \Pi - \mathcal{L}B)]I$, which must be less than or equal to the entrepreneur's personal funds A. To maximize the scope of the project, the entrepreneur contributes all his wealth, and the investment level is given by $I^* = A/[1 - (p_H R - \Pi - \mathcal{L}B)]$.

From (18), the entrepreneur's financing capacity I decreases as $\mathcal{L}$ increases, which is the inverse of the likelihood ratio and defined in (15). Specifically, $\mathcal{L}$ captures the extent of the moral-hazard problem that arises from the fact that the stock price is not perfectly informative about the entrepreneur's effort. A higher $\mathcal{L}$ implies that the stock price is less sensitive to effort and hence conveys less information, aggravating the moral hazard problem.

We now turn to two key derivatives that highlight two opposing effects of higher information processing costs.

Corollary 1. *An increase in information processing costs c reduces the liquidity premium Π and increases agency frictions $\mathcal{L}$, that is,* $\frac{d\Pi}{dc} = -\left(\frac{p_H(1-p_H)R\sigma}{c}\right)^2 < 0$ *and* $\frac{d\mathcal{L}}{dc} = \frac{1}{2p_H(1-p_H)\Delta p R\sigma} > 0$.

Corollary 1 demonstrates that higher processing costs lead to a decrease in the speculator's trading profit per unit of investment ($d\Pi/dc < 0$). This result is intuitive because higher processing costs make it harder for the speculator to obtain accurate information about the project. Conversely, higher processing costs lead to an increase in $\mathcal{L}$, implying that the agency cost per unit of investment, $\mathcal{L}B$, increases. Intuitively, processing costs weaken the speculator's incentive for information acquisition α, which makes the stock price in the secondary market less informative about the entrepreneur's effort choice, aggravating the moral hazard problem.

4. Processing Costs and Investment Level

In this section, we examine how changes in information processing costs affect the equilibrium investment level I^*. The following proposition summarizes the results.

Proposition 2. *Information processing costs* c *affect the equilibrium investment level* I^* *as follows:*

(i) *If* $B < 2\Delta p(1-p_H)p_H R\sigma$, *there exists a cost* $\hat{c} > 0$ *such that* I^* *increases with* c *for all* $c < \hat{c}$ *and decreases with* c *for all* $c > \hat{c}$.

(ii) *If* $B \geq 2\Delta p(1-p_H)p_H R\sigma$, *then* I^* *decreases with* c.

(iii) *The investment maximizing cost* $\hat{c}$ *decreases as corporate governance weakens (B increases).*

Part (i) of Proposition 2 shows that when the entrepreneur's private benefits from shirking are below a certain threshold, the equilibrium investment level I^* is an inverted-U shaped function of the processing cost c. A change in the processing cost has two opposing effects on I^*. To illustrate these effects, we differentiate $I^* = A/[1-(p_H R - \Pi - \mathcal{L}B)]$ with respect to c:

$$\frac{dI^*}{dc} = \left(-\underbrace{\frac{d\mathcal{L}}{dc}}_{>0}B - \underbrace{\frac{d\Pi}{dc}}_{<0}\right)\cdot\frac{I^*}{1-(p_H R - \Pi - \mathcal{L}B)}. \tag{19}$$

The negative effect of higher processing costs on I^* arises via their impact on the agency cost per unit of investment, $\mathcal{L}B$, as captured by $-\frac{d\mathcal{L}}{dc}B\frac{I^*}{1-(p_H R-\Pi-\mathcal{L}B)} < 0$ in (19). As noted in Corollary 1, $\mathcal{L}$ increases with higher processing costs, that is, $\frac{d\mathcal{L}}{dc} = \frac{\partial \mathcal{L}}{\partial \alpha^*}\frac{d\alpha^*}{dc} > 0$. Since the speculator chooses a lower precision as processing costs increase ($d\alpha^*/dc < 0$), the stock price becomes less informative about the entrepreneur's action, increasing $\mathcal{L}$ ($\partial\mathcal{L}/\partial\alpha^* < 0$) and aggravating the moral hazard problem. Higher agency costs reduce the pledgeable income per unit of investment ($p_H R - \Pi - \mathcal{L}B$), thereby limiting the entrepreneur's financing capacity.

The positive effect of higher processing costs on the investment level arises from their impact on the speculator's trading profit per unit of investment, as captured by $-\frac{d\Pi}{dc}\frac{I^*}{1-(p_H R-\Pi-\mathcal{L}B)} > 0$ in (19). Higher processing costs reduce the precision of the speculator's signal ($d\alpha^*/dc < 0$) and hence her trading profit, $\frac{d\Pi}{dc} = \frac{\partial\Pi}{\partial\alpha^*}\frac{d\alpha^*}{dc} < 0$, as shown in Corollary 1.

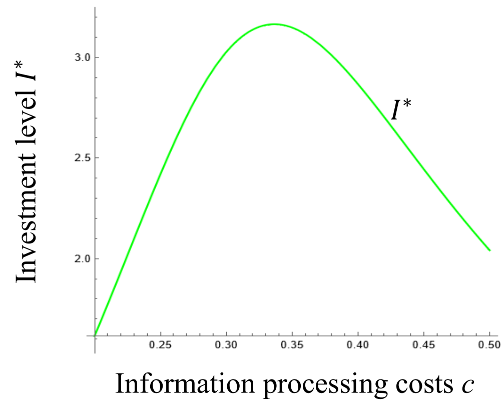

Figure 2. Investment I^*as a function of information processing costs c, given the following parameter values: $A = 0.1$, $B = 0.05$, $R = 2$, $p_H = 0.6$, $p_L = 0.2$, $\sigma = 0.4$.

Therefore, the entrepreneur encounters a lower liquidity premium to secure funding for a given investment level, increasing his financing capacity.

Figure 2 provides a numerical example of the equilibrium investment level I^* as a function of processing costs c. To explain why I^* is an inverted U-shaped function, note from Corollary 1 that changes in the processing costs c have a linear effect on the per-unit agency cost, $\frac{d\mathcal{L}}{dc}B = \frac{B}{2p_H(1-p_H)\Delta pR\sigma}$, but the impact of c on the expected trading losses for initial investors depends on the level of c, $\frac{d\Pi}{dc} = -\left(\frac{p_H(1-p_H)R\sigma}{c}\right)^2$. When processing costs are low ($c < \hat{c}$), the speculator's expected trading profit is high. As a result, an increase in c leads to a large reduction in the liquidity premium. The positive liquidity premium effect then dominates the incentive effect, and an increase in processing costs increases financing capacity. Conversely, when processing costs are high ($c > \hat{c}$), the incentive effect dominates, and an increase in processing costs decreases financing capacity.

Part (ii) of Proposition 2 shows that when the entrepreneur's private benefits from shirking are high, $B \geq 2\Delta p(1 - p_H)p_H R\sigma$, the equilibrium investment level I^* always decreases with the processing cost c. This result arises because when B is sufficiently large, the negative incentive effect of a higher c, captured by $-\frac{d\mathcal{L}}{dc}B < 0$ in (19), becomes so strong that it always dominates the liquidity premium effect, $-\frac{d\Pi}{dc} > 0$ in (19), which is not affected by B.

Part (iii) of Proposition 2 shows that the investment-maximizing cost $\hat{c}$ decreases as corporate governance weakens (B increases). This follows because higher processing costs exacerbate the moral hazard problem more quickly when B is larger. Thus, to mitigate moral hazard, the processing costs that maximize the investment level decreases with B.

5. Welfare Implications

5.1 Processing Costs and Entrepreneur Welfare

We now examine how changes in processing costs affect entrepreneur welfare $U_E = (p_H R - \Pi - 1)I^*$, specified in equation (16). The next proposition summarizes the results.

Proposition 3. *Information processing costs c affect entrepreneur welfare U_E as follows:*

(i) *If $\sigma > \frac{p_H R - 1}{(1-p_H)(1+2p_H)p_H R}$, there exists a $c_E > \hat{c}$, such that U_E increases with c for all $c < c_E$ and decreases with c for all $c > c_E$.*

(ii) *If $\sigma \leq \frac{p_H R - 1}{(1-p_H)(1+2p_H)p_H R}$, U_E decreases with c.*

(iii) *The cost c_E is independent of the firm's corporate governance, as captured by B.*

Part (i) of Proposition 3 shows that when the size of liquidity trading is sufficiently large, entrepreneur welfare U_E is an inverted U-shaped function of the processing cost c. The processing cost that maximizes U_E exceeds the level that maximizes I^*, that is, $c_E > \hat{c}$. To explain why, we differentiate $U_E = (p_H R - \Pi - 1)I^*$ with respect to c:

$$\frac{dU_E}{dc} = (p_H R - \Pi - 1)\frac{dI^*}{dc} - \underbrace{\frac{d\Pi}{dc}}_{<0} I^*. \tag{20}$$

The first term, $(p_H R - \Pi - 1)\frac{dI^*}{dc}$, shows that changes in processing costs affect entrepreneur welfare U_E indirectly through their effect on the equilibrium investment level I^*. The second term, $-\frac{d\Pi}{dc}I^* > 0$, shows that higher processing costs reduce the liquidity premium

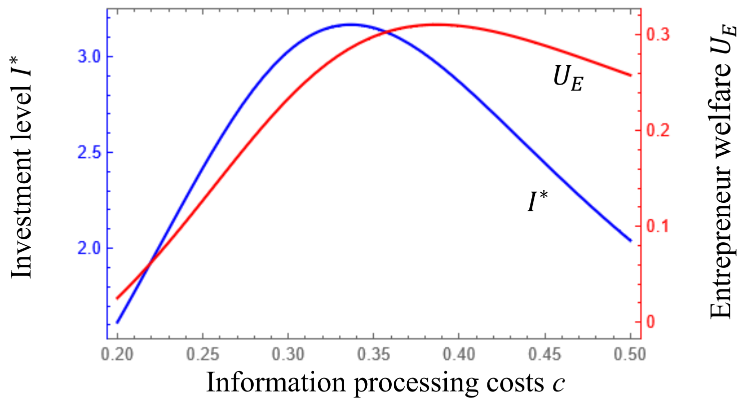

Figure 3. Investment level I^* and entrepreneur welfare U_E as functions of information processing costs c, given the following parameter values: $A = 0.1$, $B = 0.05$, $R = 2$, $p_H = 0.6$, $p_L = 0.2$, $\sigma = 0.4$.

the entrepreneur must pay for a given investment level, which directly increases entrepreneur welfare. This additional benefit explains why the processing costs that maximize entrepreneur welfare exceed those that maximize the investment level, $c_E > \hat{c}$. Figure 3 provides numerical examples of the investment level I^* and entrepreneur welfare U_E as functions of processing costs.

Part (ii) of Proposition 3 shows that when the scale of liquidity trading σ is sufficiently small, entrepreneur welfare U_E always decreases with processing costs c. In this case, the liquidity premium per unit of investment Π is small, and increased processing costs have only a small effect on reducing the speculator's trading profit. However, agency costs are high because a small σ implies small trading profits for the speculator, weakening incentives for information acquisition. Therefore, higher processing costs strongly increase agency costs, reducing financing capacity.

Part (iii) of Proposition 3 shows that a change in B does not affect the processing cost c_E that maximizes entrepreneur welfare U_E. This contrasts with the result from Proposition 2 where the processing cost $\hat{c}$ that maximizes I^* decreases with B. To see why B does not affect c_E, we substitute $\frac{dI^*}{dc}$ from (19) into $\frac{dU_E}{dc}$ in (23)(20) to obtain:

$$\frac{dU_E}{dc} = \left[-(p_H R - \Pi - 1)\frac{d\mathcal{L}}{dc}B - \mathcal{L}B\frac{d\Pi}{dc}\right]\frac{I^*}{1 - (p_H R - \Pi - \mathcal{L}B)}. \tag{21}$$

The first term in square bracket, $-(p_H R - \Pi - 1)\frac{d\mathcal{L}}{dc}B < 0$, captures the incremental loss of net surplus $(p_H R - \Pi - 1)$ due to the negative effect of higher agency costs (higher $\mathcal{L}B$) on the financing capacity. However, for a given level of $\mathcal{L}B$—which also represents the entrepreneur's expected rent per unit of investment—an increase in c improves entrepreneur welfare. This is because a lower liquidity premium enhances financing capacity, allowing the entrepreneur to earn an additional rent $\mathcal{L}B$ through the increase in investment, captured by $-\mathcal{L}B\frac{d\Pi}{dc} > 0$. Note that both effects operate through $\mathcal{L}B$, with B acting as a multiplier in both cases. Consequently, changes in B have no impact on c_E.

5.2 Processing Costs and Investor Welfare

In this section, we examine how changes in processing costs affect investor welfare. Because initial investors break even, investor welfare equals the utility of the speculator U_I in (10). Substituting $\alpha^* = p_H(1-p_H)R\sigma/c$ into U_I, we obtain:

$$\begin{gathered} U_I = \underbrace{p_H(1-p_H)\alpha^* R\sigma}_{=\Pi} \cdot I^* - \frac{c}{2}(\alpha^*)^2 \cdot I^* \\ \Longrightarrow U_I = \Pi I^* - \frac{\Pi}{2}I^* = \frac{\Pi}{2}I^*. \end{gathered} \tag{22}$$

Here, $\frac{\Pi}{2}$ represents both the speculator's net trading profit per unit of investment, given by $\frac{\Pi}{2} = p_H(1-p_H)\alpha^* R\sigma - \frac{c}{2}(\alpha^*)^2$, and the total processing costs incurred per unit of investment, given by $\frac{\Pi}{2} = \frac{c}{2}(\alpha^*)^2$. The following proposition summarizes the results.

Proposition 4. *Information processing costs c affect investor welfare U_I as follows:*

(i) *If $B < \frac{2\Delta p(p_H R - 1)}{1 + 2p_H}$, there exists a c_I, which satisfies $c_I < \hat{c} < c_E$, such that U_I increases with c for all $c < c_I$ and decreases with c for all $c > c_I$.*

(ii) *If $B \geq \frac{2\Delta p(p_H R - 1)}{1 + 2p_H}$, U_I decreases with c.*

(iii) *The cost c_I decreases as corporate governance weakens (B increases).*

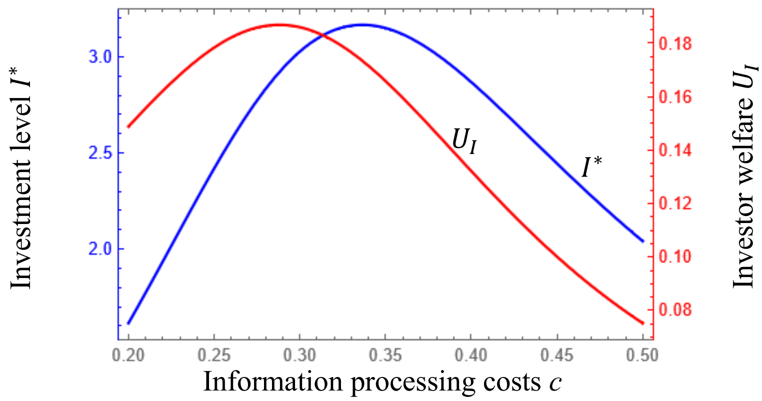

Figure 4. Investment level I^* and investor welfare U_I as functions of information processing costs c, given the following parameter values: $A = 0.1$, $B = 0.05$, $R = 2$, $p_H = 0.6$, $p_L = 0.2$, $\sigma = 0.4$.

Part (i) of Proposition 4 shows that when the entrepreneur's private benefits from shirking are low, investor welfare U_I is an inverted U-shaped function of the processing cost c. The level of c that maximizes investor welfare U_I is lower than the one that maximizes entrepreneur welfare U_E, that is, $c_I < c_E$. To see this, we take the derivative of U_I with respect to c:

$$\frac{dU_I}{dc} = \frac{\Pi}{2} \cdot \frac{dI^*}{dc} + \underbrace{\frac{d}{dc}\left(\frac{\Pi}{2}\right)}_{<0} \cdot I^*. \tag{23}$$

The first term in (23) captures how changes in the processing costs affect the speculator's payoff through its effect on the equilibrium investment level. The second term arises because higher processing costs directly reduce the speculator's rent for a given investment level. Due to this negative effect, the processing cost c_I that maximizes investor welfare is smaller than the level $\hat{c}$ that maximizes the equilibrium investment I^*, that is, $c_I < \hat{c}$. Since we know from Proposition 3 that $\hat{c} < c_E$, it follows that $c_I < c_E$. Figure 4 provides numerical examples of the investment level I^* and investor welfare U_I as functions of information processing costs.

Part (ii) of Proposition 4 shows that when the entrepreneur's private benefits from shirking are high, investor welfare U_I always decreases with processing costs c. To see this, note that $\frac{d}{dc}\left(\frac{\Pi}{2}\right)$ in the second term in (23), which captures the negative effect of higher processing costs on the speculator's rent per unit invested, does not depend on B. The first effect in (23) per unit invested can be written as follows:

$$\frac{\Pi}{2}\left(-\frac{d\mathcal{L}}{dc}B-\frac{d\Pi}{dc}\right)\frac{1}{1-(p_H R-\Pi-\mathcal{L}B)}, \tag{24}$$

which captures the effect of an increase in c on investor welfare U_I via its impact on the investment level. This term depends on B because agency frictions affect the rate with which changes in processing costs affect the investment level, which in turn determines the size of a speculator's trading profit. Since a higher B increases agency costs, the negative effect of higher processing costs on investment, $-\frac{d\mathcal{L}}{dc}B<0$, becomes stronger relative to the positive effect stemming from a lower liquidity premium, $-\frac{d\Pi}{dc}>0$. Therefore, when B is large, the agency costs are sufficiently high so that higher processing costs always decrease investor welfare.

Part (iii) of Proposition 4 shows that the processing cost that maximizes investor welfare, c_I, decreases as B increases. This follows because, as explained in Part (ii), a higher B reduces investor welfare as the negative effect on the investment level in (24) becomes stronger. Thus, to induce a higher investment level and greater trading profits, c_I decreases as B increases.

5.3 Processing Costs and Social Welfare

We now examine the impact of processing costs on social welfare, defined as $U_S \equiv U_E + U_I$. Using $U_E=(p_H R-1-\Pi)I^*$ from (16) and U_I from (22), we obtain:

$$U_S=\underbrace{(p_H R-1-\Pi)I^*}_{=U_E}+\underbrace{\Pi I^*-\frac{\Pi}{2}I^*}_{=U_I}=\left(p_H R-1-\frac{\Pi}{2}\right)I^*. \tag{25}$$

The term $p_H R-1-\frac{\Pi}{2}$ represents the social surplus per unit of investment, where $\frac{\Pi}{2}$ is the total processing costs incurred per unit of investment. The following proposition presents the results.

Proposition 5. *Suppose that* $\sigma > \frac{p_H R-1}{(1-p_H)(1+2p_H)p_H R}$ *and* $B < \frac{2\Delta p(p_H R-1)}{1+2p_H}$ *such that* U_E *and* U_I *are maximized at* c_E *and* c_I*, respectively.*

(i) *Social welfare* U_S *reaches its maximum at* c_S*, where* $c_I < \hat{c} < c_S < c_E$.

(ii) *The cost* c_S *decreases as B increases.*

Part (i) of Proposition 5 shows that the processing costs that maximize social welfare, c_S, do not maximize either investor welfare or entrepreneur welfare. To see why, we take the derivative of U_S with respect to c:

$$\frac{dU_S}{dc} = \left(p_H R - 1 - \frac{\Pi}{2}\right)\frac{dI^*}{dc} - \underbrace{\frac{d}{dc}\left(\frac{\Pi}{2}\right)}_{<0} I^*. \tag{26}$$

Higher processing costs affect social welfare through two channels. The first channel operates through their impact on the investment level, represented by $\left(p_H R - 1 - \frac{\Pi}{2}\right)\frac{dI^*}{dc}$. The second channel arises from their effect on total processing costs for a given investment level I^*, captured by $-\frac{d}{dc}\left(\frac{\Pi}{2}\right)I^* > 0$. Since $\frac{\Pi}{2} = \frac{c}{2}(\alpha^*)^2$, we can express $\frac{d}{dc}\left(\frac{\Pi}{2}\right)I^*$ as follows:

$$\frac{d}{dc}\left(\frac{\Pi}{2}\right)I^* = \left[\frac{1}{2}(\alpha^*)^2 + c\alpha^* \underbrace{\frac{d\alpha^*}{dc}}_{<0}\right]I^* = -\frac{1}{2}(\alpha^*)^2 I^* < 0. \tag{27}$$

A higher c increases total processing costs for a given α^*, but the speculator responds by choosing a lower α^*, which more than offsets the positive direct effect. Thus, a higher c reduces total processing costs, enhancing social welfare. Due to this positive effect, the socially optimal cost c_S exceeds the level $\hat{c}$ that maximizes investment I^*, that is, $c_S > \hat{c}$.

From $c_S > \hat{c}$, it immediately follows that the socially optimal cost exceeds the investors' preferred cost, $c_S > c_I$, because we know from Proposition 4 that $\hat{c} > c_I$. However, the processing cost that maximizes social welfare is lower than what is optimal for the entrepreneur, $\hat{c} < c_S < c_E$. There are two effects that explain $c_S < c_E$. First, given that c_S and c_E both exceed the level that maximizes investment (i.e., $\hat{c}$), a further increase in processing costs reduces financing capacity. The resulting decline in investment reduces social welfare by $p_H R - 1 -$

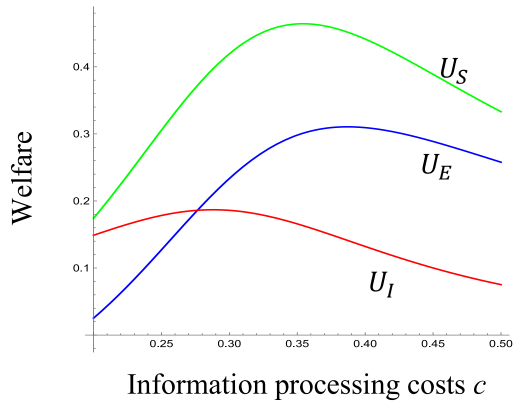

Figure 5. Entrepreneur welfare U_E, investor welfare U_I, and social welfare U_S as functions of information processing costs c, given the following parameter values: $A = 0.1$, $B = 0.05$, $R = 2$, $p_H = 0.6$, $p_L = 0.2$, $\sigma = 0.4$.

$\Pi/2$, but reduces the entrepreneur's welfare only by $p_H R - 1 - \Pi$. Second, as processing costs increase, the entrepreneur's gain from saving on the liquidity premium, $-\frac{d\Pi}{dc}I^* > 0$ in (20), is greater than the decline in total processing costs, captured by $-\frac{d}{dc}\left(\frac{\Pi}{2}\right)I^* > 0$ in (26). Figure 5 provides numerical examples of entrepreneur welfare, investor welfare, and social welfare as functions of information processing costs.

Part (ii) of Proposition 5 shows that the socially optimal cost c_S decreases as corporate governance weakens (B increases). This result follows directly from Propositions 3 and 4. While the entrepreneur's optimal cost c_E does not depend on B, the investors' optimal cost c_I decreases with B. As a result, to balance the welfare trade-off between entrepreneurs and investors, the socially optimal cost c_S decreases with B.

6. Implications and Empirical Predictions

Corporate investment and processing costs. Our analysis provides insights into how information processing costs influence corporate investment decisions. Goldstein, Yang, and Zuo (2023) find empirical evidence that the introduction of the EDGAR system between 1993 and 1996—which reduced information processing costs—led to an increase in corporate investment. This evidence does not imply, however, that ever-lower processing costs will always boost investment. Proposition 2 predicts an inverted U-shaped pattern: investment increases only until costs fall to a critical threshold, beyond which further reductions reduce investment. Thus, reducing processing costs boosts investment when those costs are initially high, which was likely the case in the pre-EDGAR era, when investors had to obtain disclosures from commercial data vendors or by visiting the SEC's public reference room in person.

Our analysis has implications for regulatory initiatives aimed at improving the accessibility of financial disclosures, such as mandating machine-readable disclosures (e.g., XBRL). The SEC has emphasized the importance of structured data, stating that "accessible and usable disclosures are central to the SEC's mission of protecting investors, maintaining fair, orderly, and efficient markets, and facilitating capital formation."[8] Our results indicate a tension among these objectives. While reducing information processing costs can improve market efficiency by facilitating information acquisition, our results indicate that such reductions do not always promote capital formation. When processing costs are already low, further reductions can, in fact, reduce capital formation.

The role of corporate governance. Proposition 2 shows that the processing cost that maximizes corporate investment is smaller in firms with weaker corporate governance. This result implies that the range over which a reduction in processing costs stimulates investment is wider when agency frictions are more severe. Under weak corporate governance, reducing processing costs improves contracting and alleviates agency problems, thereby increasing financing capacity. In contrast, when corporate governance is strong, the same reduction in processing costs primarily amplifies informed trading, which increases the liquidity premium and, as a result, reduces financing capacity. Thus, the impact of lowering information processing costs on investment depends on the severity of agency frictions and may be limited—or negative—in environments with strong corporate governance. Empirical tests should therefore divide firms by governance strength when assessing how declines in processing costs affect investment.

Processing costs preferences. Proposition 5 shows that the processing cost c_S that maximizes social welfare is smaller than the level preferred by the entrepreneur c_E. Arguably,

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[8] The Securities and Exchange Commission. "Structured Disclosure at the SEC: History and Rulemaking." SEC.gov, Jan 24, 2025. https://www.sec.gov/data-research/structured-disclosure-sec-history-rulemaking.

managers have some control over the processing costs investors face in the secondary market (Blankespoor, deHaan, Marinovic 2020). For example, managers can bury information in footnotes or use complicated or ambiguous language, excessive jargon, or lengthy disclosures. Our model suggests that firms will increase processing costs beyond the socially optimal level if not regulated. Furthermore, from Propositions 3 and 5, we know that the gap between the socially optimal processing cost and the entrepreneur's preferred level is wider in firms with weaker corporate governance. This divergence highlights the potential need for regulatory intervention to reduce information processing costs, particularly in settings characterized by high agency frictions.

7. Conclusion

This paper shows that reducing information processing costs, although often seen as unambiguously beneficial, can generate competing effects on capital formation and the welfare of various market participants. On one hand, lower processing costs improve the informativeness of secondary market prices by inducing more information acquisition, which mitigates moral hazard and thereby improves the entrepreneur's access to external financing. On the other hand, lower processing costs increase speculators' trading profits at the expense of initial investors, forcing the entrepreneur to compensate initial investors for future liquidity losses, reducing financing capacity. Due to these forces, our model predicts that corporate investment is an inverted-U shaped function of information processing costs.

The model also demonstrates that the information processing cost that maximizes entrepreneur welfare differs from the levels that maximize investor welfare and overall social welfare. Although entrepreneur and investor welfare both exhibit inverted U-shapes, their peaks occur at different points. Entrepreneur welfare is maximized at a higher level of processing costs than investor welfare because entrepreneurs aim to limit speculator trading profits to reduce the need to compensate initial investors, while speculators seek to increase these profits. Moreover, social welfare is maximized at a processing cost that lies between the investor-optimal and entrepreneur-optimal points.

Our findings suggest that policies aimed at reducing processing costs affect both the creation and the distribution of wealth, and that pushing for ever-lower processing costs—while helping speculators—can inadvertently curb economic productivity. This echoes Tobin's (1984, p. 14) concern that "…*we are throwing more and more of our resources, including the cream of our youth, into financial activities remote from the production of goods and services, into activities that generate high private rewards disproportionate to their social productivity*."

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Appendix A: Proofs of Propositions and Corollaries

Proof of Proposition 1

The entrepreneur's utility, $U_E = (p_H R - \Pi - 1)I$ from (16), increases with I. Thus, the optimal reward scheme $R_{2\sigma} \geq 0$, $R_0 \geq 0$, and $R_{-2\sigma} \geq 0$ maximizes I subject to the incentive compatibility constraint in (13) and initial investors' participation constraint in (14). Plugging $\alpha^* = p_H(1-p_H)R\sigma/c$ from (11), $\Pr(P_{2\sigma}|p) = \frac{1}{2}\left(p\frac{1+\alpha^*}{2} + (1-p)\frac{1-\alpha^*}{2}\right)$, and $\Pr(P_{-2\sigma}|p) = \frac{1}{2}\left(p\frac{1-\alpha^*}{2} + (1-p)\frac{1+\alpha^*}{2}\right)$ into the incentive compatibility in (13), we obtain:

$$\begin{aligned}\Pr(P_{2\sigma}|p_H)\,R_{2\sigma} + \Pr(P_{-2\sigma}|p_H)\,R_{-2\sigma} + [1 - \Pr(P_{2\sigma}|p_H) - \Pr(P_{-2\sigma}|p_H)]R_0 \\ \geq \Pr(P_{2\sigma}|p_L)\,R_{2\sigma} + \Pr(P_{-2\sigma}|p_L)\,R_{-2\sigma} + [1 - \Pr(P_{2\sigma}|p_L) - \Pr(P_{-2\sigma}|p_L)]R_0 \\ + BI,\end{aligned}$$

which simplifies to:

$$R_{2\sigma} - R_{-2\sigma} \geq \frac{BI}{\Pr(P_{2\sigma}|p_H) - \Pr(P_{2\sigma}|p_L)} = \frac{2BI}{\alpha^*\Delta p}. \qquad (A1)$$

The expected reward $E[R_{n+d}|p_H]$ subject to $R_{2\sigma} - R_{-2\sigma} \geq \frac{2BI}{\alpha^*\Delta p}$ is minimized by setting $R_{2\sigma} = \frac{2BI}{\alpha^*\Delta p}$ and $R_0 = R_{-2\sigma} = 0$. With this reward scheme, we obtain the lower bound for $E[R_{n+d}|p_H]$: $E[R_{n+d}|p_H] \geq \Pr(P_{2\sigma}|p_H)\frac{2BI}{\alpha^*\Delta p}$. Since $\frac{2BI}{\alpha^*\Delta p} = \frac{BI}{\Pr(P_{2\sigma}|p_H)-\Pr(P_{2\sigma}|p_L)}$ from $(A1)$, we obtain $\Pr(P_{2\sigma}|p_H)\frac{2BI}{\alpha^*\Delta p} = \frac{\Pr(P_{2\sigma}|p_H)}{\Pr(P_{2\sigma}|p_H)-\Pr(P_{2\sigma}|p_L)}BI = \mathcal{L}BI$, where $\mathcal{L} = \frac{\Pr(P_{2\sigma}|p_H)}{\Pr(P_{2\sigma}|p_H)-\Pr(P_{2\sigma}|p_L)}$. Thus, we have $E[R_{n+d}|p_H] \geq \mathcal{L}BI$.

Substituting $E[R_{n+d}|p_H] \geq \mathcal{L}BI$ into initial investors' participation constraint, $p_H RI - E[R_{n+d}|p_H] - \Pi I \geq I - A$, we obtain the upper investment bound: $I \leq \frac{A}{1-(p_H R-\Pi-\mathcal{L}B)}$. The entrepreneur therefore invests his entire wealth A to implement the highest possible investment level, resulting in $I^* = \frac{A}{1-(p_H R-\Pi-\mathcal{L}B)}$. ■

Proof of Corollary 1

Plugging $\alpha = p_H(1-p_H)R\sigma/c$ from (11) into (9), we obtain:

$$\Pi = \frac{(p_H(1-p_H)R\sigma)^2}{c}. \qquad (A2)$$

It follows immediately that $\frac{d\Pi}{dc} = -\left(\frac{p_H(1-p_H)R\sigma}{c}\right)^2 < 0$. Using $\frac{BI}{\Pr(P_{2\sigma}|p_H)-\Pr(P_{2\sigma}|p_L)} = \frac{2BI}{\alpha^*\Delta p}$ from $(A1)$, we obtain $\Pr(P_{2\sigma}|p_H) - \Pr(P_{2\sigma}|p_L) = \frac{\alpha^*\Delta p}{2}$, and $\Pr(P_{2\sigma}|p_H) = \frac{1}{2}\left(p_H\frac{1+\alpha^*}{2} + (1-p_H)\frac{1-\alpha^*}{2}\right)$. Therefore, we obtain:

$$\mathcal{L} = \frac{\Pr(P_{2\sigma}|p_H)}{\Pr(P_{2\sigma}|p_H) - \Pr(P_{2\sigma}|p_L)} = \left(p_H\frac{1+\alpha^*}{2} + (1-p_H)\frac{1-\alpha^*}{2}\right)\frac{1}{\alpha^*\Delta p}. \qquad (A3)$$

Plugging $\alpha^* = p_H(1-p_H)R\sigma/c$ into $\mathcal{L}$ and differentiating $\mathcal{L}$ with respect to c, we obtain $\frac{d\mathcal{L}}{dc} = \frac{1}{2p_H(1-p_H)\Delta p R\sigma} > 0$. ■

Proof of Proposition 2

Recall $\frac{dI^*}{dc} = \left(-\frac{d\mathcal{L}}{dc}B - \frac{d\Pi}{dc}\right) \cdot \frac{I^*}{1-(p_H R - \Pi - \mathcal{L}B)}$ from (19). Since $\frac{I^*}{1-(p_H R - \Pi - \mathcal{L}B)} > 0$, the processing cost c satisfying $\frac{dI^*}{dc} = 0$ is determined by $-\frac{d\mathcal{L}}{dc}B - \frac{d\Pi}{dc} = 0$. With $\frac{d\mathcal{L}}{dc} = \frac{1}{2p_H(1-p_H)\Delta p R\sigma}$ and $\frac{d\Pi}{dc} = -\left(\frac{p_H(1-p_H)R\sigma}{c}\right)^2$ from Corollary 1, we have:

$$-\frac{d\mathcal{L}}{dc}B - \frac{d\Pi}{dc} = -\frac{1}{2p_H(1-p_H)\Delta p R\sigma}B + \left(\frac{p_H(1-p_H)R\sigma}{c}\right)^2. \qquad (A4)$$

Observe that $-\frac{1}{2p_H(1-p_H)\Delta p R\sigma}B$ is independent of c, $\left(\frac{p_H(1-p_H)R\sigma}{c}\right)^2$ decreases with c, and the right-hand side in (A4) becomes zero at $c = \hat{c}$, where:

$$\hat{c} \equiv \left(\frac{2\Delta p}{B}\right)^{\frac{1}{2}} (p_H(1-p_H)R\sigma)^{\frac{3}{2}} > 0. \qquad (A5)$$

It is immediate to show $\lim_{c\to\infty} I^* = \lim_{c\to 0} I^* = 0$. Thus, $I^* > 0$ for $c > 0$, $\frac{dI^*}{dc} > 0$ for $c < \hat{c}$ and $\frac{dI^*}{dc} < 0$ for $c > \hat{c}$.

We now prove parts (i) and (ii) of Proposition 2. Note that when $B < 2p_H\Delta p R\sigma(1-p_H)$, $\hat{c}$ is greater than the lower bound for c from (3): $\hat{c} > p_H(1-p_H)R\sigma$. This implies that $\frac{dI^*}{dc} > 0$ for $c < \hat{c}$ and $\frac{dI^*}{dc} < 0$ for $c > \hat{c}$. When $B \geq 2p_H\Delta p R\sigma(1-p_H)$, we have $\hat{c} \leq p_H(1-p_H)R\sigma$. This implies that $\frac{dI^*}{dc} < 0$ for $c > p_H(1-p_H)R\sigma$. It follows immediately that $\frac{d\hat{c}}{dB} = -\left(\frac{\Delta p}{2}\right)^{\frac{1}{2}}\left(\frac{p_H(1-p_H)R\sigma}{B}\right)^{\frac{3}{2}} < 0$, which proves part (iii) of Proposition 2.

Lastly, we establish the existence of an equilibrium within the model's parameter space as detailed in Appendix B. The condition $B < 2p_H\Delta p R\sigma(1-p_H)$ implies $\sigma > \frac{B}{2p_H(1-p_H)\Delta p R}$.

When $B = \frac{2\Delta p(p_H R-1)}{1+2p_H}$, we have $\frac{B}{2p_H(1-p_H)\Delta pR} = \underline{\sigma}$. Also, we have $\underline{B} < \frac{2\Delta p(p_H R-1)}{1+2p_H} < \bar{B}$ so that $\bar{\sigma} > \underline{\sigma}$ at $B = \frac{2\Delta p(p_H R-1)}{1+2p_H}$. Thus, when $B > \frac{2\Delta p(p_H R-1)}{1+2p_H}$, parts (i) and (ii) of Proposition 2 may arise in equilibrium depending on the value of σ. Conversely, when $B < \frac{2\Delta p(p_H R-1)}{1+2p_H}$, then $\frac{B}{2p_H(1-p_H)\Delta pR} < \underline{\sigma}$. Since $\sigma > \underline{\sigma}$ from (5), part (i) of Proposition 2 always holds. ■

Proof of Proposition 3

Solving the equation $\frac{dU_E}{dc} = 0$, where $\frac{dU_E}{dc}$ is given in (20), generates only two solutions, c_E and c_E', as follows:

$$c_E \equiv \frac{p_H(1-p_H)R\sigma(p_H(1-p_H)R\sigma + \sqrt{K_E})}{p_H R - 1} \text{ and } c_E' \equiv \frac{p_H(1-p_H)R\sigma(p_H(1-p_H)R\sigma - \sqrt{K_E})}{p_H R - 1},$$

where $K_E \equiv p_H(1-p_H)R\sigma\left(p_H(1-p_H)R\sigma - (1-2p_H)(p_H R-1)\right)$. Observe that $c_E > c_E'$, $c_E > 0$, and $\lim_{c\to\infty} U_E(c) = \lim_{c\to-\infty} U_E(c) = 0$. This means either $U_E(c_E) > 0 > U_E(c_E')$ or $U_E(c_E') > 0 > U_E(c_E)$.

We show that c_E is the only viable solution. First, consider $p_H > \frac{1}{2}$. We then have $c_E' < 0$ because $p_H(1-p_H)R\sigma < \sqrt{K_E} \Leftrightarrow (p_H(1-p_H)R\sigma)^2 < K_E \Leftrightarrow p_H(1-p_H)R\sigma(1-2p_H)(p_H R-1) < 0 \Leftrightarrow p_H > \frac{1}{2}$. Also, we have $\frac{dU_E}{dc} = \frac{AB(2p_H-1)}{2\Delta p(p_H(1-p_H)R\sigma)^2} > 0$ at $c = 0$. This implies that U_E decreases from zero for $c < c_E'$, increases for $c_E' < c < c_E$, and U_E decreases for $c > c_E$. So, c_E is a unique solution that maximizes U_E for $c > 0$.

Now, consider $p_H < \frac{1}{2}$. Then, both solutions are positive, and $\frac{dU_E}{dc} < 0$ at $c = 0$. This implies that U_E decreases from zero for $c < c_E'$, increases for $c_E' < c < c_E$, and decreases for $c > c_E$. Thus, c_E is the unique maximizer (i.e., $U_E(c_E) > 0$) and the only viable solution.

We now prove parts (i) and (ii) of Proposition 3. Observe that when $\sigma > \frac{p_H R-1}{(1-p_H)(1+2p_H)p_H R}$, c_E is greater than the lower bound for c from (3): $c_E > p_H(1-p_H)R\sigma$. This implies that $U_E(c)$ increases with c for $c < c_E$ and decreases for $c > c_E$. When $\sigma \leq$

$\frac{p_H R-1}{(1-p_H)(1+2p_H)p_H R}$, we have $c_E \leq p_H(1-p_H)R\sigma$. This implies that $U_E(c)$ decreases with c for $c > p_H(1-p_H)R\sigma$. It follows immediately from $c_E = \frac{p_H(1-p_H)R\sigma\left(p_H(1-p_H)R\sigma+\sqrt{K_E}\right)}{p_H R-1}$ that c_E is independent of B, which proves part (iii) of Proposition 3.

It is immediate to see $c_E > \hat{c}$. The cost $\hat{c}$ satisfies $\frac{dI^*}{dc} = 0$, where $\frac{dI^*}{dc}$ is from (19), and the cost c_E satisfies $\frac{dU_E}{dc} = 0$, where $\frac{dU_E}{dc}$ is from (21):

$$\left.\frac{dI^*}{dc}\right|_{c=\hat{c}} = \left(-\frac{d\mathcal{L}}{dc}B - \frac{d\Pi}{dc}\right)\frac{I^*}{1-(p_H R - \Pi - \mathcal{L}B)} = 0.$$

$$\left.\frac{dU_E}{dc}\right|_{c=c_E} = \left(-\frac{d\mathcal{L}}{dc}B - \frac{\mathcal{L}B}{p_H R - \Pi - 1}\frac{d\Pi}{dc}\right)\frac{(p_H R - \Pi - 1)I^*}{1-(p_H R - \Pi - \mathcal{L}B)} = 0.$$

Observe that $\hat{c}$ is determined by $\underbrace{-\frac{d\mathcal{L}}{dc}B}_{-} + \underbrace{\left(-\frac{d\Pi}{dc}\right)}_{+} = 0$, while c_E is determined by $\underbrace{-\frac{d\mathcal{L}}{dc}B}_{-} + \underbrace{\frac{\mathcal{L}B}{p_H R-\Pi-1}\left(-\frac{d\Pi}{dc}\right)}_{+} = 0$. The negative effect, $-\frac{d\mathcal{L}}{dc}B < 0$, is the same. The positive effect in $\left.\frac{dU_E}{dc}\right|_{c=c_E}$ is greater than in $\left.\frac{dI^*}{dc}\right|_{c=\hat{c}}$: $\frac{\mathcal{L}B}{p_H R-\Pi-1}\left(-\frac{d\Pi}{dc}\right) > -\frac{d\Pi}{dc} > 0$. This follows because $\mathcal{L}B > p_H R - \Pi - 1$ from $1 > p_H R - \Pi - \mathcal{L}B$ due to the assumption in (5). Thus, $c_E > \hat{c}$.

We establish the existence of an equilibrium within the model's parameter space as detailed in Appendix B. Note that $\frac{p_H R-1}{(1-p_H)(1+2p_H)p_H R} < \bar{\sigma}$. When $B > \frac{2\Delta p(p_H R-1)}{1+2p_H}$, then $\frac{p_H R-1}{(1-p_H)(1+2p_H)p_H R} > \underline{\sigma}$ and $\underline{B} < \frac{2\Delta p(p_H R-1)}{1+2p_H} < \bar{B}$ from the proof of Proposition 2. Therefore, when $B > \frac{2\Delta p(p_H R-1)}{1+2p_H}$, parts (i) and (ii) of Proposition 3 may arise depending on the value of σ. Conversely, when $B < \frac{2\Delta p(p_H R-1)}{1+2p_H}$, we have $\frac{p_H R-1}{(1-p_H)(1+2p_H)p_H R} < \underline{\sigma}$. Since $\sigma > \underline{\sigma}$, we have $\sigma > \frac{p_H R-1}{(1-p_H)(1+2p_H)p_H R}$, and part (i) of Proposition 3 always holds. ■

Proof of Proposition 4

We obtain a unique solution to the equation $\frac{dU_I}{dc} = 0$, where $\frac{dU_I}{dc}$ is given in (23):

$$c_I \equiv \frac{p_H(1-p_H)R\sigma\big(B(1-2p_H) + 2\Delta p(p_H R - 1)\big)}{2B},$$

and the second-order condition of $U_I(c)$ at $c = c_I$,

$$\frac{d^2U_I}{dc^2} = -\frac{32AB^3\Delta p}{(1-p_H)p_H R\sigma\left[\big(B(1-2p_H) + 2\Delta p(p_H R - 1)\big)^2 - 8B\Delta p(1-p_H)Rp_H\sigma\right]^2} < 0,$$

shows that $U_I(c)$ is maximized at $c = c_I$. Since $\lim_{c\to 0} U_I(c) = \frac{A}{2}$ and $\lim_{c\to\infty} U_I(c) = 0$, we have $U_I(c) > 0$ for $c > p_H(1-p_H)R\sigma$. Observe that $\frac{dU_I}{dc} > 0$ at the lower bound of c (i.e., $c = p_H(1-p_H)R\sigma$) for $B < \frac{2\Delta p(p_H R-1)}{1+2p_H}$ and $\frac{dU_I}{dc} < 0$ at $c = p_H(1-p_H)R\sigma$ for $B > \frac{2\Delta p(p_H R-1)}{1+2p_H}$. In addition, we have $\underline{B} < \frac{2\Delta p(p_H R-1)}{1+2p_H} < \bar{B}$ from the proof of Proposition 2. Thus, when $B < \frac{2\Delta p(p_H R-1)}{1+2p_H}$, U_I increases with c for $c < c_I$ and decreases for $c > c_I$. When $B \geq \frac{2\Delta p(p_H R-1)}{1+2p_H}$, U_I decreases with c.

We now show that $c_I < \hat{c}$. The processing cost c_I satisfies $\frac{dU_I}{dc} = 0$, where $\frac{dU_I}{dc}$ is from (23):

$$\left.\frac{dU_I}{dc}\right|_{c=c_I} = \frac{\Pi}{2}\left[-\frac{d\mathcal{L}}{dc}B - \frac{p_H R - 1 - \mathcal{L}B}{\Pi}\frac{d\Pi}{dc}\right]\frac{I^*}{1-(p_H R - \Pi - \mathcal{L}B)} = 0.$$

Since $\frac{I^*}{1-(p_H R - \Pi - \mathcal{L}B)} > 0$, c_I is determined by $\underbrace{-\frac{d\mathcal{L}}{dc}B}_{-} + \underbrace{\frac{p_H R - 1 - \mathcal{L}B}{\Pi}\left(-\frac{d\Pi}{dc}\right)}_{+} = 0$. Observe that $1 > p_H R - \Pi - \mathcal{L}B$ from (5) implies $\Pi > p_H R - 1 - \mathcal{L}B$. Thus, the positive effect in $\left.\frac{dU_I}{dc}\right|_{c=c_I}$ is smaller than the positive effect in $\left.\frac{dI^*}{dc}\right|_{c=\hat{c}}$: $\frac{p_H R - 1 - \mathcal{L}B}{\Pi}\left(-\frac{d\Pi}{dc}\right) < -\frac{d\Pi}{dc}$. Thus, $c_I < \hat{c}$, which implies $c_I < c_E$ due to $\hat{c} < c_E$.

It immediately follows that $\frac{dc_I}{dB} = -\frac{\Delta p(1-p_H)p_H R\sigma(p_H R - 1)}{B^2} < 0$. ■

Proof of Proposition 5

Solving the equation $\frac{dU_S}{dc} = 0$, where $\frac{dU_S}{dc}$ is given in (26), generates only two solutions, c_S and c_S', as follows:

$$c_S \equiv \frac{B(p_H(1-p_H)R\sigma)^2 + \sqrt{K_S}}{2B(p_H R - 1)} \text{ and } c_S' \equiv \frac{B(p_H(1-p_H)R\sigma)^2 - \sqrt{K_S}}{2B(p_H R - 1)}$$

where $K_S \equiv B(p_H(1-p_H)R\sigma)^3\left[Bp_H(1-p_H)R\sigma + 2(p_H R - 1)\big(B(2p_H - 1) + 2\Delta p(p_H R - 1)\big)\right]$. Observe $c_S > c_S'$ and $c_S > 0$. In addition, for $B < \frac{2\Delta p(p_H R - 1)}{1 + 2p_H}$, we have $c_S' < 0$. Thus, given that $\lim_{c \to \infty} U_S(c) = \lim_{c \to -\infty} U_S(c) = 0$, and $\frac{dU_S(c)}{dc} > 0$ at $c = 0$, $U_S(c)$ is minimized at $c = c_S' < 0$, while it is maximized at $c = c_S > 0$. In addition, $p_H R - \Pi - 1 > 0$ ensures that the social surplus per unit invested, $p_H R - \frac{\Pi}{2} - 1$, remains positive. Therefore, $U_S(c) > 0$ increases for $c < c_S$ and decreases for $c > c_S$.

We can express $\left.\frac{dU_E}{dc}\right|_{c=c_E}$ from the proof of Proposition 3, $\left.\frac{dU_I}{dc}\right|_{c=c_I}$ from the proof of Proposition 4, and $\left.\frac{dU_S}{dc}\right|_{c=c_S} = \left.\frac{dU_E}{dc}\right|_{c=c_E} + \left.\frac{dU_I}{dc}\right|_{c=c_I}$ as follows:

$$\left.\frac{dU_E}{dc}\right|_{c=c_E} = \left(\underbrace{-\frac{d\mathcal{L}}{dc}B}_{-} + \underbrace{\left(1 + \frac{1-(p_H R - \Pi - \mathcal{L}B)}{p_H R - \Pi - 1}\right)\left(-\frac{d\Pi}{dc}\right)}_{+}\right)\frac{(p_H R - \Pi - 1)I^*}{1-(p_H R - \Pi - \mathcal{L}B)} = 0;$$

$$\left.\frac{dU_I}{dc}\right|_{c=c_I} = \left(\underbrace{-\frac{d\mathcal{L}}{dc}B}_{-} + \underbrace{\left(1 - \frac{1-(p_H R - \Pi - \mathcal{L}B)}{\Pi}\right)\left(-\frac{d\Pi}{dc}\right)}_{+}\right)\frac{\frac{\Pi}{2}I^*}{1-(p_H R - \Pi - \mathcal{L}B)} = 0;$$

$$\left.\frac{dU_S}{dc}\right|_{c=c_S} = \left(\underbrace{-\frac{d\mathcal{L}}{dc}B}_{-} + \underbrace{\left(1 + \frac{\frac{1}{2}\big(1-(p_H R - \Pi - \mathcal{L}B)\big)}{p_H R - \frac{\Pi}{2} - 1}\right)\left(-\frac{d\Pi}{dc}\right)}_{+}\right)\frac{\left(p_H R - \frac{\Pi}{2} - 1\right)I^*}{1-(p_H R - \Pi - \mathcal{L}B)} = 0.$$

Observe that $\frac{1-(p_H R-\Pi-\mathcal{L}B)}{p_H R-\Pi-1} > \frac{\frac{1}{2}(1-(p_H R-\Pi-\mathcal{L}B))}{p_H R-\frac{\Pi}{2}-1}$, which implies that the positive effect in $\left.\frac{dU_S}{dc}\right|_{c=c_S}$ is smaller than the positive effect in $\left.\frac{dU_E}{dc}\right|_{c=c_E}$. Thus, $c_S < c_E$. Similarly, the positive effect in $\left.\frac{dU_S}{dc}\right|_{c=c_S}$ is greater than the positive effect in $\left.\frac{dU_I}{dc}\right|_{c=c_I}$ because $1 + \frac{\frac{1}{2}(1-(p_H R-\Pi-\mathcal{L}B))}{p_H R-\frac{\Pi}{2}-1} > 1 - \frac{1-(p_H R-\Pi-\mathcal{L}B)}{\Pi}$. Thus, $c_I < c_S$.

It is immediate to show that:

$$\frac{dc_S}{dB} = -\frac{\Delta p\big((1-p_H)p_H R\sigma\big)^2(p_H R-1)}{B\sqrt{B(1-p_H)p_H R\sigma[2(p_H R-1)[B(2p_H-1)+2\Delta p(p_H R-1)]+B(1-p_H)p_H R\sigma]}} < 0.$$

Thus, c_S decreases with B. ■

Appendix B: Assumptions on the models' parameter space

We show that $p_H R - \Pi - 1 > 0$ when $\sigma < \bar{\sigma}$, where $\bar{\sigma} \equiv \frac{p_H R-1}{(1-p_H)p_H R}$. Recall from (9) and (11) that $\Pi = p_H(1-p_H)\alpha^* R\sigma$ and $\alpha^* = \frac{p_H(1-p_H)R\sigma}{c}$. Since $c > p_H(1-p_H)R\sigma$ from (3), it follows that $p_H R - \Pi - 1 = p_H R - \frac{(p_H(1-p_H)R\sigma)^2}{c} - 1 > p_H R - p_H(1-p_H)R\sigma - 1$. Also, $p_H R - p_H(1-p_H)R\sigma - 1 > 0$ when $\sigma > \bar{\sigma}$. Thus, $p_H R - \Pi - 1 > 0$ when $\sigma > \bar{\sigma}$.

We show next that $1 > p_H R - \Pi - \mathcal{L}B$ when $\sigma > \underline{\sigma}$, where:

$$\underline{\sigma} \equiv \frac{\big(B(1-2p_H)+2\Delta p(p_H R-1)\big)^2}{8B\Delta p(1-p_H)p_H R}.$$

Note that $\Pi + \mathcal{L}B$ is minimized at a unique level $c = \hat{c}$, where $\hat{c}$ is from (A5), because $\frac{d}{dc}(\Pi + \mathcal{L}B) = 0$ at $c = \hat{c}$ and $\frac{d^2}{dc^2}(\Pi + \mathcal{L}B) = \frac{2(p_H(1-p_H)R\sigma)^2}{c^3} > 0$. Substituting $c = \hat{c}$ into $\Pi + \mathcal{L}B$ gives a lower bound on $\Pi + \mathcal{L}B$: $\Pi + \mathcal{L}B \geq \left[B(2p_H-1) + 2\sqrt{2\Delta p(1-p_H)p_H BR\sigma}\right]/$

$(2\Delta p)$. At $\sigma = \underline{\sigma}$, we have $1 = p_H R - \left[B(2p_H - 1) + 2\sqrt{2\Delta p(1-p_H)p_H BR\sigma}\right]/(2\Delta p)$. Therefore, $1 > p_H R - \Pi - \mathcal{L}B$ for $\sigma > \underline{\sigma}$.

We have $\bar{\sigma} = \underline{\sigma}$ when $B = \underline{B}$, where:

$$\underline{B} \equiv 2\Delta p(p_H R - 1)\frac{(1+2p_H) - 2\sqrt{2p_H}}{(1-2p_H)^2}.$$

The equation $\bar{\sigma} - \underline{\sigma} = 0$ has two solutions: $\underline{B}$ and $\bar{B} \equiv 2\Delta p(p_H R - 1)\frac{(1+2p_H)+2\sqrt{2p_H}}{(1-2p_H)^2}$. Since $\frac{d(\bar{\sigma}-\underline{\sigma})}{dB} > 0$ at $B = \underline{B}$ and $\frac{d^2(\bar{\sigma}-\underline{\sigma})}{dB^2} = -\frac{\Delta p(p_H R-1)^2}{p_H(1-p_H)RB^3} < 0$, we have $\bar{\sigma} > \underline{\sigma}$ whenever $\underline{B} < B < \bar{B}$. We obtain $\bar{\sigma} > \underline{\sigma}$ for $\underline{B} < B < 1 - p_L R$ if $\bar{B} > 1 - p_L R$, where $1 - p_L R$ is the upper bound on B implied by $1 > p_L R + B$ (i.e., the project has a negative NPV when shirking). Further, $\bar{B} > 1 - p_L R$ holds for all $R < \bar{R}$, where $\bar{R}$ is uniquely determined by $\bar{B}(\bar{R}) = 1 - p_L \bar{R}$. When $R > \bar{R}$, we have $\bar{\sigma} > \underline{\sigma}$ for $\underline{B} < B < \bar{B}$. ■