Trust, Transparency, and Complexity

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Abstract

This paper develops a theory of the interaction between product complexity, transparency, and trust in firms, in a setting where complexity and transparency are both endogenous. The equilibrium involves non-monotonic transparency. The least-trusted firms choose the lowest product complexity, remain opaque, and substitute ex ante third-party verification for disclosure and trust. Firms with intermediate levels of trust choose intermediate levels of complexity and opt for transparency through information disclosure as a substitute for trust. Moreover, greater project complexity leads to less information disclosure, and more trusted firms choose more complex projects and disclose less information. The most-trusted firms choose maximum complexity while remaining opaque, eschewing both verification and disclosure. This generates a cross-sectional relationship between project complexity, transparency, and trust.

Keywords: Trust, Information, Information Disclosure, Transparency, Opacity, Verification

JEL Classification: D21, D25, D82, D83, D84, G32, G34

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1 Introduction

Due to the advent of mass customization (Blecker, Abdelkafi, Kaluza, and Kreutler (2007)) and the explosion of financial innovation (Allen (2012)), there is increasing complexity in both physical and financial products (e.g. Brunnermeier and Oehmke (2009) and Lusardi and Mitchell (2014)). This has elevated the role of trust in enabling adoption of these products. Customers—who may not fully comprehend all relevant product attributes—have to trust the producers in order to buy their products, and investors have to trust these producers in order to invest in them. Transparency and verification are viewed as common tools for building trust (e.g. Offermann and Rosh (2012)). The goal of this paper is to examine the interaction betweent trust, transparency, and verification in a model of endogenous product complexity.

Trust is often regarded as a lubricant of economic exchange, as it reduces transaction costs, mitigates contracting frictions, increases investor participation, and fosters economic growth (see, for example, Zak and Knack (2001), Guiso, Sapienza, and Zingales (2006, 2008), Ring (1996), and Wilson and Kennedy (1999)). Trust in society is often linked to the notion of "social capital", which contributes positively to economic growth (e.g., Algan and Kahue (2013), Fehr (2009), and Son (2016)).[1] The empirical evidence indicates a strong causal effect of trust on growth; see Bjornskov (forthcoming) for a review of this literature.[2]

The importance of trust has led to much discussion about how it is built, and a prominent mechanism that is proposed for building trust is transparency achieved through information disclosure. The argument is that more information disclosure leads to greater transparency,

[1]Consistent with this, Zak and Knack (2001) develop a theoretical model which predicts that higher levels of trust lead to higher investments and higher economic growth. Guiso, Sapienza, and Zingales (2008) present a model in which higher levels of trust lead to higher stock market participation rates. Cline and Williamson (2016) argue that trust reduces the need for formal enforcement of rules, so trust and formal institutions become substitutes. Similarly, Aghion, Algan, Cahuc, and Shleifer (2010) and Pinotti (2008) argue that trust reduces the demand for regulatory-mandated firm disclosures. Boix and Posner (1998) provide an overview of the mechanisms through which social trust affects the quality of formal institutions and policy making.

[2]For example, Knack and Keefer (1997) document that trust is associated with stronger economic performance, and that trust is stronger in countries that more effectively protect property and contract rights.

and this leads to greater trust.[3] For example, Schnackenberg and Tomlinson (2014) write: "Many have argued that organizational transparency is a salve for many maladies and helps re-establish trust." In a financial market context, this suggests that greater information disclosure should lead to a lower cost of capital for the firm since it becomes more transparent.[4] This has led to a large literature on voluntary information disclosure and regulatory disclosure requirements.[5] It has also been suggested that greater information disclosure can help the buyers of financial products deal with increasing product complexity, suggesting that the demand for transparency may also depend on product/information complexity (e.g. Brunnermeier and Oehmke (2009)).

Various strands of the literature have thus indicated a link from information disclosure to transparency to building trust in product sellers, thereby helping buyers cope with complexity. However, the empirical evidence is mixed. While there is evidence that greater transparency is associated with a lower cost of capital (e.g., Andrade, Bernile, and Hood (2013)), there is little direct evidence on the relationship between transparency and trust in the cross-section. Anecdotal evidence suggests that greater transparency need *not* be associated with greater trust.[6] Some of the most trusted institutions often disclose less information than their less-trusted counterparts.[7] For example, Vural (2018) provides empirical evidence on the disclosure practices of publicly-listed Swedish family firms in which controlling owners

[3]Nayar (2009) notes: "[...] and one of the most uncomplicated ways of seeding trust is by 'stretching the envelope of transparency'," See also Federal Trade Commission (2013). See also Bennis, Goleman, and O'Toole (2008), Fombrun and Rindova (2000), and Perotti and von Thadden (2005).

[4]Greater transparency means lower adverse selection costs. Theoretical models in which this effect is encountered are Lambert, Leuz, and Verrachia (2006) and Thakor (2015); see also Andrade, Bernille, and Hood (2008) and Foucault, Pagano, and Roell (2013).

[5]See, for example, Boot and Thakor (2001) and Fishman and Hagerty (1992). These papers show that greater information disclosure by firms can weaken incentives for speculators to become informed, thereby creating tension between the greater transparency created directly by disclosure and the reduced transparency created indirectly through the altered incentives of informed investors.

[6]This may be true even when there is a benevolent regulator overseeing a monitor (like a bank) with reputational concerns. In such a setting, Marinovic and Szydlowski (2019) show that the regulator may not provide transparency through disclosure because doing so destroys the monitor's reputational incentives.

[7]Consider Berkshire Hathaway as an example. It routinely stockpiles billions of dollars in cash, a practice that activist investors would frown upon in companies managed by less trusted executives than Warren Buffett. Yet the company's annual reports (and Buffett's letter to shareholders) reveal little about its plans for the use of the cash.

have a strong influence on the corporate governance decisions of the firm, including corporate disclosure. The paper documents that these firms, in which the usual owner-manager agency problems are less severe (which is consistent with these firms being more trusted), disclose less information in annual reports than non-family firms do. de Fine Licht (2011) provides evidence that transparent decisionmaking weakens general trust in healthcare.

In an environment in which product/information complexity makes transparency economically meaningful, what is the relationship between transparency and trust? We address this question with a simple theoretical model in which both transparency—achieved through information disclosure—and complexity are endogenously co-determined. In our model, transparency does not build trust, but rather it *substitutes* for trust when product complexity is chosen to not be too high. For sufficiently high complexity, only trust suffices to enable trade. Thus, high complexity can be pursued only by the most trusted producers. And these producers choose to remain opaque. Our analysis thus provies an economic rationale for the evidence that there may sometimes be a negative association between transparency and trust.

The model specifics are as follows. A firm makes a choice of projects that it finances with outside equity. It can choose between a good project the investors will fund, and a project that investors do not like because it yields the manager a private benefit but gives nothing to outside investors. Thus, there is a classic agency conflict between a controlling inside shareholder and non-controlling outside shareholders. Trust in a firm is the probability investors attach to the firm investing in the good project they like.[8]

Firms have the ability to disclose information. Greater information disclosure has two opposing effects. The functional aspect of disclosure is that it increases transparency by increasing the precision of the signal investors receive about the firm's project choice, which

[8] This is consistent with the notion of trust in earlier research. For example, Gambetta (2000) views trust as "the subjective probability with which an agent assesses that another agent or group of agents will perform a particular action." Lewis and Weigert (1985) state: "Although trust in general is indispensible in social relationships, it always involves an unavoidable element of risk and potential doubt." Morrison and Wilhelm (2015) characterize trust as something that does not rely upon the threat of punishment to achieve commitment.

thus reduces the firm's cost of capital. The dysfunctional aspect is that it is directly costly due to the "two-audience signaling" problem, which involves the firm's cash flow being lowered due to the competitive reactions triggered by its information disclosure (see Bhattacharya and Ritter (1982)).[9] The optimal amount of disclosure strikes a balance between these two forces.

We then introduce an "information complexity" parameter, which is meant to capture how complex the disclosed information is and how costly it would be for investors to process it. The idea is that firms differ in terms of the nature of the projects that they may undertake, or the products that they sell, with some being more complex than others—e.g. a firm that produces phone books versus one that sells highly customized swaps or engages in complex derivative transactions. Some information can be readily communicated at a low cost by firms, while other information may be very costly for the sender to communicate or costly for the receiver to process. Complexity can also be functional in that it represents welfare-enhancing innovation, or dysfunctional in that it is obfuscation that increases the seller's rent while possibly making the buyer worse off (e.g. Gabaix and Laibson (2006)). We focus on the functional aspect of complexity and assume that the expected (first-best) payoff on the good project is increasing in its information complexity.[10] Finally, in the cross-section, firms differ in the trust that investors place in them ex ante.

With this model, we establish the aforementioned relationship between trust, transparency, and complexity, and also show that trust has a positive externality. A greater presence of trusted firms in the cross-section induces more self-interested firms to behave as if they are trustworthy. There are some products, however, that are "inherently opaque" but using disclosure to achieve transparency is either infeasible or too costly relative to al-

[9]There is a significant banking literature that studies the pros and cons of information disclosure by banks and regulators in the context of stress tests, and this literature highlights other costs of greater disclosure. See Dang, Gorton, and Holmstrom (2017), Goldstein and Leitner (2018), Leitner and Yilmaz (2019), and Thakor (2015).

[10]Any project for which this is not true—that is, it has higher information complexity and a lower expected value than another project—will be strictly dominated and not in the firm's efficient investment opportunity set.

ternative mechanisms. For example, fintech payment systems like Alipay and WeChat Pay are clearly not transparent to users, but are widely used. Why? The answer is verification: a friend, co-worker, or family member tries it and it works, and thus you are willing to use it. To accomodate this, we expand our model to include ex ante third-party verification.[11] Such verification is ubiquitous—examples include inspections with real estate transactions and public audits of firms' financial statements.

To model direct verification of the firm's project choice, we assume the firm hires a monitor who incurs a private cost to discover the firm's project choice, and report it to investors. Since the monitor's incentive to shirk and misreport must be accounted for, we follow Rahman (2012) and solve for the optimal contracts needed to resolve the problem. This analysis shows that verifiability may substitute for disclosure-induced transparency for low levels of project complexity, but is dominated by disclosure for higher levels of complexity. This paints a picture of *non-monotonic transparency*—for very simple projects, the firm chooses verifiability while remaining opaque, and then switches to disclosure and transparency for higher levels of complexity, with disclosure diminishing as complexity increases. Eventually, the most complex projects are managed only by the most trusted firms, and these firms disclose nothing. In a sense, trust eliminates the need to unravel complexity, which echoes Lewis and Weigert's (1985) observation that a function of trust is the reduction of perceived complexity.

The model is parsimonious. It rests primarily on only one friction—hidden project choice that proxies for unknown product attributes—and two key properties of complexity, namely that higher complexity adds more value, but more complex information is more difficult to process. With this, the analysis generates a hierarchy of firms' choices based on how trusted they are. At the lowest end of the trust continuum, firms choose the least complexity but remain opaque and use ex ante third-party verification. For intermediate levels of trust, firms choose greater complexity with transparency, but transparency declines as complexity

[11]This is distinct from the ex post costly state verification analyzed by Townsend (1979).

increases. For high levels of trust, firms choose maximum complexity but return to being opaque. Complexity endogenously increases with trust.

Despite the modeling parsimony, the intuition underlying the model is quite general. In a theory in which transparency is costly to achieve and the cost of disclosure increases with complexity, there will be a complexity high enough at which the firms forgoes transparency. Think of an investment bank that has a highly complex portfolio of derivative contracts that include customized swaps as well as numerous other businesses like merger advisory services, all of which involve proprietary and confidential client information: such information is not only costly (or even infeasible) for the bank to disclose, but also costly for investors to process.[12] The cost generated by the resulting opacity can deter participation by the firm (bank) if the cost is sufficiently high. Trust acts as a mediating variable in determining this cost—the higher the trust, the lower the cost of opacity. This means there is a complexity threshold below which disclosure dominates opacity and above which no-disclosure opacity is preferred by the firm. But even in the region below this complexity threshold, disclosure need not always be optimal. When the product/service is quite simple, having the necessary information verified by a third party may involve such a low cost that it is even cheaper than the cost of disclosure.[13] So when complexity is very low, the firm remains opaque and relies on verification, leaving disclosure-based transparency to operate only for intermediate levels of complexity.

This paper is related to the literature on information disclosure and transparency discussed earlier. It is also related to the literature on trust and economic outcomes that was discussed earlier. Prominent contributions include Knack and Keefer (1997) and La Porta,

[12]Boot and Thakor (2001) model the idea that information may differ in the cost incurred by receivers to process it, although they do not discuss disclosure complexity. Jin, Luca, and Martin (2020) provide evidence that receivers make more errors in processing more complex information.

[13]For example, think of mobile payment apps. The one maintaining the app may conclude that there is no need to disclose information when users can (almost) costlessly verify its reliability by asking their friends. Or consider a widget manufacturer who hires a third party to certify to the customer that the product meets quality and specification standards. The customer can check on the third party's diligence quite easily by randomly sampling some widgets to inspect.

Lopez de Silanes, Shleifer, and Vishny (1997).[14] Trust can emerge due to the quality of the legal system and strategic interactions (Axelrod (1984)) or optimal investment in social capital (Glaeser, Laibson, and Sacerdote (2002)). Guiso, Sapienza, and Zingales (2006) provide a survey and the link of trust to cultural variables. Thakor and Merton (2018) show that trust insulates lenders against the adverse reputational consequences of bad credit outcomes in some states of the world, thereby facilitating continued access to low-cost financing. Morrison and Wilhelm (2015) examine the role of trust as an extralegal commitment device that greatly affects how investment banks function. None of the papers in this literature examine the relationship between trust, complexity, and transparency. Moreover, in contrast to the previous literature, transparency and verification do not build trust in our model. Rather, they substitute for trust when trust is not very high. This is also consistent with the reported lack of empirical correlation between trust and transparency.

Our paper is also related to the literature on the seller-chosen complexity of products. It has been noted that financial products have become increasingly complex—see, for example, Celerier and Vallee (2017) and Ghent, Torous, and Volkanov (2017). A burgeoning literature focuses on the dysfunctional aspect of complexity. It points out that product complexity, rather than serving more finely differentiated customer needs, may be the consequence of intentional obfuscation of undesirable product attributes by firms selling to unsophisticated customers.[15] See Gabaix and Laibson (2006), Carlin (2009), and Pagano and Volpin (2012). The common element in all these papers is that this obfuscation allows rent extraction from unsophisticated customers.[16] In contrast to this literature, we focus on the functional aspect of complexity and assume that innate product value is increasing in complexity (as in Allen

[14]Trust also affects international trade. Guiso, Sapienza, and Zingales (2009) use data on bilateral trust between European countries to document that lower bilateral trust leads to less trade between two countries, less portfolio investment, and less direct investment.

[15]See Spiegler (2016) for a survey of this literature.

[16]A recent contribution to this literature by Asriyan, Foarta, and Vanasco (2018) assumes that information received by consumers about more complex products is also less precise and shows that the choice of product complexity depends on whether buyers have optimistic or pessimistic prior beliefs about product quality. Complex products are sold to optimistic buyers who are willing to disregard imprecise information and buy the product, whereas simple products are sold to pessimistic buyers who process (precise) information about the product.

(2012), and Oehmke and Zawadowski (2019)). Moreover, we focus on different tradeoffs in the choice of complexity—namely that between the higher profitability of a more complex product and the higher cost of external financing—and examine how trust influences this tradeoff.

The rest of the paper is organized as follows. Section 2 develops the base model. Section 3 provides the analysis. Section 4 introduces the alternative of ex ante verification. Section 5 discusses examples that correspond to our results. Section 6 concludes. All proofs are in the Appendix.

2 The Model

Consider an economy in which all agents are risk neutral and the riskless rate of interest is zero. Imagine a penniless firm wholly-owned by a manager who needs $\$I$ to invest in a project at date $t = 0$ that will pay off at $t = 1$. All external financing is raised using equity.[17]

The manager must first irreversibly choose the project he wishes to invest in and then seek financing. However, absent any information disclosure by the firm, investors cannot tell what type of project the manager has chosen from the set $\{G, B\}$. The G project pays off a random cash flow $\tilde{x}$ that takes a value $X \in \mathbb{R}_+$ at $t = 1$ with probability $1 - q$. This payoff at $t = 1$ is pledgeable and contractible. Thus, it can be used to compensate investors for the equity investment they make at $t = 0$. The B project gives the manager a private benefit of $\tilde{\beta}$ which takes a value of $\overline{\beta} \in \mathbb{R}_+$ with probability $r \in (0, 1)$ and a value of 0 with probability $1 - r$.[18] This project produces no pledgeable cash flow that can be used to compensate investors.

[17] The results are not sensitive to whether external financing is raised using debt or equity.

[18] This private benefit has multiple interpretations. It could just be a non-contractible rent available to the manager when he invests, in the spirit of perquisites consumption in Jensen and Meckling (1976). Alternatively, it may represent the cost of personal effort for the manager in producing $\tilde{x}$ plus some non-contractible rents for the manager.

2.1 Managerial Types

There are two types of managers: trustworthy (T) and non-trustworthy (N). Each manager privately knows his own type. The trustworthy managers always choose G. The type-N managers are self interested and chooe the project that maximizes their expected utility. The prior probability is $p \in \left[\underline{p}, 1\right)$ that the manager is type T and $1 - p$ that he is type N, where $\underline{p} > 0$ is a lower bound. This prior probability is common knowledge and can be viewed as the manager's ex ante reputation for being trustworthy.[19]

2.2 External Financing

At $t = 0$, the manager selects the project and then raises I from outside shareholders in exchange for a fraction $1 - f$ of ownership, where $f \in [0, 1]$ is the fraction retained by the owner-manager. At $t = 1$, outside shareholders receive $1 - f$ of the pledgeable cash flow of the project. There are no other assets in place. Equity is priced to yield investors an expected return of zero.

2.3 Project Complexity

The G project can vary in complexity. For example, it may simply be an extension of what the firm is currently doing, in which case it would have low complexity. Alternatively, it could represent a new, highly innovative R&D project that has substantial complexity and is unfamiliar to those outside the firm. For a financial institution, a low-complexity investment may be expanding its branch network, whereas a high-complexity project may be getting into a new business involving complex financial instruments and potential risk exposures.

[19] The idea that a completely trustworthy person (type T above) acts in accorance with the collective good reflects Lewis and Weigert's (1985) remark: "Trust exists in a social system insofar as the members of that system act according to and are secure in the expected futures constituted by the presence of each other in their symbolic representations." Yet, Lewis and Weigert (1985) also recognize that trust is not absolutle, and that when we trust someone, we take the risk that that trust may not be warranted, stating: "We would not have to accept this risk if there were some functional alternative to trust."

We model this choice of complexity in a simple way. Suppose there are two extremes: at one extreme is high simplicity (s) and at the other is high complexity (c). The firm's choice of complexity is a parameter $\theta \in [0, 1]$ that we call the "degree of complexity", and it is the weight attached to c. Higher values of θ denote greater complexity. The highly complex project has a payoff $X = X_c$ and the highly simple project has a payoff $X = X_S$, with $X_c > X_S > 0$. The actual payoff $X(\theta)$ corresponding to a choice of θ is $X(\theta) = \theta X_c + [1 - \theta]X_S$. Thus, more complex projects have higher payoffs conditional on success. The idea is that these involve products with, say, greater customization for customers, and hence generate greater utility, allowing them to be sold at higher prices.

2.4 Information Disclosure

Outside investors cannot tell a priori which project was selected by the manager. To help investors discern the manager's project choice, the manager can disclose information resp-resented by $\eta \in [0, \overline{\eta}]$. Investors can observe the firm's η after the firm chooses it. This disclosure costs the firm $\psi(\eta) \in \left[0, \overline{\psi}\right]$, with $\psi' > 0$, $\psi'' > 0$, $\psi(0) = 0$, $\psi'(0) = 0$, and $\psi\left(\overline{\eta}\right) = \overline{\psi} > 0$. These costs would include the direct physical losses due to the "two-audience signaling" problem, wherein information disclosure to investors also inadvertently reveals it to the firm's product market competitors (e.g. Bhattacharya and Ritter (1982)). The equilibrium value of η is endogenous.

When information is disclosed, it produces a probability $C_s(\eta) \in [0.5, 1]$ that investors will correctly identify the firm's project choice with the highly simple project, and $C_c(\eta) \in [0, 1]$ that they will identify it correctly with the highly complex project. We assume $C_s(0) = 0.5$, $C_s\left(\overline{\eta}\right) < 1$, $C_s'(\eta) > C_c'(\eta)\ \forall\, \eta \in [0, \overline{\eta}]$. For simplicity, we normalize $C_c(\eta) = 0\ \forall\, \eta$ and let $C_s(\eta) > C_c(\eta)\ \forall\, \eta$, $C_s'(\eta) < 0$, $C_s''(\eta) < 0$, in order to satisfy the condition that investors find it easier to correctly identify the firm's project choice when it is highly simple than when it is highly complex. That is, when the firm chooses a disclosure η, investors receive a signal ϕ

about the firm's project choice that has precision dependent on η:

$$C_s(\eta) = \Pr(\phi = G \mid G, \eta) = \Pr(\phi = B \mid B, \eta) \tag{1}$$

$$1 - C_s(\eta) = \Pr(\phi = G \mid B, \eta) = \Pr(\phi = B \mid G, \eta) \tag{2}$$

This specification captures in a simple way the idea that investors have greater difficulty in processing information about more complex projects.[20] Further, it also means that the marginal effectiveness of disclosure by the firm in improving investors' ability to discern the firm's project choice is lower when complexity is higher.

For a choice of complexity θ, the probability that investors will correctly identify the firm's project choice is:

$$\begin{aligned} C(\eta, \theta) &\equiv \theta C_c(\eta) + [1-\theta]C_s(\eta) \\ &= [1-\theta]C_s(\eta) \end{aligned} \tag{3}$$

In what follows, the firm's choice of θ will be endogenized as well. Like η, the choice of θ is also commonly observed, and we assume that a firm can invest in only one project. Further, the B project can be dressed up to look identical to a G project in complexity. This means observing η and θ does not allow investors to distinguish G from B.

2.5 Summary of Timeline and Sequence of Events

Figure 1 is the summary of the timeline and events.

[20] This is similar to the assumption in Asriyan, Foarta, and Vanasco (2019) about the greater difficulty customers have in processing information about more complex projects.

Figure 1: Timeline of Events

$t = 0$	$t = 1$
▶ Manager irreversibly chooses project: either B or G and complexity θ of G. ▶ Manager chooses to disclose information η about project choice. Investors observe η. ▶ Manager issues equity and surrenders ownership $1 - f$ to raise I for the project ▶ Outside shareholders receive signal ϕ about project choice and determine $1 - f$ endogenously in a market equilibrium	▶ Project payoff is observed ▶ Investors collect fraction $1 - f$ of observed payoff and manager keeps fraction f

3 Analysis

We begin by imposing a restriction on the exogenous parameters to focus on the cases of interest:

$$q\left[X(\theta) - \psi\left(\overline{\eta}\right)\right] > I + \overline{\beta}\,\forall\,\theta \in [0, 1] \tag{4}$$

This means that the G project regardless of its complexity and information disclosure, is socially preferred to the B project. Further, it is assumed that

$$[1 - r]qX(\theta) < I\,\forall\,\theta \in [0, 1] \tag{5}$$

which means that no funding will be available from the market if it is common knowledge that the probability of a type-T manager is zero.

To set a benchmark, let us first examine the case in which there is no choice of θ and no information disclosure by the firm. In this case, investors cannot tell what type of project has been selected by the firm. Let $\alpha(p) \in [0,1]$ represent the probability investors assign to the event that the firm has chosen G. Then it is easy to show that the market equilibrium condition that determines f, call it f_0 in this case, is given by:

$$[1 - f_0]\,\alpha(p)qX(\theta) = I \tag{6}$$

which is the outside shareholders' breakeven condition at a riskless rate of 0 and no disclosure ($\eta = 0$). Throughout, the equilibrium concept we use is Nash equilibrium. Now, it can be shown that:

$$\alpha(p) = \begin{cases} p + [1-p][1-r] & \text{if } f_0 qX \in \left(0, \overline{\beta}\right) \\ 1 & \text{if } f_0 qX \geq \overline{\beta} \end{cases} \tag{7}$$

To interpret (7), note that $f_0 qX$ is the manager's share of the payoff on G. When this share is less than $\overline{\beta}$, the manager will choose G when $\tilde{\beta} = 0$ and will select B when $\tilde{\beta} = \overline{\beta}$. Hence, the probability that G will be chosen is p (the probability that the manager's type is T) plus $[1-p][1-r]$, which is the probability that the manager's type is U and the manager selects G because $\tilde{\beta} = 0$. However, when $f_0 qX$ exceeds $\overline{\beta}$, both T and U unconditionally select G, so the probability is 1 that G will be chosen. This now leads to the first result.

Proposition 1 (Positive Trustworthiness Externality): *Holding θ and η fixed, there exists a $p* \in (0,1)$ such that the firm is always considered trustworthy when the prior belief that the manager is trustworthy exceeds $p*$. In this case, both the type T and type U managers select G. For $p < p*$, U acts as a self-interested manager and selects B with probability r. Thus, the fractional ownership the manager retains, f_0, is increasing in p for all $p < p^*$ and then unaffected by p for all $p \geq p^*$.*

The intuition comes straight from (6), which shows that $\alpha(p)$ is increasing in p as long as $f_0 qX \in \left(0, \overline{\beta}\right)$. Since $1 - f_0$ can be shown to be decreasing in p (see the proof of Proposition

Figure 2: Ownership Retained by the Manager as a Function of β

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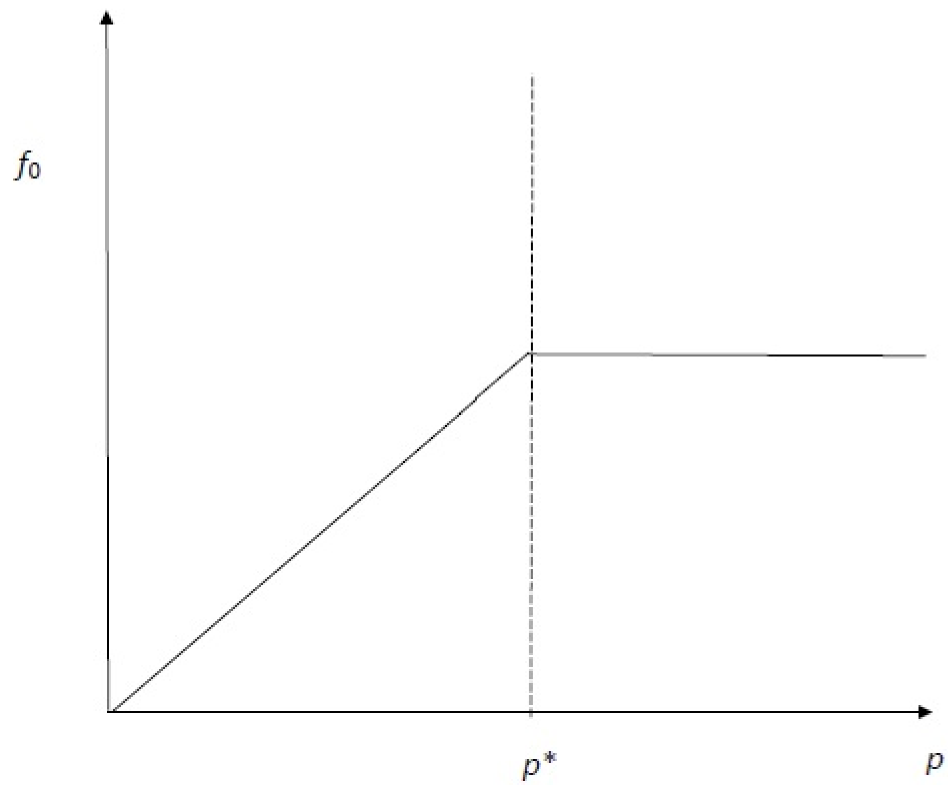


1), we see that f_0 is increasing in p in this range. Once f_0qX goes above $\overline{\beta}$, the firm is always choosing G, so the ownership fraction that must be sold to raise I no longer depends on p. *Figure 2* depicts the ownership retained by the manager as a function of β.

This result highlights the "spillover" effect or externality generated by other firms seeking financing, if we view p as reflecting rational expectations on the part of investors about the proportion of trustworthy firms in the cross-section. When the market is populated by sufficiently many trustworthy firms, investors act as if all firms are trustworthy, even though they know that not all are (note that $p* < 1$). Thus, trustworthy firms generate a positive social externality for *all* firms.

The intuition for this result is that when p increases, f also increases, so the manager encounters "cheaper" equity financing and is able to raise I by surrendering a smaller ownership fraction. This increases the value of G to him and reduces the agency cost associated with him choosing B. In a sense, trust begets trustworthy behavior.

Next we turn to the firm's information disclosure policy η for a fixed θ. The manager solves the following problem:

$$\max_{\eta \in [0,\overline{\eta}]} f(\eta) q \left[X(\theta) - \psi(\eta)\right] \tag{8}$$

subject to

$$\begin{aligned} &\{p + [1-p][1-r]\} \, C(\eta,\theta) \, \{[1-f] q \left[X(\theta) - \psi(\eta)\right] - I\} \\ &\qquad + \{[1-p]r\} \, \{1 - C(\eta,\theta)\} \, \{-I\} = 0 \end{aligned} \tag{9}$$

Note that (9) is the equilibrium market pricing constraint that determines f. This maximization assumes that in equilibrium $fq[X - \psi(\eta)] < \overline{\beta} \, \forall \theta$. The quantity $p + [1-p][1-r]$ is the probability that G is chosen, $C(\eta, \theta)$ is the probability that this choice will be correctly detected by investors in which case they expect to receive $[1-f]q\left[X(\theta) - \psi(\eta)\right] - I$ at $t = 1$. Investors believe that with probability $[1-p]r$, B will be chosen and their signal ϕ will incorrectly identify the project choice as G, so funding will be provided, causing investors to lose I. Whenever investors' signal $\phi = B$, they refuse to provide the financing I.

Before proceeding further, the following result is useful.

Lemma 1: *Regardless of the project chosen by the manager, every firm will choose the same η and θ, which are the choices that a firm investing in G would make.*

The intuition for this result is that the type-T manager is always going to choose G and hence the project complexity and information disclosure that corresponds to that project choice rationally anticipating the reaction of investors to that choice in setting $1 - f$. Hence, if a type-U manager who is investing in B deviates from those choices of θ and η, he will be unambiguously identified as choosing B and no funding will be available. Next we have:

Proposition 2: *Within the range of exogenous parameter values for which the inequality $fq[X(\theta) - \psi(\eta)] < \overline{\beta}$ holds given the equilibrium choices of firms, a firm with a higher θ (more complex projects) chooses a lower η (disclosure level).*

This proposition shows that a firm that has a more complex project chooses to disclose less information and be more opaque. The intuition is as follows. Greater project complexity makes it more difficult for investors to process the information disclosed by the firm. Formally, the *marginal* impact of disclosure on the precision of the signal about project choice received by the investors is smaller when project complexity is greater. Consequently, the marginal benefit of greater disclosure in changing the cost of external finance is smaller when project complexity is higher. However, the marginal cost of information disclosure in reducing the project payoff is unchanged. Hence, less information is disclosed when project complexity is higher.

Finally, we solve the full problem in which the firm chooses project complexity, θ. All that is exogenously fixed now is the reputation for trustworthiness, p. The manager solves the following problem:

$$\max_{\eta \in [0,\overline{\eta}], \theta \in [0,1]} f(\eta) q \left[X(\theta) - \psi(\eta)\right] \tag{10}$$

subject to

$$\begin{aligned} &\alpha_1(p) C(\eta,\theta)[1-f]\left[q\left[X(\theta)-\psi(\eta)\right]-I\right] \\ &\quad + [1-\alpha_1(p)]\left\{1-C(\eta,\theta)\right\}\left\{-I\right\} = 0 \end{aligned} \tag{11}$$

$$\alpha_1(p) \equiv p + [1-p][1-r] = pr + [1-r] \tag{12}$$

Analysis of this maximizaiton problem leads to the final result:

Proposition 3: *There exists a critical value of p, say $\hat{p}^* \in (0,1)$, defined by*

$$\hat{p}^* = \frac{I}{r\left[qX(1) - \overline{\beta}\right]} - \frac{[1-r]}{r} \tag{13}$$

such that for all values of $p < \hat{p}^*$*, firms with better reputations for being trustworthy (higher values of* p*) choose more complex projects (higher values of* θ*). That is,* $d\theta^*/dp > 0$ *for all* $p < \hat{p}^*$*. For all* $p \geq \hat{p}^*$*, firms choose* $\theta = 1$ *and* $\eta = 0$*, regardless of* p*. Here* $X(1) \equiv X_c$*.*

This proposition says that more trustworthy firms choose greater complexity. Combining this with Proposition 2, we see that it means that more trustworthy firms are are not only more complex, but they disclose *less* information and are *intentionally* more opaque. This result sheds light on the empirical evidence discussed in the Introduction. Moreover, once p is sufficiently high, firms choose the maximum project complexity and the minimum disclosure. Greater trust thus leads to less transparency.

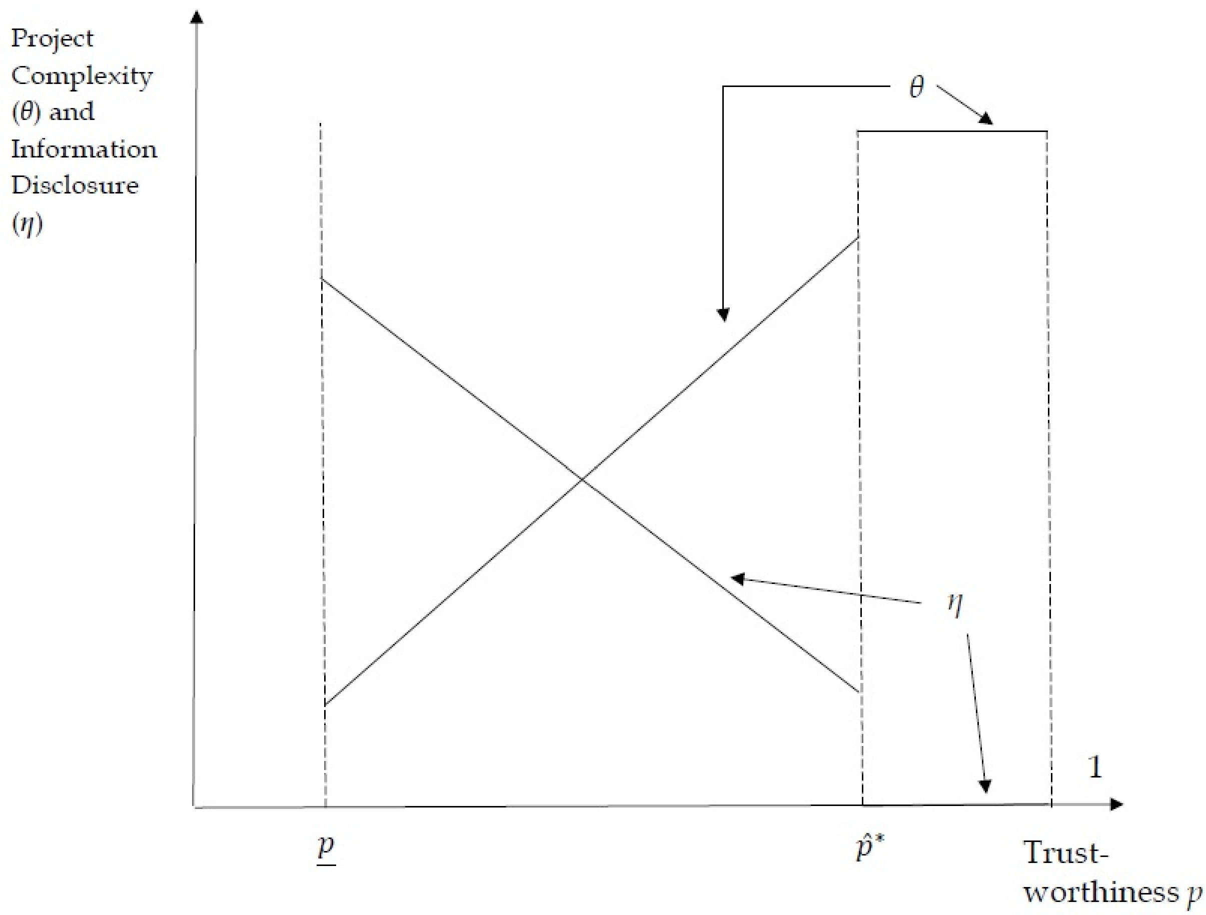
The intuition is that when the firm is more trusted, the marginal cost of disclosing less information in terms of the consequent increase in its cost of external finance (i.e. $1 - f$) is smaller. The marginal benefit of disclosing less information (which is a lower disclosure cost) is the same. This means it is less costly at the margin for a more trusted firm to disclose less information. Since it is optimal to disclose less information when project complexity is greater (Proposition 2), a more trusted firm finds it optimal to choose a more complex project with its higher first-best expected value.[21] See *Figure 3* below.

4 Verifiability and Regulation

Thus far we have shown that transparency achieved through information disclosure is a *partial* substitute for trust. However, the efficacy of information disclosure declines when project complexity increases, so the most complex firms are the most opaque and this makes

[21] It is useful to compare our analysis here to Thakor and Merton's (2018) theory which is built around model uncertainty. In one model of the world—referred to as Model I—agents are viewed as being trusted, so they always choose G regardless of circumstances. In another model of the world—referred to as Model II—agents choose G only if it is utility-maximizing to do so under the circumstances. In our context, there may be two observationally distinct groups of firms at the outset. Those in Model I would all choose $\theta = 1$ and $\eta = 0$. Those in Model II would choose $\theta = 1$ and $\eta = 0$ if $p \geq \hat{p}^*$, and would choose $\theta < 1$ and $\eta > 0$ with η decreasing in θ for all $p < \hat{p}^*$. In the multiperiod setting of Thakor and Merton (2018), project failure at the end of the first period would not affect the trusted firms described by Model I, but the firms in Model II—particularly those with p just above $\hat{p}^*$—may be forced to switch to simpler projects and become more transparent.

Figure 3: Trust, Complexity, and Disclosure



trust essential for them to operate. That is, absent trust, firms cannot undertake very complex projects. In this section we discuss alternatives to trust: verifiability and regulation.

4.1 Verifiability

Our previous analysis shows that information disclosure by firms is one way to address investors' lack of information. However, the analysis also shows that disclosure is optimally incomplete, so the information gap between the firm and investors is never bridged completely. This leaves room for other mechanisms to complement direct disclosure. We now examine one such mechanism—verification, which involves monitoring of the firm to verify project choice.

There are two type of verifiability—ex post and ex ante. Our base model already incorporates ex post verifiability of the project cash flow, and contracts are conditional on that verifiability.[22] The actual project choice is not verifiable ex post, but this does not matter. This is because we have limited liability, so when $\tilde{x} = 0$ and it is determined ex post that the firm invested in B at $t = 0$, there is nothing investors can do. Thus, adding ex post verifiability of project choice to the model would not change anything.

Consider now ex ante verifiability of project choice. By assumption, investors cannot observe this choice. That is, suppose investors can hire a monitor to verify the firm's project choice ex ante. This role is routinely played by entities such as auditors. Even credit rating agencies play this role by specifying the firm's default risk through the rating given to the firm, which is an indication of project choice. A question this raises is: who will monitor the monitor, given that the monitor will have incentives to shirk? That is, if ex ante verification is costly for the monitor and the monitor's output itself—verification of the firm's project choice—is not verifiable, then how does one ensure that the monitor will do the job? In a dynamic setting, reputational considerations will influence the monitor, but we take a

[22]This means we are not in the type of setting considered by Townsend (1979), where ex post cash flows are unobservable and can be verified only at a cost.

different approach here.[23]

Rahman (2012) provides a theoretical framework that examines this problem. The basic idea is as follows. The monitor is asked by investors to verify the firm's project choice with probability $\sigma \in [0, 1]$ at $t = 0$. It costs the monitor $K(\theta) > 0$ to do the verification and the monitor privately observes whether the cost of verification was actually incurred. We assume $K' > 0$ and $K'' > 0$. If the cost is incurred, the monitor can determine the firm's project choice at date $t = 0$ without error. If the cost is not incurred, nothing is learned. Thus, the key for investors is to ensure that the monitor actually verifies the firm's project choice. So investors ask the firm to choose G with probability $\mu \in [0, 1]$ and B with probability $1 - \mu$. The firm does not know *when* the monitor is asked to monitor, and the monitor does not know which project the firm has been asked to choose.

There is moral hazard at two levels. First, the firm may not choose G. Second, the monitor may report a project choice without verification. In equilibrium, two incentive compatibility conditions are satisfied: the firm always chooses the project it is asked to and the monitor always verifies project choice when asked to. Given this and non-negativity restrictions on payments, the contracts offered by investors are as follows:[24]

Firm: The firm is given financing I and paid a share $f_1 \in (0, 1)$ of the final payoff if there is no monitoring or if there is monitoring, the firm was asked to choose project $i \in \{G, B\}$ at $t = 0$, and the monitor reported that the firm chose the project i at $t = 0$ it was asked to.

Monitor: The monitor is paid nothing if not asked to monitor. It is paid M_1 if asked to monitor, the firm is asked to choose G, the monitor reported G at $t = 0$ and the project payoff at $t = 1$ is $X(\theta)$. The monitor is paid M_2 if asked to monitor, the firm is asked to choose B, the monitor reported a choice of B at $t = 0$, and the project payoff is zero at

[23]Such incentives are examined by Marinovic and Szydlowski (2019), as discussed earlier.

[24]There is a third moral hazard problem. The investors—who privately know what they asked the firm to choose—may not pay the monitor even when a correct report is provided, claiming that the firm was asked to make a different choice. The structure of contracts below takes care of this moral hazard problem.

$t = 1$.

At $t = 0$: Thus, the sequence of events is as follows. Investors announce the probabilities σ and μ publicly. Then they privately instruct the firm to choose B or G, and privately instruct the monitor to verify project choice or not. If the monitor was *not* asked to verify the firm's project choice or if the monitor reports to investors that the firm chose the project that coincides with what the investors had instructed the firm to choose, then the firm is given financing I. The firm is denied financing if the monitor reports a project choice other than what the firm was asked to make. Since the project payoff with B as well as in the failure state with G is zero, the firm will need to raise $I + M_2$ at $t = 0$ and keep M_2 as a verifiable deposit beyond the reach of the manager or investors until $t = 1$.

At $t = 1$: The project payoff is publicly observed, so the total amount available for payouts is the project payoff plus M_2.

We now consider the relevant incentive compatibility (IC) constraints. We start by considering the monitor's incentives. If the monitor verifies project choice at a cost K, its expected payoff is

$$\mu q M_1 + [1 - \mu] M_2 - K \tag{14}$$

If the monitor does not verify project choice and reports G, the expected payoff is:

$$\mu q M_1 \tag{15}$$

If the monitor does not verify project choice and reports B, the expected payoff is:

$$\mu [1 - q] M_2 + [1 - \mu] M_2 \tag{16}$$

The two IC constraints for the monitor to invest K in verification are that (14) is no smaller than (15), and that (15) is no smaller than (16). Since these two constraints are binding in equilibrium, the solutions yield

$$M_2 = K\left[1-\mu\right]^{-1} \tag{17}$$

$$M_1 = K[1-\mu q]\left\{\mu q[1-\mu]\right\}^{-1} \tag{18}$$

Since K is a deadweight cost, the socially efficient solution is obtained in the limit as $\sigma \to 0$, $\mu \to 1$. However, as (17) and (18) reveal, as $\mu \to 1$, $M_1 \to \infty$ and $M_2 \to \infty$. In practice, there may be upper bounds on how big M_1 and M_2 can be. Let $\hat{M}_2$ be the maximum feasible value of M_2. This yields the equilibrium value of μ, call it μ^*, as:

$$\mu^* = 1 - K(\theta)\left[\hat{M}_2\right]^{-1} \tag{19}$$

So the equilibrium M_1, call it M_1^*, is given by:

$$M_1^* = K(\theta)\left[1-\mu^* q\right]\left\{\mu^* q\left[1-\mu^*\right]\right\}^{-1} \tag{20}$$

The IC constraint for the firm to choose G when it is asked to is:

$$\sigma\left\{f_1 q\left[X(\theta) - M_1^* + \hat{M}_2\right]\right\} + [1-\sigma]\left\{f_1 q\left[X(\theta) + \hat{M}_2\right]\right\} \geq \sigma[0] + [1-\sigma]\overline{\beta} \tag{21}$$

The left-hand side (LHS) of (21) is the firm's expected payoff from G and the right-hand side (RHS) is its expected payoff from B. The probability is σ that the monitor is asked to verify, and in this case, the firm's expected payoff is the term multiplying σ. If there is no verification (probability $1-\sigma$), the expected payoff is higher by M_1^*, the amount that does not need to be paid to the monitor. The RHS reflects the fact that if the firm chooses B and the monitor verifies the choice, no financing is provided, whereas if there is no verification, financing is provided and the manager enjoys the private benefit of $\overline{\beta}$. Here f_1 is chosen to ensure that the participation constraint of investors to provide $I + \hat{M}_2$ at the equilibrium choices is satisfied. Since (21) is binding in equilibrium, we have

$$\sigma = \frac{f_1 q \left[X(\theta) + \hat{M}_2 - \overline{\beta}\right]}{q f_1 M_1^* - \overline{\beta}} \tag{22}$$

where M_1^* and $\hat{M}_2$ are given in (19) and (20). In what follows, as assume $2\mu q > 1$. This is sufficient for $X + \hat{M}_2 > M_1^*$.

4.2 Comparison of Ex Ante Verification to Disclosure

The efficiency loss from the verification approach is:

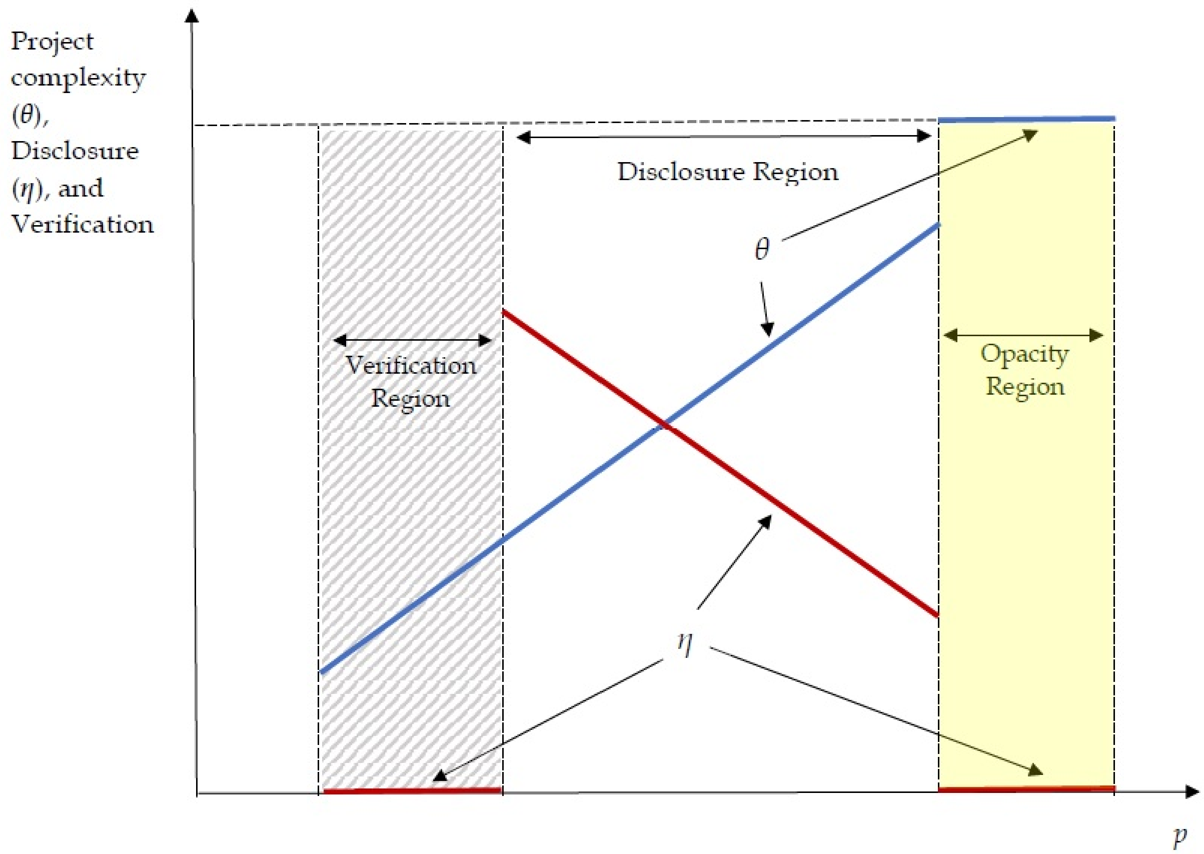
$$\mathcal{L}(\theta) = \sigma \left\{\mu q M_1^* + [1-\mu]\hat{M}_2\right\} + [1-\mu] q X(\theta) \tag{23}$$

The efficiency loss is related to both the deadweight costs of verification and the loss from permitting investment in B. Note that $\mathcal{L}(\theta)$ is increasing in $K(\theta)$ and $X(\theta)$. This leads to the next result.

Proposition 4: *A firm with a reputation for trust parameter $p > \hat{p}^*$ will never choose ex ante verification, and will choose maximum complexity $\theta = 1$ and no disclosure $\eta = 0$. For firms with $p < \hat{p}^*$, if disclosure dominates verification at $p = \underline{p}$, no firm will choose verification and the equilibrium will be as described in Proposition 3. If verification dominates disclosure at $p = \underline{p}$ but $K(\theta)$ becomes sufficiently large at a θ corresponding to some $p < \hat{p}^*$, then there will exist a $\tilde{p} \in \left(\underline{p}, \hat{p}^*\right)$ such that all firms with $p \in \left[\underline{p}, \tilde{p}\right)$ will choose verification and no disclosure, firms with $p \in [\tilde{p}, \hat{p}^*)$ choose complexity increasing in p and disclosure that is decreasing in p, and all firms with $p \geq \hat{p}^*$ choose $\theta = 1$ and $\eta = 0$.*

The intuition is that the cost of disclosure, $\psi(\eta)$, is increasing in disclosure η, but η is decreasing in θ, and θ is increasing in p. So as p increases, η declines and $\psi(\eta)$ declines. By contrast, the loss due to verification keeps increasing in θ. Thus, relative to verification, disclosure is least desired at $p = \underline{p}$, when η takes its highest value. Thus, if disclosure is

Figure 4: Trust, Complexity, Disclosure, and Verification



preferred at $p = \underline{p}$, it will be preferred for all $p > \underline{p}$. But if verification is preferred at $p = \underline{p}$ and $K(\theta)$ rises with θ (and hence with p) sufficiently rapidly, firms with some $p = \tilde{p} < \hat{p}^*$ will switch to disclosure after initially choosing verification. *Figure 4* depicts this situation.

Thus, transparency is non-monotonic. For the simplest projects, there is verification and no disclosure, so there is opacity. These are undertaken by firms with the lowest reputations for being trustworthy. For intermediate levels of trustworthiness, there is transparency, achieved through information disclosure for moderately complex projects. The most complex projects are undertaken only by those with the strongest reputations for trustworthiness, and these firms disclose nothing, so there is again opacity.

This analysis hinges on upper bounds on M_1 and M_2. If there were no bounds, the efficiency losses from verification can be asymptotically made to vanish. In this case, verification will dominate disclosure until $p = \hat{p}^*$.

4.3 Regulation

The losses with ex ante verifiability arise from the cost of verification, $K(\theta)$, and the efficiency lost due to sometimes asking the firm to choose B. A trusted regulator can eliminate the loss from asking the firm to choose B. The cost K will still remain. However, a trusted regulator, be eliminating one of the two efficiency losses with verifiability, can facilitate replacing disclosure with verification in more circumstances than possible without a regulator. Consequently, regulation can help reduce both verification and disclosure costs and permit firms to disclose less because the word of the trusted regulator substitutes (at least partially) for direct disclosure by the regulated firm.

5 Examples

In this section, we discuss some examples to illustrate our results.

Example 1: *Retail Financial Advice and Technology in Consumer Finance.*

Retail financial advice provides a good example of verification in a world of financial products involving technology (e.g. Willis (2011)). One reason why retail investors may turn to financial advisors is provided by our model. The technology involved in many of these financial products—how they do what they are designed to do—is opaque to retail investors. There is no reason for investors to trust the technology developed by technology providers. So retail investors turn to financial advisors to provide third-party verification of the technology and its usefulness in delivering the services associated with the product. The advisor can rely on past analyses (such as using spreadsheets) as a benchmark against which to verify the superiority of the black box representing the new technology. This assures retail customers who end up using the technology despite not necessarily trusting the seller or having transparency.

Example 2: *Disclosures Improve Transparency in Credit Markets.*

There are numerous papers that have documented how disclosures—even those that are unverifiable—improve transparency and lower the cost of financing. For instance, Michels (2012) provides an example in the context of P2P lending. Other examples are disclosures made by firms that are raising capital through IPOs. In these examples, there may be some level of trust that investors have in those seeking financing but it is not high enough to ensure financing at terms attractive to issuers. Transparency substitutes for trust and lowers the cost of financing.

Example 3: *Trusted Opaque Firms.*

There are numerous examples of firms whose track record has enabled them to build trust and they thus need neither transparency nor verification. We discussed some of these in the Introduction. Firms like Berkshire Hathaway, Apple, and Microsoft report billions of dollars in cash on their balance sheet, but rarely disclose much information about specific intended uses. Goldman Sachs has a highly complex portfolio of activities and typically disclosed far less information about its businesses and their profitability than most of its competitors (e.g. Hoffman (2020)).

6 Conclusion

This paper theoretically examined the extent to which information transparency achieved through information disclosure can substitute for trust. This analysis produces three main results. First, the presence of trustworthy firms produces a positive externality for other firms that may be purely self-interested in the sense that it can lower the cost of capital for these firms enough to induce them to act in the same manner as trusted firms. Second, firms that have more complex projects choose to disclose less information to investors. Third, firms that are more trusted optimally choose more complex projects, disclose less information, and be more opaque. These results reverse the usual causality that greater transparency leads to more trust. Rather, firms that are more trusted optimally choose greater complexity and lower transparency.

We also examine the role of verification by a monitor as an alternative to disclosure. We account for the challenge of motivating the monitor to verify at a personal cost and report project choice truthfully to investors, and we characterize the resulting efficiency losses. We show that there are circumstances in which transparency is non-monotonic in the firm's underlying reputation for being trustworthy—firms with weak reputations choose simple projects, opt for verifiability, and remain opaque, firms with intermediate reputations choose information disclosure with intermediate complexity projects, and the firms with the strongest reputations choose the most complex projects with no disclosure.

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Appendix

Proof of Proposition 1: Rearranging (5) gives us:

$$
\begin{aligned}
f_0 &= \frac{qX\left\{p+[1-p][1-r]\right\}-I}{qX\left\{p+[1-p][1-r]\right\}} \\
&= 1-\frac{I}{qXA}
\end{aligned}
\tag{A.1}
$$

where

$$A \equiv p+[1-p][1-r] \tag{A.2}$$

Now, $\partial A/\partial p = r > 0$, and $\partial f_0/\partial A > 0$, which means $\partial f_0/\partial p > 0$. Now, the manager will select G when $\tilde{\beta} = \overline{\beta}$ as long as $f_0 qX > \overline{\beta}$, which (upon substituting for f) means:

$$qX\left\{1-\frac{I}{AqX}\right\} > \overline{\beta} \tag{A.3}$$

Note that the left-hand side of (A.3) is increasing in p. The critical value of p, call it p^*, at which (A.3) becomes an equality is a solution to

$$qX - \frac{I}{p^* + [1-p^*]\,[1-r]} = \overline{\beta} \tag{A.4}$$

Solving (A.4) yields

$$p^* = \frac{I}{r\left[qX-\overline{\beta}\right]} - \frac{1-r}{r} \tag{A.5}$$

When $p > p^*$, (A.3) holds and the manager chooses G when $\tilde{\beta} = \overline{\beta}$, and thus G is chosen for all $\tilde{\beta}$. Consequently, once p exceeds p^*, further increases in p have no effect on f_0. When $p < p^*$, the inequality in (A.3) is reversed and the manager chooses B when $\tilde{\beta} = \overline{\beta}$. Finally, it is straightforward to verify that, given (4), $p^* \in (0,1)$. ■

Proof of Lemma 1: The proof follows directly from the discussion in the text. ■

Proof of Proposition 2: When $fq[X(\theta) - \psi(\eta)] < \overline{\beta}$, the firm's manager solves the program in (8)-(9). Substituting (9) in (8) and simplifying gives the maximand:

$$q[X(\theta) - \psi(\eta)] - I - I\left[\alpha_1(p)^{-1} - 1\right]\left[\{[1-\theta]C_s(\eta)\}^{-1} - 1\right] \tag{A.6}$$

where

$$\alpha_1(p) \equiv pr + [1-r] \tag{A.7}$$

The first-order condition for the optimal η is

$$-I\left[\{\alpha_1(p)\}^{-1} - 1\right]\left[\frac{-C_s'(\eta)}{[1-\theta]\,[C_s(\eta)]^2}\right] - q\psi'(\eta) = 0 \tag{A.8}$$

The second-order condition is

$$\frac{I\left[\{\alpha_1(p)\}^{-1} - 1\right]}{[1-\theta]}\left\{\frac{C_s''(\eta)}{[C_s(\eta)]^2} - \frac{2\,[C_s'(\eta)]^2}{[C_s(\eta)]^3}\right\} - q\psi''(\eta) < 0 \tag{A.9}$$

since $C_s'' < 0$ and $\psi'' > 0$.

Now totally differentiating the first-order condition (A.8) with respect to θ, and dropping the arguments of C_s, we have:

$$-I\left[\{\alpha_1(p)\}^{-1} - 1\right]\left[C_s'/C_s^2\right][1-\theta]^{-2} + SOC\left[\frac{d\eta^*}{d\theta}\right] = 0 \tag{A.10}$$

which yields:

$$\begin{aligned}\frac{d\eta^*}{d\theta} &= \frac{I\left[\{\alpha_1\}^{-1} - 1\right][C_s'/C_s^2]\,[1-\theta]^{-2}}{SOC} \\ &< 0 \end{aligned} \tag{A.11}$$

■

Proof of Proposition 3: Assume first that $fq\left[X(\theta)-\psi(\eta)\right] < \overline{\beta}$. Then the objective function that is being maximized is given by (A.6). Using the Envelope Theorem, the first-order condition for the optimal θ is:

$$qX'(\theta) - I\left[\{\alpha_1\}^{-1} - 1\right]\left[C_s\left[1-\theta\right]^2\right]^{-1} = 0 \qquad \text{(A.12)}$$

where $X'(\theta) = X_c - X_s > 0$. The second-order condition is:

$$S\hat{O}C \equiv -2I\left[\{\alpha_1\}^{-1} - 1\right]\{C_s[1-\theta]\}^{-3} < 0 \qquad \text{(A.13)}$$

which clearly holds. Now totally differentiating (A.12) with respect to p yields:

$$S\hat{O}C\left[\frac{d\theta^*}{dp}\right] + I\left[C_s\left[1-\theta\right]^2\right]^{-1}\left[r\{\alpha_1\}^{-2}\right] = 0 \qquad \text{(A.14)}$$

Thus,

$$\frac{d\theta^*}{dp} = \frac{-Ir}{S\hat{O}C\left[C_s\left[1-\theta\right]^2\alpha_1^2\right]} > 0 \qquad \text{(A.15)}$$

Now let $\hat{p}^*$ be the smallest value of p satisfying:

$$f\left(0,\hat{p}^*\right)qX(1) = \overline{\beta} \qquad \text{(A.16)}$$

where $1 - f\left(0,\hat{p}^*\right)$ is the ownership fraction that must be sold to investors when $p = \hat{p}^*$ and $\eta = 0$ and $X(1)$ is the value of $X(\theta)$ with $\theta = 1$, i.e., $X(1) \equiv X_c$. Note that $\psi(0) = 0$. Here:

$$f\left(0,\hat{p}^*\right) = 1 - \frac{I}{qX(1)\{\hat{p}^*r + [1-r]\}} \qquad \text{(A.17)}$$

Substituting (A.17) in (A.16) and solving leads to

$$\hat{p}^* = \frac{I}{r\left[qX(1)-\overline{\beta}\right]} - \frac{1-r}{r} \qquad \text{(A.18)}$$

Clearly, for all $p \geq \hat{p}^*$, the type-N manager will choose G even when $\tilde{\beta} = \overline{\beta}$ (Proposition 1). Hence, no disclosure η is needed and the firm can optimally choose $\theta = 1 \; \forall \; p \geq \hat{p}^*$. This means that for $p \geq \hat{p}^*$, θ and η remain constant. For all $p < \hat{p}^*$, the type-N manager chooses G when $\tilde{\beta} = 0$ and B when $\tilde{\beta} = \overline{\beta}$. And in this range of p values, $d\theta^*/dp > 0$, as proved earlier. It is clear that, given (5), $\hat{p}^* > 0$. Further, given (4), $\hat{p}^* < 1$. Thus, $\hat{p}^* \in (0, 1)$. ■

Proof of Proposition 4: Straightforward from the discussion in the text. ■