# Information Sensitivity and the Scope of Financial Intermediation*

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**Abstract**

How valuable is a lender's information about a borrower? We present a model to argue that even in the absence of standard screening and monitoring motives, informed lending creates value through incentive contracts that are tailored to the borrower's current concerns. In our setting, borrowers with highly volatile but highly productive investment projects benefit most from contracting with informed lenders. When information acquisition is costly, only lenders with a sufficiently wide bank scope acquire information. In line with the empirical record from the repeal of the Glass-Steagall Act, we show that increasing bank scope is efficiency-enhancing at the firm level.

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# 1 Introduction

In this paper, we present a theoretical model of financial intermediation in the presence of two frictions: a hidden-action problem on the side of the borrower, and asymmetric information between lender and borrower about the nature of the optimal action to be taken by the borrower. We develop a notion of information sensitivity at the firm level by comparing a firm's maximal borrowing capacity when faced with an informed lender as opposed to an uninformed lender. The model allows us to characterize this information sensitivity as a function of the fundamentals of the firm. We find that highly volatile firms are particularly sensitive to lender informedness, and especially so if they are simultaneously highly productive. We then extend the model to allow for endogenous information acquisition by lenders that differ in the scope of their monitoring expertise. We show that lenders may be reluctant to acquire information about highly volatile but highly productive firms, despite the fact that information is highly valuable for these firms. Indeed, it may be the case that only lenders of sufficiently wide scope and close alignment of expertise to the firm's needs can be persuaded to actively monitor the firm. Our paper thus provides a rationale for permitting the existence of lenders of wide scope: increasing bank scope enhances the efficiency of financial intermediation at the firm level through increased information acquisition.

Why is the setting of our model of practical relevance? As an example, consider a bank that provides financing to a firm that conducts research and development in multiple areas. How does the bank assess which products would benefit most from additional research at a given time? How does the bank safeguard that the funds it provides are not misappropriated? These questions are difficult to answer for a lender that possesses less expertise about a firm's strengths and weaknesses, as well as market conditions, than the firm itself. The lender can therefore be thought of as asymmetrically informed about the firm's optimal course of action, as well as about the diligence of the firm's actions. Taking a broader view, similar issues are likely to be at play whenever a prospective borrower is engaged in a complex line of business, or subject to frequent changes in its businesses environment. At least one of these concerns is likely to apply to many firms in the U.S. and, in particular, to large, publicly listed firms.

We show that the joint presence of moral hazard and profoundly impacts the optimal design of financing agreements. In contrast to standard intermediation contracts, lending agreements must now satisfy two objectives. First, the agreement must provide incentives for the borrower to reveal its information about the optimal action to be taken. Second, the agreement must provide incentives to induce the optimal action, even when it cannot be observed by the lender. As we show in this paper, simultaneously satisfying both objectives may often require conflicting incentive schemes, forcing the lender to either abandon one objective or to cede steep information rents to the firm. This reduces the firm's borrowing capacity, and has important firm-level real effects: if the lender is unable to offer a contract that implements the appropriate action, projects with positive net present value will not be implemented, leading to losses in production efficiency.

We formally explore these issues by developing a model of financial intermediation with moral hazard and asymmetric information. In the proposed framework, the two contracting frictions are tightly linked: when information asymmetries between borrower and lender shrink, the financial intermediary is better placed to overcome the borrower's moral hazard. In particular, we assume that the type of moral-hazard problem faced by the borrower is stochastic: in one state of the world, there is a growth option that is subject to misappropriation by the firm, while the firm can engage in *asset substitution* or *risk shifting* via a risky gamble in the other state of the world. In a first-best world, the lender would like to encourage the growth option while deterring the risky gamble.

Asymmetric information arises because the firm is informed about the state of the world, while the bank is not. We model the decision to adopt the growth option as a standard hidden-action problem, in which high output realizations represent the "best news" about the firm's action in the sense of Milgrom (1981). As in Innes (1990), optimal incentive provision then requires that the firm receive only the upside of the project through a standard debt contract. In contrast, we model the risky gamble as a technology that allows the firm to simultaneously increase the probability of both high *and* low realizations of output while lowering expected output, as in Jensen and Meckling (1976). Since the gamble reduces expected output, the firm does not choose the gamble whenever it is sufficiently exposed to its downside risk. If, on the other hand, the firm is exposed only to the upside, as is the case in the standard debt contract, the firm *will* have incentives to choose the gamble. As such, a tension arises in the optimal incentive provision across states: the contract that efficiently provides incentives to choose the growth option in one state may *also* provide incentives to choose the risky gamble in the other state. The model thus gives rise to adverse selection in incentive contracts.

We show that an uninformed lender may be forced to resolve this tension by providing incentives in one state of the world only, or by ceding steep moral-hazard rents to provide incentives in every state of the world. The optimal contract offered by an uninformed lender falls into one of three classes: *full-incentive contracts* that provide incentives for the appropriate action in each state, *implementation contracts* that implement the growth option but fail to deter the firm from accepting the risky gamble, and *deterrence contracts* that deter the firm from accepting the risky gamble but fail to implement the growth option. Two sources of inefficiency arise due to asymmetric information. First, the firm may not choose the appropriate action in every state, as in an implementation or a deterrence contract, and second, the lender may have to cede particularly high moral-hazard rents to the firm to provide incentives. The latter inefficiency arises because the bank cannot tailor incentives to each state of the world when it is asymmetrically informed. As such, it may have to pay implementation rents to the firm even when the growth option is not available.

An informed lender is able to sidestep these difficulties. Since the state of the world is common knowledge under symmetric information, the lender efficiently provides incentives in every state by offering explicitly state-contingent contracts. Hence, the firm chooses the optimal action in every state, and the lender cedes only minimal moral-hazard rents to the firm. We refer to the resulting efficiency gains as the *firm-level information sensitivity*, as it captures the extent to which efficiency increases when the lender is informed.

In the optimal contract, the gains from contracting with an informed lender vary substantially with the underlying characteristics of the borrower. Indeed, we show in Proposition 2 that highly volatile and highly productive firms are especially well placed to realize efficiency gains from lender informedness. This is the case because incentive contracts that are not precisely tailored to the state of the world are particularly costly when outcomes are volatile, while providing incentives for the efficient action in every state is more valuable when the firm is highly productive. Since an informed lender provides incentives to choose the efficient action in every state, informed lending also leads to further *endogenous* increases in realized volatility and productivity at the firm level.

Given the value of information in our framework, we then ask whether an uninformed lender can be persuaded to acquire information at a cost, and if so, which kinds of intermediaries are most likely to acquire information. To this end, we extend our model so as to accommodate syndicates of banks – as is customary in loan origination – with heterogenous monitoring expertise. We argue that banks with different monitoring expertise are complements in information acquisition: an equity analyst's forecast of the state of an industry can be combined with a commercial banker's in-depth knowledge of a firm's inner workings to produce an accurate assessment of its prospects, for example. When monitoring skills are dispersed among lenders, free-rider problems emerge between lenders whenever monitoring activity is not fully contractible: one bank may rely too much on the other syndicate members' efforts, and shirk on its own duties to investigate the firm's performance. We provide a simple framework to assess the sources of coordination failures in monitoring. We show that there is underinvestment in information if monitoring expertise is very dispersed, or a firm is exceptionally hard to monitor. Crucially, we show in Proposition 5 that firms that are simultaneously highly volatile and highly productive may find it relatively harder to provide information-acquisition incentives to banks, *despite* the fact that information is more valuable to such firms. Highly volatile and highly productive firms will therefore strongly benefit from any enhancements in banks' willingness to produce information, for example through reduced coordination failures in monitoring.

We then argue that one way of overcoming coordination failures may be by increasing the *scope of banking*. If a single bank possesses all necessary monitoring expertise in house, it captures all benefits of increased information production as a private benefit, and the free-riding problem disappears. In the United States, financial deregulation provides a laboratory to empirically test the key predictions of our model. Namely, the gradual repeal of the Glass-Steagall Act in the 1990s allowed the establishment of *universal banks*, large financial institutions active in a wide variety of banking activities. Through the lens of our model, the wide scope of universal banks serves to reduce coordination failures in information acquisition. Our model thus predicts that the advent of universal banks allowed banks and firms to realize gains from informed lending. We use our theoretical framework to generate testable predictions. In particular, the model suggests increases in both volatility and productivity for universal-bank-financed firms, and decreases in the size of loan syndicates in the presence of universal banks. In a companion paper (Neuhann and Saidi (2013)), we show that these predictions are borne out in the data: universal bank-financed firms indeed exhibit substantially higher volatility and increases in firm-level total factor productivity (TFP).

Our results therefore point to an efficiency-enhancing aspect of permitting banks of wide scope: the advent of universal banking allowed firms to realize investment opportunities that they may not previously have been able to bring to fruition. In this sense, our paper contributes to the recent policy debate regarding the optimal regulation of banks. While to date this debate has focused on considerations of bank size (too big to fail) and aggregate stability, we emphasize the role of bank scope and its effects on real outcomes at the firm level.

The remainder of the paper is organized as follows. We begin by describing the model setup as well as the sources of moral hazard and asymmetric information in Section 2. In Section 3, we characterize the optimal contract. Before analyzing the full-fledged model with both moral hazard and asymmetric information, we first analyze two benchmark settings: the first-best setting with symmetric information and no moral hazard, and an intermediate setting in which information is symmetric but there is moral hazard. The optimal contracts in these benchmark settings serve to provide intuition as to the nature of the optimal contract in the full model, and highlight the value of information in designing optimal financial contracts. We then use the characterization of the optimal contract to derive our preferred measure of firm-level information sensitivity, namely the firm's maximal borrowing capacity as a function of the lender's informedness. In Section 4, we extend our model to incorporate information acquisition by lender syndicates. Finally, we discuss the key empirical predictions of our model in Section 5, and Section 6 concludes.

### Related Literature

Our model has four key features. First, we argue that the extent of asymmetric information between borrower and lender is an important determinant of firm-level outcomes, and we use optimal intermediation contracts to link these outcomes to firm characteristics. Second, we provide a model in which asymmetric information determines the extent to which the lender can provide incentives to overcome the firm's moral hazard, generating adverse selection on incentive contracts. Third, we allow for endogenous information acquisition by banks to alleviate this adverse selection. Fourth, we argue that the scope of banking is an important determinant of lenders' incentives to acquire information. In the following, we link each of these features to the existing literature, and establish how our model innovates on extant approaches.

In the sense that we vary the degree of information asymmetry between borrower and lender, our paper is related to a large literature on relationship banking, such as Sharpe (1990), Rajan (1992), and von Thadden (2004). In these papers, lending relationships serve to reduce information asymmetries *within* a relationship, with two key effects. First, there may be informational rents captured by the lender, which expose the borrower to hold-up. Second, the lender may be able to make flexible financial decisions that enhance the value of the firm. Bolton, Freixas, Gambacorta, and Mistrullie (2013) develop a model of relationship banking over the business cycle based on Bolton and Freixas (2006), and provide evidence for information acquisition in lending relationships. Our paper takes a similar approach in that we are interested in the effects of reductions in informational frictions as determinants of firm-level efficiency gains. However, our model differs in that we analyze the role of *scope* rather than repeated interactions as the key driver of our results. As shown empirically by Degryse and van Cayseele (2000), the dimension of a bank-firm relationship, as determined by the bank's scope, dominates the length of the relationship in characterizing the benefits and efficiency gains. Furthermore, we link firm primitives, most notably risk and productivity, to efficiency gains from contracting with an informed lender that is well placed to overcome the firm's moral hazard. Conversely, Bolton, Freixas, Gambacorta, and Mistrullie (2013) center their attention on relationship lending over the business cycle, without linking the state of the world (the business cycle) to any firm-level frictions (such as moral hazard in our model).

Our paper is also related to the literature on performance monitoring by markets or investors in the tradition of Holmström and Tirole (1993), who discuss the role of outside investors' information about managerial effort. In our model, we discuss the importance of asymmetric information about the optimal course of action in mediating the ability of investors to overcome asymmetric information about managerial effort. Our paper therefore discusses a different type of information asymmetry than Holmström and Tirole (1993), and leads to predictions about the type of projects chosen by firms in response to this asymmetry.

More generally, our work connects with papers that study the interaction of moral hazard and adverse selection (*generalized agency models* in the terminology of Myerson (1982)), such as Baron and Besanko (1987). Also, Sung (2005) analyzes a dynamic generalized agency model in the context of managerial compensation. To the best of our knowledge, we are the first to apply a framework with adverse selection on incentive contracts to financial intermediation. In that we focus on the firm-level effects of changes in lender informedness, our paper is also similar in spirit to Greenwood, Sanchez, and Wang (2010), who develop a model of financial intermediation based on Townsend (1979) to analyze the characteristics of firms financed in equilibrium. While Greenwood, Sanchez, and Wang (2010) scrutinize general-equilibrium effects, we argue that changes at the level of the bank-firm relationship are crucial in determining the ability of firms to obtain financing.

In addition, we endogenize the lender's information-acquisition decision, and study its interaction with borrower characteristics. In this regard, our model relates to previous work that studies endogenous information acquisition in finance, such as van Nieuwerburgh and Veldkamp (2010) and, in particular, Yang and Zeng (2013), who scrutinize optimal security design by a borrower that tries to provide incentives for a lender to produce information that is valuable to the borrower. Our contribution is to incorporate the information-acquisition decision in a financial-intermediation framework with moral hazard, and to study its implications for firm-level outcomes.

Lastly, by providing an application to bank scope, our paper is related to a sizeable literature on universal banking that focuses on the ability of universal banks to simultaneously offer loans and underwriting services. Kanatas and Qi (1998) and Kanatas and Qi (2003) argue that universal banks can save on information costs by monitoring a firm once and for all, while stand-alone banks have to exert monitoring effort for each service separately. As such, firms may become locked in to a universal bank due to reduced information costs. This lock-in has adverse affects on a universal bank's incentives: if the bank expects to be able to sell a loan to a firm when underwriting fails, it may exert less effort in underwriting. A trade-off thus arises between bank effort and reduced information costs. Boot and Thakor (1997) also consider downsides of universal banking in a related setting. In their model, universal banks' ability to cross-sell diverse financial instruments leads to diminished incentives for financial innovation. Finally, Laux and Walz (2009) and Lóránth and Morrison (2012), among others, analyze the competitive effects of cross-selling.

Our model differs from these papers along two key dimensions. First, we do not impose exogenous restrictions on the set of financial instruments available to banks. Instead, we hold the set of available financial instruments fixed, and ask whether increases in scope allow a lender to use this set more efficiently. While banks clearly differ in terms of the instruments they offer, we argue that these distinctions are much finer than a dichotomy of debt versus equity suggests. We therefore establish the benefits of bank scope *beyond* those arising from differences in the set of financial instruments. Second, we explicitly characterize the resulting efficiency gain in terms of firm primitives, most notably risk, productivity, and the complexity of a firm's activities. This allows us to generate sharp predictions regarding the value of universal banks – or, for that matter, banks with a wider scope of banking activities – for firms of different types. In doing so, our argument rests solely on the notion that universal banking may serve to reduce information asymmetries between borrower firms and lender banks. While this in itself reflects one of the potential benefits of universal banking (see, for instance, Boot (2000)), in our model it leads to and reinforces another feature: the optimal contract under universal banking consists of a rich set of state-contingent securities, which implies flexibility in security design.

# 2 Model Setup

This section sets up a model of financial intermediation with asymmetric information and moral hazard. We consider a single risk-neutral firm and a single risk-neutral bank that agree to an intermediation contract in order to finance a risky project. The type of moral hazard faced by the firm is stochastic: in one state of the world, the firm can misappropriate capital for private consumption, while it can engage in asset substitution or risk shifting in the other state. Asymmetric information arises because the firm is informed about the state of the world, whereas the bank is not. As such, the bank must overcome moral-hazard frictions without precisely knowing the type of friction, leading to adverse selection.[1]

[1] For expositional ease, we focus on a simple setting with two states of the world and three potential profit realizations at the firm level. This setting allows us cleanly characterize the key forces at play in our model. Nevertheless, none of our key results depend on this structure.

The key equilibrium quantity we are interested in is a firm's maximal borrowing capacity, or pledgeable income; it is well known that, in models of financial intermediation, a firm's borrowing capacity is a key statistic that summarizes the extent to which the borrower is constrained by frictions. We characterize the optimal contract, and argue that the interaction of moral hazard and asymmetric information yields stark inefficiencies relative to a benchmark with symmetric information about the state of the world. In particular, we show that the two frictions may combine to sharply reduce a firm's borrowing capacity. We then relate these inefficiencies to firm-level characteristics. We show that firm-level volatility is a particularly important impediment to efficient financial intermediation under asymmetric information, and especially so for highly productive firms.

Throughout the paper, we assume that contracting occurs under full commitment. One drawback of this assumption is that it precludes any discussion of hold-up by an informed lender as in Rajan (1992). In terms of our key equilibrium quantity, pledgeable income, this is immaterial: even with hold-up, the banker cannot extract funds above and beyond the maximal amount that the firm can credibly promise to repay.

## 2.1 Basic Environment

We consider the problem of a penniless firm seeking funds for an investment project with uncertain prospects that requires a fixed amount of start-up funding $k_0$. Time is discrete, and runs for three dates, $t = \{0, 1, 2\}$. At date 0, the firm commits to an intermediation agreement with one or more banks, and invests. At date 1, a random variable $z \in Z$ is realized. We refer to $z$ as the state of the world, and say that it is either *high* ($h$) or *low* ($l$), i.e., $Z = \{h, l\}$. The state of the world is high with probability $\gamma$, and low with complementary probability $(1 - \gamma)$. When talking about a generic state of the world $z$, the probability of that state occurring is $\Pr(z)$. At date 2, the project outcome $X_j \in X \equiv \{X_1, X_2, X_3\}$ is realized, with $X_3 > X_2 > X_1$.[2]

## 2.2 Production Technology

Fix the set of project outcomes $X$. The firm's technology is then given by the probability distribution over $X$. At date 0, the firm is born with a basic production technology $p = \{p_1, p_2, p_3\}$. At date 1, a new technology $q^z = \{q_1^z, q_2^z, q_3^z\}$ arrives in addition to the basic technology $p$. The firm's date-1 technology portfolio is thus given by $\{p, q^z\}$. The firm must then decide which technology to employ for production. If $z = l$, implementing the new technology is costless. If $z = h$, implementing requires an additional capital investment of size $k_1$. The value of the new technology $q^z$ depends on the state of the world. In particular, we assume that

$$q^h X - k_1 > pX > q^l X.$$

[2] For simplicity, we let $X$ be evenly spaced, although this assumption can easily be relaxed.

That is, it is efficient to implement the new technology if the state of the world is high, but inefficient to do so when the state of the world is low. Throughout the paper, we will sometimes refer to $q^h$ as a *growth option* and to $q^l$ as a *gamble*. The expected value of the growth option is given by

$$\pi_h = \gamma\left((q^h - p)X - k_1\right) > 0,$$

while the expected *cost* of the gamble is

$$\pi_l = (1-\gamma)\left(p - q^l\right)X > 0.$$

We maintain the following assumptions:

**Assumption 1 (Distributional Shifts)** *$q^l$ is a strict spread of $p$, and $q^h$ is a weak spread of $p$, i.e., $q_1^l > p_1$, $q_1^h \geq p_1$, and $q_3^l, q_3^h > p_3$. Furthermore, $q_3^h - p_3 > q_1^h - p_1$ and $q_3^l - p_3 < q_1^l - p_1$.*

The assumption that $q^h$ is a spread of $p$ is not strictly necessary, and can easily be relaxed, but highlights some key properties of the model. The assumption that $q^l$ is a strict spread of $p$ *is* necessary, however: it is only by increasing the probability mass on the highest *and* the lowest outcome that an asset-substitution problem arises.

**Assumption 2 (Likelihood Ratio)** *The likelihood ratio of $q^h$ with respect to $p$ is highest at outcome 3:*

$$X_3 = \arg\max_X \frac{Pr(X|q^h)\mu}{Pr(X|q^h)\mu + Pr(X|p)(1-\mu)}$$

*for any prior $\mu \in (0,1)$. Hence, outcome 3 is the "best news" about the firm's choice of production technology in the sense of Milgrom (1981).*

Finally, we let $\tilde{q} = \gamma q^h + (1-\gamma)q^l$ denote the expected distribution over outcomes when the new technology is chosen in every state of the world, and $\hat{q} = \gamma q^h + (1-\gamma)p$ the expected distribution over outcomes when the *efficient* technology is chosen in every state of the world.

## 2.3 Information Structure and Sources of Moral Hazard

There are two potential frictions between the borrower and the bank. First, the state of the world $z$ is the entrepreneur's private information. As such, the bank's only source of information about $z$ is a report $\hat{z} \in \{h, l\}$ by the entrepreneur, which need not be truthful but is fully contractible. We call this friction *asymmetric information*. Second, the entrepreneur's technology choice is unobservable to the bank and, thus, not contractible. In particular, we assume that the entrepreneur can misappropriate any capital intended for use in the implementation of the growth option for private consumption. We denote the entrepreneur's unobserved decision to *implement* ($i$) or *discard* ($d$) the new technology in state of the world $z$ by $a(z) \in \{i, d\}$. Since the fact that $a$ is unobservable leads to an agency problem, we call this friction *moral hazard*.

When $z = h$, the growth option is the efficient technology. To ensure implementation, the bank must design a contract such that is in the *private* interest of the entrepreneur to forego private consumption in favor of implementation. Generically, the only way of doing so is to allow the entrepreneur to capture moral-hazard rents. In contrast, when $z = l$, the new technology is inefficient, and the bank would like to provide incentives to deter the firm from adopting the gamble. In designing an intermediation agreement, the bank therefore strives to optimally resolve the tension between providing incentives for the firm to adopt the appropriate technology in every state of the world and minimizing the rents it must cede to the firm in order to do so.

A recurring theme throughout the paper is the interaction of the moral-hazard and asymmetric-information frictions in determining the nature of the optimal contract. Intuitively speaking, the bank must provide incentives to overcome the firm's moral-hazard problem at the technology-adoption stage without knowing whether the firm must decide between $q^h$ and $p$ or between $p$ and $q^l$. The bank can deal with these enhanced intermediation frictions in different ways. It could, for example, opt to disregard one of the incentive problems, and aim to provide incentives to implement $q^h$ *or* to safeguard deterrence of $q^l$ only. This would allow the bank to economize on moral-hazard rents accruing to the firm, but it would also require it to hazard the consequences of an inefficient technology choice in the other state. Alternatively, it could aim to simultaneously provide incentives to choose the efficient technology in every state of the world, potentially at the expense of ceding particularly high rents to the firm.

We classify the optimal contract according to whether the bank provides incentives to choose the appropriate technology in every state. If the contract provides incentives to choose the growth option when $z = h$ and to discard the gamble when $z = l$, we say the contract is a *full-incentive contract*. When the contract provides incentives in one state of the world only, we call the contract a *partial-incentive contract*. A partial-incentive contract that only provides incentives to implement the growth option in state $h$ is an *implementation contract*, while a contract that only provides incentives to deter the gamble in state $l$ is a *deterrence contract*. Figure 1 summarizes the classification of contracts.

To focus on the interaction of the moral-hazard and asymmetric-information frictions, we assume that all investment at date 0 is fully contractible, so that $\kappa_0$ cannot be misappropriated for private consumption by the entrepreneur. Finally, we assume that the entrepreneur first reports $\hat{z}$, then observes the resulting continuation contract offered by the bank, and only then makes his adoption decision $a$.

## 2.4 Contract Space and Strategies

Contracting takes place at date 0 under full commitment. An intermediation contract is a tuple $\mathcal{C} = \{\kappa_0, \tau(\hat{z}), \kappa_1(\hat{z})\}_{\hat{z} \in \{h,l\}}$, where $\kappa_0$ denotes the initial date-0 capital transfer from bank to firm, $\tau(\hat{z}) = [\tau_1(\hat{z}), \tau_2(\hat{z}), \tau_3(\hat{z})]$ denotes the repayment schedule from firm to bank conditional on $\hat{z}$ and the project outcome, and $\kappa_1(\hat{z})$ denotes an additional date-1 capital

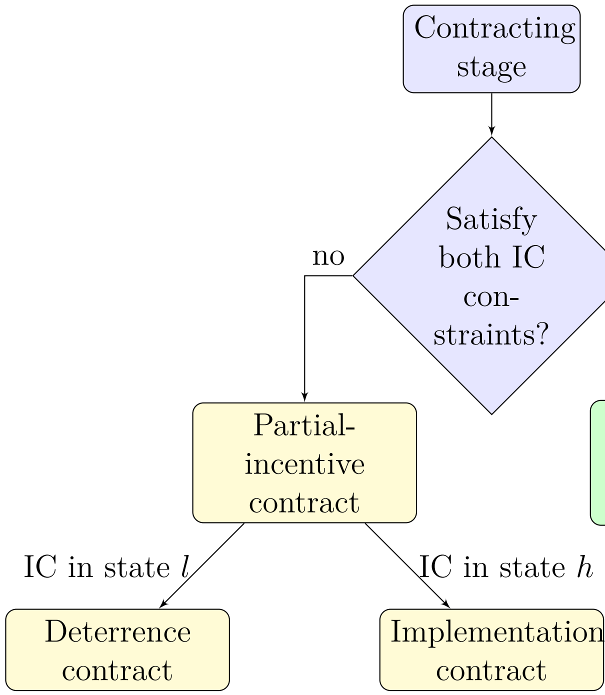


Figure 1: Contract Classes

transfer from bank to firm conditional on $\hat{z}$. The firm's *wages* or, equivalently, the firm's residual profits after repayment are given by $w(\hat{z}) = X - \tau(\hat{z})$. Contracts are subject to the entrepreneur's *limited liability*, i.e., $\tau(\hat{z}) \leq X$ for all $\hat{z}$. We refer to $\bar{\mathcal{C}} = \{\tau(\hat{z}), \kappa_1(\hat{z})\}_{\hat{z}\in(h,l)}$ as the *continuation contract* detailing only the repayment schedules and additional fund transfers for technology adoption. Whenever there is no risk of confusion, we use the terms *contract* and *continuation contract* interchangeably. A strategy for the bank is a contract offer $\mathcal{C}$, while a strategy for the firm is a pair of functions $\hat{z} : Z \to Z$ and $a : Z^2 \to \{i, d\}$, consisting of an adoption decision $a(z, \hat{z})$ and a reporting decision $\hat{z}(z)$. We denote the optimal reporting strategy given a contract offer by $\hat{z}^*(z)$, and the optimal adoption decision given $\hat{z}^*$ by $a^*(z, \hat{z})$. Since the entrepreneur has full discretion about the choice of technology for every $z$, the technology used in production is an equilibrium outcome. We denote this technology by:

$$Q(a, \hat{z}, z) = \begin{cases} q^h & \text{if } (a, z) = (i, h) \text{ and } \kappa_1(\hat{z}) \geq k_1 \\ q^l & \text{if } (a, z) = (i, l) \\ p & \text{otherwise.} \end{cases}$$

Since the entrepreneur is free to misappropriate any capital intended for implementation, choosing the growth option forces him to incur a private cost in terms of foregone private consumption $c$. This cost is given by:

$$c(a, z) = \begin{cases} k_1 & \text{if } (a, z) = (i, h) \\ 0 & \text{otherwise.} \end{cases}$$

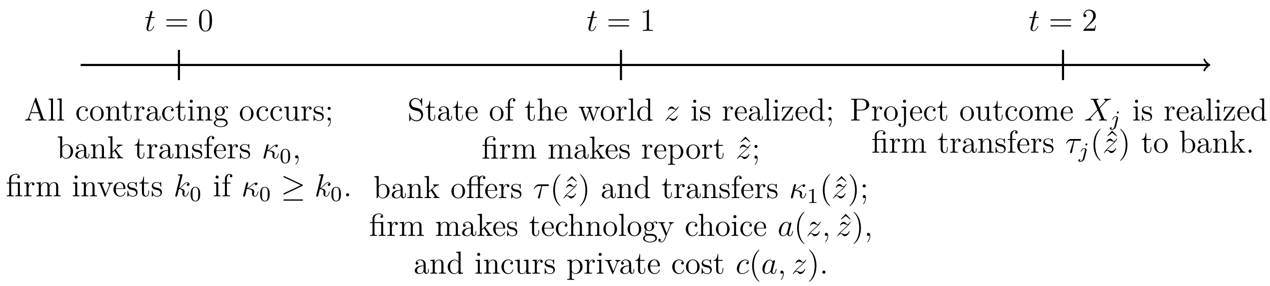


Figure 2: Timing of Events

At the optimal strategy $\{a^*(z, \hat{z}^*(z)), \hat{z}^*(z)\}$, the optimal technology choice in state $z$ is a function of $z$ only, and is given by:

$$Q^*(z) \equiv Q\left(a^*(z, \hat{z}^*(z)), \hat{z}^*(z), z\right).$$

Similarly, we let $\kappa_1^*(z)$, $c^*(z)$, and $w^*(z)$ denote, respectively, the additional capital transfer, the private cost of the adoption decision, and the firm's wages under the optimal strategy. Given the firm's optimal strategy, the firm's total *expected wages* are:

$$W = \sum_z \Pr(z) \left[ \underbrace{Q(z) w(\hat{z}^*(z))}_{\text{residual profits}} \quad + \quad \underbrace{\kappa_1^*(z) - c^*(z)}_{\text{misappropiated capital}} \right].$$

The contracting setup and the timing of events is summarized in Figure 2.

Throughout the paper, we assume that the firm has all bargaining power, so that the contracting stage takes the form of a take-it-or-leave-it-offer from firm to bank. For simplicity, we also normalize the outside options of both bank and firm to zero. Since the firm has full bargaining power, the key equilibrium quantity in the model is the maximum repayment that the firm can credibly promise to the bank while respecting incentive-compatibility and individual-rationality constraints. Since outside options are equal to zero for both bank and firm, the project will be financed if and only if pledgeable income exceeds the total expected capital outlays by the bank. Throughout our analysis, we focus on changes in pledgeable income as we vary bank and firm characteristics. Whenever there is no risk of confusion, we use the term *optimal contract* to denote the continuation contract that maximizes pledgeable income.

# 3 Characterization of the Optimal Financing Contract

In this section, we describe the continuation contract that maximizes pledgeable income under asymmetric information, moral hazard, and limited liability. Recall from above that the optimal strategy for the firm given a contract offer $\mathcal{C}$ is given by $\{a^*(z, \hat{z}^*(z)), \hat{z}^*(z)\}$, leading to an optimal technology choice in state $z$ given by $Q^*(z)$. Then, the optimal continuation contract is the solution to the following program:

$$T = \max_{\{\tau(\cdot),\kappa_1(\cdot)\}} \quad \sum_z \Pr(z)\left[Q^*(z)\tau(\hat{z}^*) - \kappa_1(\hat{z}^*(z))\right] \tag{P}$$

s.t $(i)$ for every $(z, \hat{z})$

$$a^*(z,\hat{z}) = \arg\max_a \quad Q(a,z,\hat{z})\left(X - \tau(\hat{z})\right) + \kappa_1(\hat{z}) - c(a,z) \tag{IC}$$

$(ii)$ for every $z$

$$\hat{z}^*(z) = \arg\max_{z'} \quad Q(a^*(z,z'),z,z')\left(X - \tau(z')\right) + \kappa_1(z') - c(a^*(z,z'),z) \tag{REV}$$

$(iii)$ $\tau(z) \leq X$ for every $z$. (LL)

The incentive-compatibility constraint (IC) and the information-revelation constraint (REV) require that the firm choose its technology and its reporting strategy so as to maximize its private benefit, while (LL) imposes limited liability on the part of the entrepreneur. Pledgeable income, which we refer to as $T$, is then the value of the program (P). Since the outside options for bank and firm are normalized to zero, the project is financed whenever $T \geq k_0$. We begin the characterization of the optimal continuation contract by establishing two benchmarks: the optimal contract given symmetric information about $z$ and no moral hazard, and the optimal contract with symmetric information *and* moral hazard.

## 3.1 First-best Benchmark

To establish the first-best benchmark, suppose that the bank has perfect information about the state of the world $z$, and that the implementation decision is observable and contractible, so that there is no asymmetric information and no moral hazard. Since $z$ is contractible, the bank is able to offer two distinct repayment schedules for each realization of $z$. As the growth option is more productive than the basic technology, it is optimal to implement it whenever $z = h$; as the gamble is less productive than the basic technology, it is optimal to discard the new technology whenever $z = l$. Since the implementation decision is contractible, the bank can ensure that the firm adopts the efficient technology in every state of the world at no cost.

The optimal first-best contract is therefore a full-incentive contract for every $\pi_h, \pi_l \geq 0$. To maximize pledgeable income, the bank sets $\tau(h) = \tau(l) = X$, and provides sufficient additional capital to implement the growth option only when $z = h$, i.e., $\{\kappa_1(h), \kappa_1(l)\} = \{k_1, 0\}$. To ensure incentive compatibility, the bank must then only force the firm to return $\kappa_1(h)$ whenever the firm does not implement the growth option. Pledgeable income in the first-best setting is thus given by:

$$T^{FB} = \gamma\left(q^h X - k_1\right) + (1-\gamma)pX.$$

### 3.2 Moral Hazard and Symmetric Information about $z$

We now assume that $z$ is common knowledge and contractible, but that the adoption decision is neither observable nor contractible. As such, there is symmetric information about $z$ and moral hazard. As in the first-best setting, the bank is able to design repayment schedules $\{\tau(h), \tau(l)\}$ and transfers $\{\kappa_1(h), \kappa_1(l)\}$ that are explicitly contingent on $z$. In contrast to the first-best setting, however, the bank must provide incentives to overcome the firm's moral-hazard problem in every state of the world. Our goal is to contrast the optimal contract in this setting with the optimal contract that arises when the bank faces *both* moral hazard and asymmetric information about $z$. To this end, we refer to the current setting as *symmetric information* (SI), and the setting in which the bank faces both agency frictions simultaneously as *asymmetric information* (AI).

Under the presumption that the bank wants to implement $q^h$ when $z = h$, and $p$ when $z = l$, we can specialize (IC) to two state-contingent incentive-compatibility constraints of the following form:

$$p(X - \tau(l)) \geq q^l(X - \tau(l)) \tag{DET}$$

$$q^h(X - \tau(h)) \geq p(X - \tau(h)) + \kappa_1(h). \tag{IMP}$$

(DET) states that $\tau(l)$ must be such that the firm prefers $p$ to $q^l$ in state $l$, while (IMP) states that $\tau(h)$ must be such that the firm prefers $q^h$ to $p$ in state $h$.

The agency problem in state $l$ is particularly simple: the bank does not need to offer *any* wages to satisfy (DET). Indeed, $\tau(l) = X$ satisfies (DET), and transfers all project returns to the bank.

**Lemma 1** *A pure-equity contract is any contract that satisfies $\tau = \alpha X$ for some $\alpha \in [0, 1]$. Any pure-equity contract satisfies* (DET)*.*

**Corollary 1** *$\tau(l) = X$ satisfies* (DET)*.*

Since it is costless to satisfy (DET), the bank will always find it optimal to provide incentives to choose the basic technology in state $l$.

The incentive problem in state $h$ is harder to overcome: since the firm can misappropriate $\kappa_1(h)$, providing incentives to implement the growth option will generically require the bank to cede moral-hazard rents to the firm. What is the most efficient way for the bank to deal with this friction? First, note that the tightness of (IMP) is strictly increasing in $\kappa_1(h)$. As such, the bank will never place more than the required $k_1$ units of additional capital at risk of misappropriation.

**Lemma 2** *Suppose that the adoption decision is not contractible. Then $\kappa_1(\hat{z}) \leq k_1$ for any $\hat{z}$.*

Second, standard results from agency theory indicate that the bank should pay the firm only after those project outcomes that represent the "best" news, namely that the firm did indeed choose $q^h$ over $p$. Assumption 2 then implies that the bank minimizes the firm's moral-hazard rents stemming from (IMP) by paying wages after outcome 3 only.

**Lemma 3** *The wage schedule* $w^{SI}(h) = [0, 0, \omega^{SI}]$ *with*

$$\omega^{SI} = \frac{k_1}{q_3^h - p_3}$$

*satisfies* (IMP), *and yields the minimal expected wage payment among all wage schedules that satisfy* (IMP).

If the bank offers $w^{SI}(h)$, the firm receives expected wage payments

$$W^{SI} = \gamma q_3^h \omega^{SI}.$$

Subtracting the expected wage payments from the expected productivity gains $\pi_h$ associated with the growth option, the expected value of implementing the growth option to the bank is

$$\pi_h^{SI} = \pi_h - W^{SI}.$$

The bank thus finds it worthwhile to provide incentives to implement the growth option in state $h$ if and only if $\pi^{SI} > 0$.

**Lemma 4 (Optimal Contract under Symmetric Information and Moral Hazard)** *If* $\pi_h^{SI} > 0$*, the optimal contract under symmetric information is* $\bar{\mathcal{C}}^{SI} = \{\tau^{SI}(h), \tau^{SI}(l), k_1, 0\}$ *where*

$$\tau^{SI}(h) = \begin{bmatrix} X_1 \\ X_2 \\ X_3 - \frac{k_1}{q_3^h - p_3} \end{bmatrix}, \qquad \tau^{SI}(l) = \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix}.$$

*The firm receives expected wages* $W^{SI} = \gamma q_3^h \left(\frac{k_1}{q_3^h - p_3}\right)$*, and pledgeable income is* $T^{SI} = \hat{q}X - \gamma k_1 - W^{SI}$*.*

*If* $\pi_h^{SI} \leq 0$*, then the optimal contract is of the form* $\bar{\mathcal{C}}^{SI} = \{X, X, 0, 0\}$*. The firm receives zero expected wages, and pledgeable income is* $T^{SI} = pX$*.*

In line with standard results in agency theory, the bank provides implementation incentives in state $h$ by tilting the firm's wages to the upside. In state $l$, the firm's agency problem can be overcome by offering the firm no wages at all: since choosing $p$ does not require additional investment, the bank does not need to put any further capital at risk.

Relative to the first-best setting, two sources of inefficiency arise. First, pledgeable income is reduced because the bank must provide rents to the firm in order to implement the growth

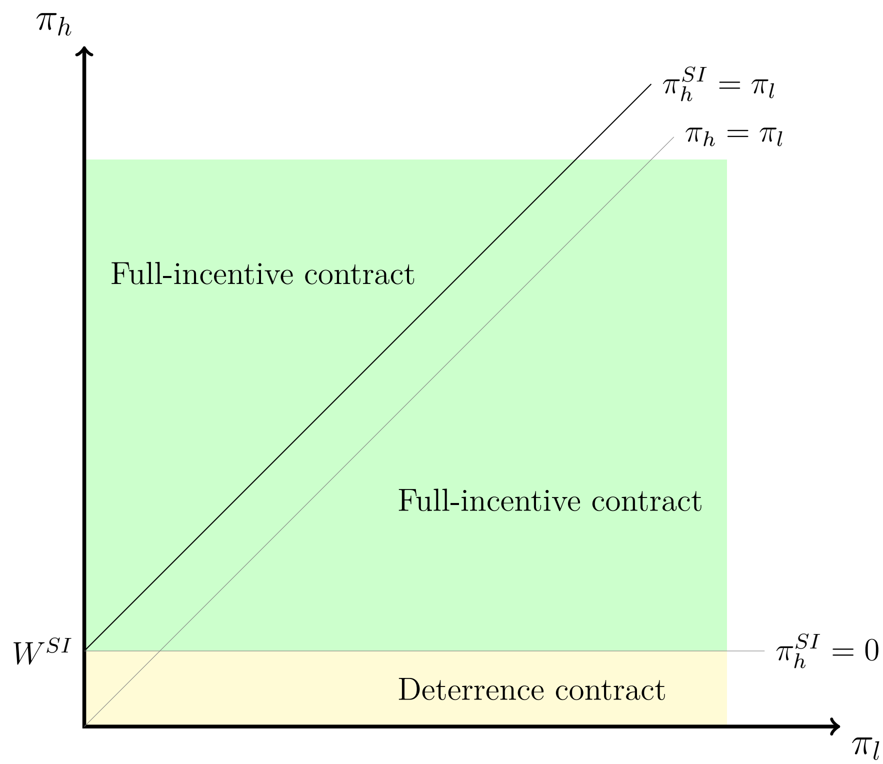


Figure 3: Optimal Contract Regions with Symmetric Information about $z$ and Moral Hazard

option. Second, these rents may be so large that the bank foregoes the implementation of the growth option: the firm may operate the inferior technology $p$ even though $q^h$ is available. In Figure 3, this second source of inefficiency is depicted as the yellow area: when $\pi_h$ is small but positive, the bank chooses a deterrence contract even though a full-incentive contract was optimal in the first-best setting.

It is useful to note that the provision of incentives to implement the growth option in state $h$ in no way impinges on the bank's ability to provide incentives to choose technology $p$ in state $l$. This is the case only because we assumed that $z$ is common knowledge and fully contractible. As the next section will show, a strong tension between incentive provision in the two states of the world emerges when $z$ is no longer contractible.

### 3.3 Moral Hazard and Asymmetric Information about $z$

We now consider the situation in which $z$ is the firm's private information and the implementation decision continues to be unobservable. Thus, the bank simultaneously faces both moral hazard and asymmetric information. To highlight the key difference relative to the setting in which there is only moral hazard, we refer to this setting simply as *asymmetric information* (AI), and take it to be understood that moral hazard is present *in addition* to asymmetric information.

When the bank is uninformed about $z$, it must, in essence, provide incentives to overcome the firm's moral-hazard problem at the technology-adoption stage without knowing whether the firm must decide between $q^h$ and $p$ or between $p$ and $q^l$. Formally, we require that the contract not be explicitly conditioned on $z$, but rather on the firm's report $\hat{z}$ only. The bank's uncertainty about the nature of the firm's moral-hazard problem leads to tension between the optimal incentive provision in each state: the bank may have to forego providing incentives in one state of the world in order to efficiently provide them in the other state, or the bank must cede steep moral-hazard rents in order to be able to provide incentives in both states of the world. As described in Figure 1, the optimal contract may, thus, be either a deterrence contract, an implementation contract, or a full-incentive contract.

To characterize the optimal contract, we first characterize the optimal contract within each class, and then determine the optimal contract class. We begin by describing the optimal partial-incentive contracts, i.e., deterrence contracts that satisfy only (DET) and implementation contracts that satisfy only (IMP), and then analyze the optimal full-incentive contract. Throughout, we refer to deterrence contracts using the subscript $D$, and to implementation contracts using the subscript $I$.

### 3.3.1 Optimal Partial-incentive Contract

The optimal deterrence and implementation contracts are simple to characterize: for each class of partial-incentive contracts, the optimal contract is a variant of the optimal contract under symmetric information. In particular, the optimal partial-incentive contract under asymmetric information amounts to offering the firm *one* of the two state-contingent repayment schedules that the bank makes use of under symmetric information in every state of the world. That is, in the optimal deterrence contract, the bank offers $\tau^{SI}(l)$ for all $z$, while in the optimal implementation contract, the bank offers $\tau^{SI}(h)$ for all $z$.

**Lemma 5 (Optimal Deterrence Contract)** *The optimal deterrence contract under asymmetric information is* $\bar{\mathcal{C}}_D^{AI} = \{X, X, 0, 0\}$. *The firm receives zero expected wages, and pledgeable income is given by* $T_D^{AI} = pX$.

**Lemma 6 (Optimal Implementation Contract)** *The optimal implementation contract under asymmetric information is* $\bar{\mathcal{C}}_I^{AI} = \{\tau^{SI}(h), \tau^{SI}(h), k_1, k_1\}$. *The firm receives expected wages* $W_I^{AI} = (1-\gamma)k_1 + \tilde{q}_3\left(\frac{k_1}{q_3^h - p_3}\right)$, *and pledgeable income is given by* $T_I^{AI} = \tilde{q}X - \gamma k_1 - W_I^{AI}$.

Since the bank is resigned to satisfying only one of the two incentive constraints, it looks for the repayment schedule that maximizes pledgeable income and provides sufficient rents for the firm to guarantee the desired technology choice. This is precisely the problem that the symmetric-information contract solved *state by state*. Since the bank is no longer able to offer state-contingent contracts, it responds by choosing a particular state-contingent repayment schedule it found optimal under symmetric information, and offers it to the firm in both states of the world.

Hence, the bank provides efficient incentives in one state of the world, but fails to do so in the other. If the bank chooses a deterrence contract, this leads to an inefficient choice of $p$ when $z = h$, since the more productive technology $q^h$ would have been available. If the bank chooses an implementation contract, three intertwined sources of inefficiency arise. First, the firm captures moral-hazard rents even when $z = l$, as the bank offers the same repayment schedule in both states of the world. Second, the bank must make the additional transfer $k_1$ in both states of the world. The firm thus receives the transfer even when there is no productive use for it. Third, the firm chooses the inefficient technology $q^l$ when $z = l$, even though $p$ would have been available. We define the date-0 expected value of implementing the growth option using an implementation contract under AI as:

$$\begin{aligned}\pi_{h,I}^{AI} &= \gamma(q^h - p)X - \gamma k_1 - W_I^{AI} \\ &= \pi_h - W_I^{AI},\end{aligned}$$

i.e., the difference of the growth option's expected productivity gain $\pi_h$ and the firm's moral-hazard rents $W_I^{AI}$. The upside of an implementation contract is that the bank is able to capture $\pi_{h,I}^{AI}$ when $z = h$. On the downside, the bank suffers the inefficiency costs $\pi_l$ when $z = l$. In the optimal partial-incentive contract, the bank thus chooses an implementation contract only if the upside is sufficiently large relative to the downside. As such, the optimal partial-incentive contract is an implementation contract if $\pi_{h,I}^{AI} \geq \pi_l$, and it is a deterrence contract otherwise. We denote the optimal partial-incentive contract by $\mathcal{C}_{PI}^{AI}$.

### 3.3.2 Optimal Full-incentive Contract

We now turn to characterizing the optimal full-incentive contract. Full incentives can be obtained through both *pooling* and *separating* contracts. In a pooling contract, the bank offers the same contract after any $\hat{z}$, while in a separating contract, it offers distinct repayment schedules for each $\hat{z}$. The advantage of a separating contract is that the bank is able to tailor additional transfers to the state of the world so as to avoid transferring $k_1$ when the growth option is not available. On the downside, achieving separation means that the bank must design the contract in such a way that reporting the true state of the world is in the firm's interest. This will force the bank to surrender information rents to the firm. We refer to pooling contracts using the subscript $P$, and to separating contracts using the subscript $S$.

**Lemma 7 (Optimal Full-incentive Pooling Contract)** *The optimal full-incentive pooling contract is* $\bar{\mathcal{C}}_P^{AI} = \{\tau_P^{AI}, \tau_P^{AI}, k_1\, k_1\}$ *with*

$$\tau_P^{AI} = \begin{bmatrix} X_1 \\ X_2 - \xi_l \omega_P \\ X_3 - \omega_P \end{bmatrix} \quad where \quad \xi_l \equiv \frac{q_3^l - p_3}{p_2 - q_2^l} \in \left(0, \frac{1}{2}\right) \quad and \quad \omega_P \equiv \frac{k_1}{(q_3^h - p_3) - \xi_l(p_2 - q_2^h)}.$$

*The firm receives wages* $W_P^{AI} = \hat{q}_2 \xi_l \omega_P + \hat{q}_3 \omega_P + (1 - \gamma)k_1$*, and pledgeable income is* $T_P^{AI} = \hat{q}X - \gamma k_1 - W_P^{AI}$.

This contract is best understood in the context of the symmetric-information contract $\bar{C}^{SI}$. In that contract, when $z = h$, the bank minimized the firm's information rents by offering a debt contract that paid the firm only in state 3, and, when $z = l$, chose a pure-equity contract in accordance with Lemma 1. The constraint (IMP) therefore leads the bank to skew the firm's wages to the upside, while (DET) leads the bank to smooth the firm's wages. $\bar{\mathcal{C}}_P^{AI}$ balances these two forces by providing sufficient skewness to satisfy (IMP), and sufficient smoothness to satisfy (DET). Relative to the symmetric-information contract, this comes at the cost of higher wage payments after outcomes 2 *and* 3, as well as wasted transfers $k_1$ when $z = l$.[3]

Next, the optimal separating contract under the presumption[4] that $\tau(h)$ satisfies (IMP) but not (DET), and $\tau(l)$ satisfies (DET) but not (IMP) is characterized in Lemma 8. Under this presumption, (REV) can be specialized to two truthful-revelation constraints of the form:

$$q^h(X - \tau(h)) \geq p(X - \tau(l)) \tag{REV-h}$$
$$p(X - \tau(l)) \geq q^l(X - \tau(h)) + k_1. \tag{REV-l}$$

In the Appendix, we show that a necessary and sufficient condition for $\tau(h)$ to satisfy both (IMP) and (REV-h) is:

$$q^h(X - \tau(h)) \geq \max\left\{q^l(X - \tau(h)) + k_1, p(X - \tau(h)) + k_1\right\}. \tag{IMP-S}$$

The ability of the firm to make an unverifiable report about the state of the world therefore results in an incentive constraint that is as if the firm had the choice of implementing any of the three technologies at the same time. As under symmetric information, the bank responds to a report of $\hat{z} = h$ by offering wages only after outcome 3. Since $q_3^l > p_3$, (IMP-S) implies that the wages must be *higher* under asymmetric information, however.

**Lemma 8 (Optimal Full-incentive Separating Contract)** *Assume* $(q_3^h - q_3^l)X_3 > k_1$. *Then, the optimal separating contract is given by* $\bar{\mathcal{C}}_S^{AI} = \{\tau_S^{AI}(h), \tau_S^{AI}(l), k_1, 0\}$ *where*

$$\tau_S^{AI}(h) = \begin{bmatrix} X_1 \\ X_2 \\ X_3 - \frac{k_1}{q_3^h - q_3^l} \end{bmatrix}$$

*and* $\tau_S^{AI}(l)$ *is the pure-equity contract that satisfies the truth-telling constraint* (REV-l) *with equality:*

$$p\tau_S^{AI}(l) = pX - q^l(X - \tau_S^{AI}(h)) - k_1.$$

*The firm receives expected wages* $W_S^{AI} = \tilde{q}_3\left(\frac{k_1}{q_3^h - q_3^l}\right) + (1-\gamma)k_1$, *and pledgeable income is*

[3] To understand why the contract does not involve wages in state 1, note that doing so would actually weaken the incentives to choose $q^l$ over $p$.

[4] In the Appendix, we show that separating contracts are equivalent to pooling contracts whenever $\tau^h$ satisfies both (DET) and (IMP). It is, thus, without loss of generality to focus on the class of separating contracts that is discussed in this section.

$T_S^{AI} = \hat{q}X - \gamma k_1 - W_S^{AI}$.

The optimal separating contract preserves incentives to choose the efficient technology in each state of the world at the cost of having to satisfy a truth-telling constraint. Vis-à-vis the symmetric-information contract, two sources of inefficiency arise. First, the bank must pay higher expected wages in state $h$ than under symmetric information. Second, the firm also captures rents in state $l$, because it would otherwise have an incentive to misreport the state of the world.

Then, the optimal full-incentive contract is the contract that cedes smaller rents to the firm:

**Lemma 9 (Optimal Full-incentive Contract)** *$W_P^{AI} \leq W_S^{AI}$ if and only if $\frac{q_3^h}{q_2^h} \leq \frac{q_3^l}{q_2^l}$. Let $\mathcal{C}_{FI}^{AI}$ denote the optimal full-incentive contract under asymmetric information. Then $\mathcal{C}_{FI}^{AI} = \mathcal{C}_P^{AI}$ if $\frac{q_3^h}{q_2^h} \leq \frac{q_3^l}{q_2^l}$, and $\mathcal{C}_{FI}^{AI} = \mathcal{C}_S^{AI}$ otherwise. The firm receives expected wages $W_{FI}^{AI} = \min\left\{W_P^{AI}, W_S^{AI}\right\}$, and pledgeable income is $T_{FI}^{AI} = \hat{q}X - \gamma k_1 - W_{FI}^{AI}$.*

The proof is obvious, and follows from comparing pledgeable income. A separating contract is preferred to a pooling contract only if $q_3^l$ is not too close to $q_3^h$. When $q_3^l$ is close to $q_3^h$, it is easy for a firm in state $l$ to mimic a firm in state $h$ on the upside. This makes it difficult to induce separation using a debt contract and, thus, makes separating contracts unattractive.

What are the differences between full-incentive and partial-incentive contracts? On the upside, a full-incentive contract allows the bank to capture efficiency gains in the production technology. Compared to an implementation contract, the bank captures the efficiency gain $\pi_l$ arising from the optimal choice of $p$ in state $l$, but cedes higher moral-hazard rents. Compared to a deterrence contract, the bank captures $\pi_{h,FI}^{AI} = \pi_h - W_{FI}^{AI}$. This trade-off can be summarized as comparing

$$\Delta\pi \equiv \min\{\pi_l, \pi_{h,I}^{AI}\}$$

to

$$\Delta W \equiv W_{FI}^{AI} - W_I^{AI}.$$

Proposition 1 states that the bank chooses a full-incentive contract whenever the upside outweighs the downside. Figure 4 depicts the decision rules underlying the proposition.

**Proposition 1 (Optimal Contract)** *Denote the optimal contract under asymmetric information by $\mathcal{C}_*^{AI}$. Then $\mathcal{C}_*^{AI} = \mathcal{C}_{FI}^{AI}$ if $\Delta W \leq \Delta\pi$, and $\mathcal{C}_*^{AI} = \mathcal{C}_{PI}^{AI}$ otherwise. Pledgeable income is*

$$T_*^{AI} = \max\{T_D^{AI}, T_I^{AI}, T_P^{AI}, T_S^{AI}\} < T^{SI}.$$

*The firm receives expected wages*

$$W_*^{AI} = W_{j^*}^{AI},$$

*where $j^* = \arg\max_j T_j^{AI}$ denotes the contract that maximizes pledgeable income under asymmetric information.*

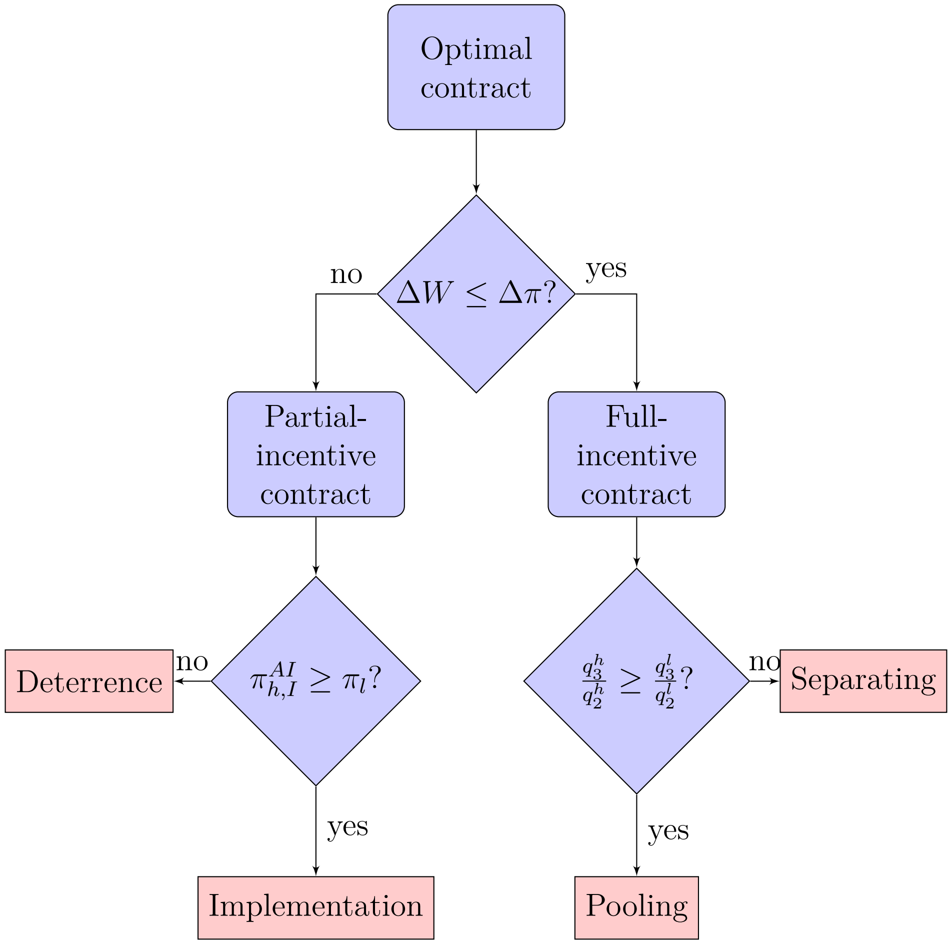


Figure 4: Optimal Contract with Asymmetric Information about $z$ and Moral Hazard

As before, the proof follows immediately from comparing pledgeable income. The inefficiencies that arise under asymmetric information and moral hazard are shown in Figure 5. The yellow area at the bottom is the inefficiency that arises from moral hazard alone: whenever the adoption decision is not contractible, the bank must cede rents to the firm, and these rents may be large enough to discourage the bank from attempting the growth option. The red area depicts the inefficiencies that arise from the interaction of the moral-hazard and asymmetric-information frictions: in the presence of both frictions, the provision of incentives in one state of the world impedes on the bank's ability to provide incentives in the other state of the world.

In region [II], the bank resolves this tension in favor of deterrence: the productivity advantage of the growth option is not large enough to warrant incurring the expected cost of the gamble. In region [I], this ordering is reversed: the value of the growth option is sufficiently high relative to the cost of the gamble, and the bank is willing to accept the downside risk associated with an implementation contract. Only in region [III] does the bank offer a full-incentive contract: the benefit of the growth option and the cost of the gamble are both large enough to warrant ceding the full-incentive wages $W_{FI}^{AI}$ to the firm. Nevertheless, an inefficiency also arises in this area, as the required rents that the bank must

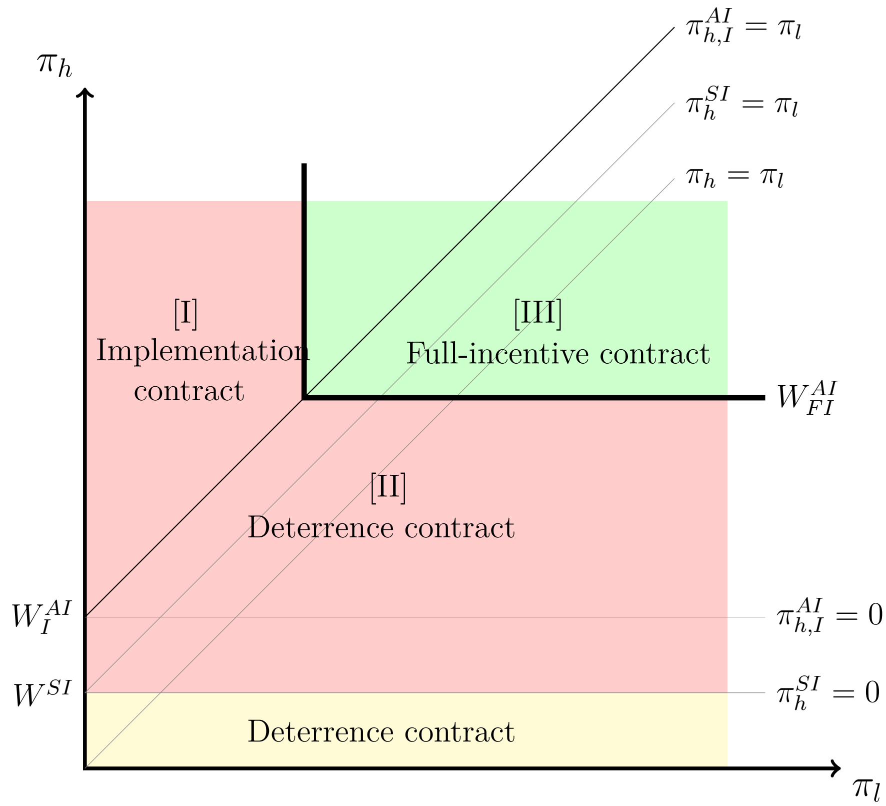


Figure 5: Optimal Contract Regions with Asymmetric Information about $z$ and Moral Hazard

cede to the firm are larger under asymmetric information and moral hazard than under moral hazard alone.

## 3.4 Firm Characteristics and the Value of Information

Having characterized the optimal contract, we now provide an analysis of the characteristics of firms that lead them to choose a particular class of contracts under asymmetric information, and discuss the value of information in financial intermediation.

**Corollary 2 (Firm Characteristics and Contract Class)** *Firm characteristics and optimal contract class are related as follows:*

1. *Firms with highly productive growth options, i.e., high $\pi_h$, choose an implementation or a full-incentive contract.*

2. *Firms with highly unproductive gambles, i.e., high $\pi_l$, choose a deterrence contract or a full-incentive contract.*

3. *Firms with high $\pi_h$* and *high $\pi_l$ choose a full-incentive contract.*

4. *Firms where $q_3^l$ is close to $q_3^h$ prefer a pooling contract to a separating contract. Similarly, firms with high values of $\xi_l$ prefer a separating contract to a pooling contract.*

5. *The optimal contract exhibits a bias towards deterrence: $\pi_h$ must be substantially larger than $\pi_l$ to warrant an implementation or a full-incentive contract.*

6. *Firms exhibit high values of $\pi_l$ when $q^l$ puts more weight on low outcomes than does $p$. Hence, high values of $\pi_l$ are associated with low values of $\xi_l$.*

This corollary follows immediately from Figure 5. In our model, firms that exhibit large differences in productivity depending on the technology choice, as measured by $\pi_h$ and $\pi_l$, are more likely to choose full-incentive contracts. Since $q_3^h$ is associated with high $\pi_h$, high-$\pi_h$ firms are also relatively likely to choose a separating contract over a pooling contract. Finally, firms with high values of $\pi_l$ tend to prefer a pooling contract, as $\pi_l$ is negatively associated with $\xi_l$. Note that while firms with high $\pi_h$ are more productive due to the value of their growth options, so are firms with high $\pi_l$ in the sense that they are already very productive, implying that it is imperative to deter these firms from accepting the gamble. In what follows, we will call firms with high $\pi_h$ and/or high $\pi_l$ *high-productivity firms*.

We now use our characterization of the optimal contract to derive a firm-level measure of the *value of information* in financial intermediation. In our model, information about the state of the world is valuable because it allows for increased efficiency in providing incentives to the entrepreneur. When the bank is uninformed, it must weigh the costs and benefits of providing incentives to adopt the new technology in the good state and to refrain from doing so in the bad state. If the bank is informed, it can precisely tailor the contract to the state of the world. In this section, we first precisely characterize the value of information, and then generate comparative statics with respect to two key firm-level characteristics: volatility and productivity. Throughout, we define the value of information to be given by $\Delta T \equiv T^{SI} - T_*^{AI}$, i.e., the change in pledgeable income generated by the bank's becoming informed about $z$.

**Lemma 10 (Value of Information)** *Among partial-incentive contracts, the value of information is*

$$\Delta T_D = \pi_h - W^{SI} \quad \textit{and} \quad \Delta T_I = \pi_l + \left(W_I^{AI} - W^{SI}\right)$$

*for deterrence and implementation contracts, respectively. Among full-incentive contracts, the value of information is*

$$\Delta T_P = W_P^{AI} - W^{SI} \quad \textit{and} \quad \Delta T_S = W_S^{AI} - W^{SI}$$

*for pooling and separating contracts, respectively. The value of information in the optimal partial incentive contract is*

$$\Delta T_{PI} = \min\{\Delta T_D, \Delta T_D\},$$

*while the value of information in the optimal contract is*

$$\Delta T = \min\{\Delta T_D, \Delta T_I, \Delta T_P, \Delta T_S\}.$$

As we show next, the value of information depends crucially on firm-level characteristics, such as volatility. To establish this fact, conduct the following thought experiment: what are the effects on firm-level outcomes when a firm's production technology becomes more volatile? To isolate the effects of changes in volatility from those of changes in productivity, we consider mean-preserving spreads of the distributions $q^h$, $q^l$, and $p$. We also focus on a particular class of distributional spreads that affects all distributions symmetrically. In essence, we thus ask how the borrowing capacity of the firm varies as it becomes more volatile in general.

**Definition 1** *A symmetric mean-preserving spread of size $\mu$ is defined as adjusting $q^h$, $q^l$, and $p$ according to:*

$$q^h(\mu) = [q_1^h + \mu, q_2^h - 2\mu, q_3^h + \mu], \qquad q^l(\mu) = [q_1^l + \mu, q_2^l - 2\mu, q_3^l + \mu],$$

*and*

$$p(\mu) = [p_1^l + \mu, p_2^l - 2\mu, p_3^l + \mu].$$

*subject to $\mu \in [0, \bar{\mu})$ with $\bar{\mu} = \min\left\{1 - q_1^l, \frac{q_2^l}{2}, 1 - q_3^h\right\}$.*

Symmetric mean-preserving spreads are analytically convenient because they preserve[5] the ordering of likelihood ratios and leave the differences between the probability distributions unchanged: $q^z(\mu) - p(\mu) = q^z - p$ for all $z$ and any $\mu \in [0, \bar{\mu})$, and $q^h(\mu) - q^l(\mu) = q^h - q^l$ for any $\mu \in [0, \bar{\mu})$. Nevertheless, a $\mu$-spread does affect the *value* of the optimal contract. What is more, the value of the optimal symmetric-information contract is affected differentially from the optimal asymmetric information contract. As such, Proposition 2 shows that $\mu$-spreads will generally lead to variation in the value of information.

**Proposition 2 (Value of Information and Volatility)** *Take a uniform mean-preserving spread of size $\mu$, define $\xi_h \equiv \frac{q_3^h - p_3}{p_2 - q_2^h}$ analogously to $\xi_l$, and note that $\xi_h \in \left(\frac{1}{2}, 1\right)$. Then:*

1. *The value of information is strictly increasing in $\mu$ if the firm chooses an implementation or a full-incentive separating contract.*

2. *The value of information in a full-incentive pooling contract is strictly increasing in $\mu$ if and only if $\gamma < \gamma^*(\xi_l, \xi_h) = \frac{\xi_h(1-2\xi_l)}{\xi_h - \xi_l}$. Furthermore, $\gamma^*(\xi_l, \xi_h)$ is strictly decreasing in $\xi_l$ and $\xi_h$, and $\gamma^*(\xi_l, \xi_h) \in (0, 1)$ for all $\xi_l, \xi_h$.*

[5] A sufficient condition for a symmetric mean-preserving spread to preserve the ordering of likelihood ratios for any $q^z$ with respect to $p$ and for any $\mu \in [0, \bar{\mu})$ is $q_3^h - p_3 > q_1^h - p_1$ and $q_3^l - p_3 < q_1^l - p_1$. This condition is satisfied by Assumption 1.

3. *The value of information is strictly decreasing in $\mu$ if the firm chooses a deterrence contract.*

While we relegate the proof of the proposition to the Appendix, it is useful to provide the argument for an example. To this end, consider the case of a full-incentive separating contract. Using the definitions of $W_S^{AI} - W^{SI}$, the value of information under a separating contract is

$$\Delta T_S = \left( \frac{\tilde{q}_3}{q_3^h - q_3^l} \right) k_1 - \left( \frac{\gamma q_3^h}{q_3^h - p_3} \right) k_1 + (1-\gamma) k_1.$$

Since $\tilde{q} = \gamma q^h + (1-\gamma) q^l$, we have that $\tilde{q}(\mu) = \gamma q^h(\mu) + (1-\gamma) q^l(\mu)$. Hence, $\tilde{q}_3(\mu) = \tilde{q}_3 + \mu$, i.e., $\tilde{q}(\mu)$ places more probability mass on state 3 than does $\tilde{q}$. Recalling that $q^h(\mu) - q^l(\mu)$ and $q^h(\mu) - p(\mu)$ are independent of $\mu$, it follows that

$$\Delta T_S(\mu) = \left( \frac{\tilde{q}_3}{q_3^h - q_3^l} \right) k_1 - \left( \frac{\gamma q_3^h}{q_3^h - p_3} \right) k_1 + (1-\gamma) k_1 + \mu \left( \frac{k_1}{q_3^h - q_3^l} - \gamma \frac{k_1}{q_3^h - p_3} \right).$$

Since $q_3^l > p_3$, $\Delta T_S(\mu)$ is strictly increasing in $\mu$. To understand why, note that the optimal full-incentive separating contract and the optimal symmetric-information contract both consist of debt contracts that pay the firm in state 3 only. A mean-preserving spread increases the likelihood of state 3, thereby increasing expected wage payments and lowering pledgeable income for both contracts. Crucially, however, the distributional spread affects the two contracts differentially. There are two reasons for this. First, the face value of debt in a separating contract is lower than in a symmetric-information contract. Second, in the symmetric-information contract, the bank pays wages to the firm only when $z = h$. In the separating contract, asymmetric information allows the firm to capture information rents in both states of the world. Both effects combine to reduce pledgeable income more substantially under a separating contract. The value of information increases. In fact, a slightly deeper point emerges: the effects on the value of information are driven by a reallocation of probability mass towards states of the world that are particularly costly to the bank under asymmetric information.

This is also true of the value of information in a deterrence contract. In this class of contracts, the bank uses a pure-equity contract in both states of the world. A mean-preserving spread of all distributions thus leaves the value of the optimal deterrence contract unchanged. In contrast, the optimal contract under symmetric information pays the firm in state 3 when $z = h$. After a mean-preserving spread, the expected cost of these wages increases, thereby reducing pledgeable income in the symmetric-information contract and decreasing the value of information. Under an implementation contract, these forces are reversed. In an implementation contract, the bank offers a debt contract in both states of the world. Hence, pledgeable income is reduced for all $z$, while in the symmetric-information case, it is reduced only in state $h$. The value of information increases.

Finally, consider a full-incentive pooling contract. This contract is the only contract that involves wage payments in state 3 *and* state 2. While a mean-preserving spread increases expected wages in state 3, it *reduces* expected wages in state 2. The overall effect on expected wages is therefore driven by the relative size of wages in states 2 and 3. In particular, the change in the value of information is determined by the relative size of $\gamma$ and $\gamma^*(\xi_l, \xi_h)$. To see why this is the case, note first that, for a fixed value of $\gamma^*(\xi_l, \xi_h)$, the value of information is likely to decrease when $\gamma$ is large. This is the case because the symmetric-information contract involves wage payments when $z = h$, which implies that the difference in expected wages is smaller when $z = h$ than when $z = l$. Second, for a fixed $\gamma$, the value of information is likely to increase when $\gamma^*(\xi_l, \xi_h)$ is large or, equivalently, when $\xi_l$ and $\xi_h$ are small. When is this the case? Note that we can write $\xi_z = 1 - \frac{q_1^z - p_1}{p_2 - q_2^z}$. Hence, $\xi_z$ is small when the downside risk of the new technology, as proxied for by $q_1^z - p_1$, is large. For a fixed level of productivity, firms with risky new technologies are thus more likely to experience increases in the value of information after increases in volatility. This is the case because information is particularly valuable when being informed allows the bank to avoid particularly costly downside risks.

# 4 Information Acquisition

Up to this point, we have focused on determining the value of information in financial intermediation, taking the information structure as given. In this section, we now endogenize the information structure by allowing banks to invest in costly information acquisition. Our goal in this section is to explore the extent to which banks have incentives to acquire information about a firm, even if doing so is not contractible. As in the previous sections, we relate the ability of a bank to provide incentives to firm-level characteristics, such as the production technology, and develop a notion of *firm-level information sensitivity.* Finally, we ask whether the structure of the banking industry as a whole is of relevance to the information-acquisition process at the firm level. We take the view that if banks are small and have narrow monitoring expertise, then a firm may need to contract with multiple banks, or *syndicates*, so as to have access to sufficient monitoring expertise. As an adverse consequence, large syndicates of banks may suffer from coordination failures due to free-riding problems. We then argue that increasing the scope of banking may alleviate these coordination failures and generate efficiency gains.

To address these issues, we make two key changes to our model. First, we allow the firm to obtain financing from an endogenously chosen syndicate of banks that are heterogenous in their monitoring expertise. Second, banks obtain information about the firm by exerting unobservable effort. This introduces moral hazard on the part of the banks into the information-acquisition process.

We present a deliberately stylized information structure, with the goal of focusing squarely on the scope for coordination failures among banks in its relation to firm characteristics. We assume that every firm is characterized by a set of nodes $\mathcal{N}$, with $N = |\mathcal{N}|$ denoting the number of nodes. These nodes can be understood as sources of news, or different activities the firm is engaged in. We model the information-acquisition process by assuming that correctly interpreting the information available about the firm at a given node requires specialized expertise. For example, if one learns about the prospects of new a technological development, it may require specialized knowledge to be able to assess the relevance of this development for a given firm, or the industry it operates in.

To fix ideas, suppose that news about the new technology $q^z$ arrives at one particular node $n$. We let $\phi_n$ denote the probability of the new technology arriving at node $n$, with $\sum_n \phi_n = 1$ and $\phi$ the vector of $\phi_n$'s. We refer to the node in which the news occurs as $n^*$, and assume that $n^*$ is not observable. That is, neither bank nor firm knows which node the new technology has arrived in. The different nodes thus have no implications for firm productivity, and serve only to parametrize the complexity of the information-acquisition process. As such, the new technology has the same properties irrespective of the node in which it arrives, and it can be implemented by the firm even without knowledge of $n^*$.

We start from the presumption that the firm is perfectly informed about the state of the world $z$: whenever news about the new technology arrives at any node, $z$ is immediately revealed to the firm. In contrast, every bank only receives a signal $\theta$ about $z$. To focus on coordination failures in monitoring, we assume that each bank observes the *same* signal. The precision of this common signal depends on each bank's monitoring capability, and the effort each bank exerts in monitoring. A given bank $j$'s monitoring capability is characterized by a set $B_j \subseteq \mathcal{N}$. If $n \in B_j$, we say that bank $j$ has monitoring expertise at node $n$. If $n \notin B_j$, then the bank is ignorant about node $n$. If the bank has monitoring expertise at a given node, it can decide whether to monitor the firm at node $n$ at a fixed cost. If the bank has no expertise, we assume that the cost of monitoring the firm at node $n$ is prohibitively high. The cost of monitoring is given by:

$$c_j(n) = \begin{cases} c & \text{if } n \in B_j \\ \infty & \text{otherwise.} \end{cases}$$

The cost of shirking is normalized to zero.

If the bank exerts effort ($e$) at node $n$, and news about the new technology arrive at node $n$, the common signal is fully revealing of $z$. If the bank instead shirks ($ne$) at node $n$, or if the the technology did not arrive at node $n$, the signal is completely uninformative. Denote a given bank's monitoring decision at node $n$ by $m \in \{e, ne\}$. Then, the resulting common signal is given by:

$$\theta(m, n, z) = \begin{cases} z \text{ w.p. } 1 & \text{if } m = e \text{ and } n = n^* \\ \emptyset & \text{otherwise,} \end{cases}$$

where $\emptyset$ denotes that no information has been produced.

We say that $\theta = \theta^I$ whenever an informative signal has been produced, and $\theta = \theta^{NI}$ when no information has been produced. Each bank must decide on its monitoring effort *before* the realization of $n^*$. That is, the bank decides on its monitoring activity before knowing whether its effort will result in an informative signal or not. If the bank exerts effort at node $n$, the signal is informative with probability $\phi_n$. If the bank shirks at $n$, the informativeness of the signal depends on the monitoring of the bank that has expertise at $n$, and whether

$n = n^*$. In particular, if the bank shirks at $n^*$ and no other bank monitors $n^*$, then the signal is uninformative with probability 1. Throughout, we assume that $m$ is each bank's private information, and that $\theta$ is not contractible.

After the common signal has been realized, one bank in the syndicate is selected randomly and with equal probability. This bank then produces a contractible report $\hat{z}_b(\theta)$ about the state of the world that is made available to the firm. Since the reporting bank is drawn randomly, whether or not a given bank has exerted effort in monitoring cannot be ascertained from its reporting behavior. We call this property *anonymity.* In combination with the fact that $m$ is not observable, anonymity gives rise to a moral-hazard problem in monitoring: since each bank must incur a private cost of effort, each bank only monitors if it is in its private interest to do so. In addition, a free-riding problem may arise: while the costs of monitoring are private, the benefits of an informative signal are shared by all banks.

Since each bank's payoff from monitoring is determined by its expected private benefits, the bank's decision to engage in monitoring is itself determined by the terms of the contract. To fully characterize the optimal monitoring strategy, we now extend our contracting framework from Section 2 to include the bank's decision to acquire information. We do so in the simplest possible manner. At time 0, a given syndicate of banks and the firm agree to an intermediation contract $\mathcal{C}$ under full commitment. This contract can be explicitly conditioned on the reports $\hat{z}$ and $\hat{z}_b$ of the firm and the reporting bank, respectively. A contract in the extended setting with endogenous information acquisition is thus given by a tuple $\mathcal{C} = \{\kappa_0, \tau(\hat{z}, \hat{z}_b), \kappa_1(\hat{z}, \hat{z}_b)\}_{\hat{z},\hat{z}_b \in Z}$, while a continuation contract in the extended setting is $\bar{\mathcal{C}} = \{\tau(\hat{z}, \hat{z}_b), \kappa_1(\hat{z}, \hat{z}_b)\}_{\hat{z},\hat{z}_b \in Z}$.

Throughout, we again focus on the contract that delivers the maximum pledgeable income. We adopt the convention that the bank makes its report $\hat{z}_b$ before the firm reports $\hat{z}$. In practice, this assumption implies that the bank's report always trumps the firm's report: when there is disagreement between bank and firm, an outside observer will always side with the bank. Alternatively, the assumption can be interpreted as allowing bank and firm to agree to contract covenants that are triggered at the bank's choosing. Naturally, this means that the firm's strategy is now also function of $\hat{z}_b$. By an abuse of notation, a strategy for the firm then is a pair of functions $\hat{z} : Z^2 \to Z$ and $a : Z^3 \to \{i, d\}$, consisting of an adoption decision $a(z, \hat{z}, \hat{z}_b)$ and a reporting decision $\hat{z}(z, \hat{z}_b)$. The firm's optimal strategy is given by $a^*(z, \hat{z}_b)$ and $\hat{z}^*(z, \hat{z}_b)$, and results in the technology choice $Q^*(z, \hat{z}_b)$. The timing in this setting is summarized in Figure 6.

## 4.1 Optimal Syndicate Structure

In this section, we first analyze the incentives to acquire information of a given bank within a syndicate. We then characterize the syndicate structure that maximizes the likelihood of information acquisition. Throughout, we denote by $V(\cdot)$ the total expected repayments from the firm to the syndicate of banks, and by $V_j(\cdot)$ the expected payments to bank $j$. By the anonymity property and because banks are risk neutral, it is without loss of generality to

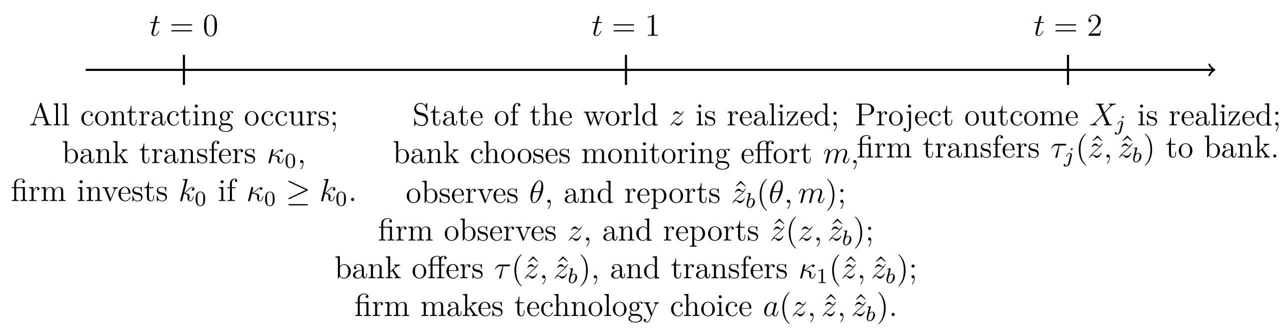


Figure 6: Timing of Events in the Extended Setting with Information Acquisition

restrict attention to linear sharing rules with the syndicate of banks, i.e.,

$$V_j(\cdot) = s_j V(\cdot)$$

with $s_j \in [0, 1]$ for all $j$, $\sum_j s_j = 1$, and $s$ the vector of $s_j$'s.

To analyze each bank's optimal strategy, first consider the optimal reporting strategy $\hat{z}_b(\theta)$ of the bank randomly selected to make the report. The value of a given continuation contract $\bar{\mathcal{C}}$ to the syndicate of banks in state $z$ after report $\hat{z}_b$ is $V = Q^*(z, \hat{z}_b)\tau(z, \hat{z}_b) - \kappa_1(z, \hat{z}_b)$. The optimal reporting strategy $\hat{z}_b^*(m)$ of the reporting bank $j$ then satisfies:

$$\hat{z}_b^*(\theta) = \arg\max_{\hat{z}_b} \quad s_j \left( Q^*(z, \hat{z}_b)\tau(z, \hat{z}_b) - \kappa_1(z, \hat{z}_b) \right). \tag{TT}$$

The linearity of the sharing rule thus implies unanimity among banks in reporting: (TT) is satisfied if and only if

$$\hat{z}_b^*(\theta) = \arg\max_{\hat{z}_b} \quad Q^*(z, \hat{z}_b)\tau(z, \hat{z}_b) - \kappa_1(z, \hat{z}_b).$$

The value to the syndicate of continuation contract $\bar{\mathcal{C}}$ in state $z$ after signal $\theta$ is

$$v(z, \theta) = Q^*(z, \hat{z}_b^*(\theta))\tau(z, \hat{z}_b^*(\theta)) - \kappa_1(z, \hat{z}_b^*(\theta)).$$

The expected value of the contract given monitoring decision $m$ is

$$V(\theta) = \sum_z \Pr(z) v(z, \theta),$$

and bank $j$'s expected value is $V_j(\theta) = s_j V(\theta)$.

Now consider bank $j$'s decision to exert effort in monitoring. If the bank exerts effort at node $n$, it produces an informative signal with probability $\phi_n$. If the bank shirks (and no other bank monitors $n$), no information is produced with probability $\phi_n$, and information production depends on the other banks' choices with probability $1 - \phi_n$. Define the value of information to the syndicate of banks as

$$\widehat{\Delta T} \equiv V(\theta^I) - V(\theta^{NI}).$$

Then bank $j$ exerts effort at node $n$ if and only if

$$c \leq \phi_n s_j \widehat{\Delta T}. \tag{ACQ}$$

That is, the bank acquires information if and only if its private benefit of doing so exceeds its private monitoring cost. In what follows, we refer to $\widehat{\Delta T}$ as the bank's *information-acquisition incentives*. As a corollary, information acquisition occurs with probability 1 if and only if (ACQ) holds at every $n$ and for at least one $j$ assigned to monitor node $n$. An obvious implication is that pledgeable income is decreasing in the cost of monitoring. In addition, the probability of capturing information gains is higher for firms that must be monitored at few nodes, and is lower for firms for which the distribution of $\phi_n$ is more dispersed. One can therefore interpret $N$ as the measure of *complexity* of a firm's activities, and the concentration of $\phi_n$ as a measure of the information sensitivity of a firm. Finally, the sharing rule $s$ impacts each bank's incentives to monitor: if $s_j$ is large, then bank $j$ has a large stake in the final transfer from the firm to its creditors. This suggests that the monitoring intensity depends crucially on the way financing and repayment are shared among banks.

We now show how $s$ can be chosen to maximize information acquisition. Throughout, we take the information-acquisition incentives $\widehat{\Delta T}$ as given. In the next section, we will determine the value of $\widehat{\Delta T}$ under the optimal contract. We assume that the firm is free to contract with any number of banks, and promises each bank $j$ a fraction $s_j$ of the total repayments, with $\sum_j s_j = 1$. We say that the firm does not contract with bank $j$ if $s_j = 0$. Finally, we say that monitoring is *efficient at node* $n$ if monitoring node $n$ increases pledgeable income by more than the cost of information acquisition.

**Definition 2 (Efficient Monitoring)** *Let $\Delta T$ denote the value of information to the firm as defined in Lemma 10. Monitoring is efficient at node $n$ if*

$$c \leq \phi_n \Delta T.$$

**Assumption 3** *Monitoring is efficient at every node $n \in \mathcal{N}$.*

Even if monitoring is efficient at every node, it may be too costly to provide incentives to the syndicate of banks to do so. Accordingly, we let $\mathcal{N}' \subseteq \mathcal{N}$ denote the set of nodes for which the firm wants to provide information-acquisition incentives. To achieve this goal, the firm must choose $s$ such that

$$c \leq \phi_n s_j \widehat{\Delta T} \quad \text{for at least one } j \text{ at each node } n \in \mathcal{N}'. \tag{IAI}$$

How does the firm optimally go about satisfying this condition? Two observations simplify the answer. First, the monitoring cost at a given node is identical for all banks that have monitoring expertise at this node. Second, there are economies of scope in monitoring: if a bank chooses to monitor some node $n$ at which it has expertise, then it will automatically choose to monitor any other node $k$ at which it has expertise as long as $\phi_k \geq \phi_n$. Whenever the firm is able to contract with a bank that has expertise at multiple nodes, it can therefore exploit that the bank's incentive constraint will bind only at one node, and will be satisfied automatically at all other nodes at which the bank has expertise. In particular, the firm needs to provide incentives only at the node with the minimal probability of arrival $\phi_n$.

An immediate implication of this fact is that the *effective* set of nodes at which the firm must provide incentives is a subset of $\mathcal{N}'$, and that it is a *strict subset* of $\mathcal{N}'$ whenever any bank has expertise at multiple nodes. We denote this set by $\mathcal{N}^*(\mathcal{N}')$, and refer to it as the *minimal-incentive set* for a given set of desired nodes $\mathcal{N}'$. As this section will show, the ability of banks to monitor multiple nodes will serve to reduce the cardinality of the minimal-incentive set, thereby increasing the efficiency of financial intermediation. Indeed, the firm must provide information acquisition incentives at a given node $n$ to only one bank. We refer to this bank as node $n$'s *designated monitor*. For now, note that the sharing rule $s$ must only satisfy the weaker version of (IAI), namely

$$c \leq \phi_n s_j \widehat{\Delta T} \quad \text{for at least one } j \text{ at each node } n \in \mathcal{N}^*(\mathcal{N}').$$

Since each node $n \in \mathcal{N}^*(\mathcal{N}')$ requires exactly one designated monitor, the number of banks that the firm contracts with under the optimal sharing rule $s$ is exactly $N^* = |\mathcal{N}^*(\mathcal{N}')|$, the cardinality of $\mathcal{N}^*(\mathcal{N}')$. Given these preliminaries, the following proposition characterizes the optimal sharing rule $s^*$.

**Proposition 3 (Optimal Syndicate Structure)** *Suppose the firm wants to incentivize information acquisition at all nodes in some set $\mathcal{N}$. Let $\mathcal{N}^*(\mathcal{N}')$ denote the minimal-incentive set given $\mathcal{N}$, and, without loss of generality, refer to the designated monitor at node $j \in \mathcal{N}^*(\mathcal{N}')$ as bank $j$. Then, for each bank $j$, the optimal sharing rule $s^*$ is given by*

$$s_j^* = \frac{1}{\phi_j \left(\sum_{n=1}^{N^*} \left(\frac{1}{\phi_n}\right)\right)}. \tag{S*}$$

*For any $j$, $s_j = 1$ if and only if $N^* = 1$, and $s_j^* \in (0,1)$ if $N^* > 1$. Under the optimal sharing rule $s^*$, the information-acquisition incentive constraint at each node $n$ thus reads:*

$$c \leq c^* = \frac{\widehat{\Delta T}}{\left(\sum_{n=1}^{N^*} \left(\frac{1}{\phi_n}\right)\right)}. \tag{IAI*}$$

In general, this constraint is tighter (i) the larger $N^*$ and (ii) the more dispersed the distribution over $\phi$ is. Since $N^*$ is small when individual banks have monitoring expertise at multiple nodes, (IAI*) yields one of the key predictions of our model: banks that possess expertise in a wide array of activities are better at acquiring information about firms and are, thus, better at lending to firms that are more efficiently intermediated under symmetric information. The following example elucidates the mechanics behind these arguments.

**Example 1** *The firm's information structure is characterized by three nodes, so that* $\mathcal{N} = \{n_1, n_2, n_3\}$*. We assume that* $\phi_1 = \frac{1}{2}$ *and* $\phi_2 = \phi_3 = \frac{1}{4}$*, and that it is efficient to produce information at every node, i.e.,*

$$c \leq \phi_n \Delta T \quad \text{for all } n. \tag{EIE}$$

*The firm wants to incentivize information acquisition at every node, so that* $\mathcal{N}' = \mathcal{N}$*. The firm is free to contract with one, two, or three of the three available banks (bank 1, bank 2 and bank 3). Is the firm able to satisfiy* (EIE) *for each* $n$*? As alluded to above, the answer depends crucially on the distribution of monitoring expertise across banks.*

*Suppose each bank has expertise at exactly one node. Without loss of generality, let bank* $n$ *have expertise at node* $n_n$*. Then, the minimal-incentive set is* $\mathcal{N}^* = \mathcal{N}$*. The cardinality of* $\mathcal{N}^*$ *is* $N^* = 3$*, the optimal monitoring structure is given by*

$$s_1^* = \frac{1}{5}, \qquad s_2^* = \frac{2}{5}, \qquad s_3^* = \frac{2}{5},$$

*and the firm is able to provide incentives to monitor all nodes if and only if*

$$c \leq c^* = \frac{\widehat{\Delta T}}{10}.$$

*Suppose now that bank 1 has expertise at nodes 1 and 2, while banks 2 and 3 continue to have expertise at nodes 2 and 3, respectively. As the cost of monitoring a node at which the bank has expertise is symmetric across banks, the bank prefers to contract with banks 1 and 3 only: since bank 1 has expertise at node 2, providing incentives to bank 1 to monitor node 2 is equally costly as providing the same incentives to bank 2, but automatically satisfies bank 1's incentive constraint at node 1 because* $\phi_1 > \phi_2$*. The minimal-incentive set is thus* $\mathcal{N}^* = \{n_2, n_3\}$*. The cardinality of* $\mathcal{N}^*$ *is* $N^* = 2$*, the optimal monitoring structure is given by*

$$s_1^* = \frac{1}{2}, \qquad s_2^* = 0, \qquad s_3^* = \frac{1}{2},$$

*and the firm is able to provide incentives to monitor all nodes if and only if*

$$c \leq c^* = \frac{\widehat{\Delta T}}{8}.$$

*Finally, suppose that bank 1 has expertise at all three nodes. The bank thus prefers to provide incentives to firm 1 only. Without loss of generality, since* $\phi_2 = \phi_3$*, assume that the firm provides incentives at node 2 rather than node 3. Then, the minimal-incentive set is* $\mathcal{N}^* = n_2$*. The cardinality of* $\mathcal{N}^*$ *is* $N^* = 1$*, the optimal monitoring structure is given by*

$$s_1^* = 1, \qquad s_2^* = 0, \qquad s_3^* = 0,$$

*and the firm is able to provide incentives to monitor all nodes if and only if*

$$c \leq c^* = \frac{\widehat{\Delta T}}{4}.$$

The example demonstrates that the firm finds it easier to provide incentives for bank monitoring when it contracts with fewer banks that have a broader range of expertise: the threshold value of $c$ above which no information is acquired increases from $\widehat{\Delta T}/10$ to $\widehat{\Delta T}/4$. The intuition behind this result is simple. When contracting with only a few banks, the firm is able to promise a larger stake to each individual bank. This increases the incentives of the banks to produce information by alleviating the free-rider problem in information acquisition. One can easily see that this effect becomes stronger when the distribution over $\phi$ is particularly dispersed, as $\sum_n (1/\phi_n)$ increases sharply when $\phi_n$ is small for a particular $n \in \mathcal{N}^*$. It is natural to consider firms with dispersed distributions over $\phi$ to be *informationally sensitive*, since they tend to require extensive bank expertise to be monitored efficiently. In the setting at hand, the value of bank scope is thus particularly high for informationally sensitive firms.

## 4.2 Information-acquisition Incentives in the Optimal Contract

In the previous section, we characterized the optimal syndicate structure as the sharing rule $s$ that maximizes information acquisition for a given value of information-acquisition incentives $\widehat{\Delta T}$. In this section, we show how $\widehat{\Delta T}$ is endogenously determined by the intermediation contract between firm and bank syndicate. To this end, recall that the key benefit of bank monitoring in our model is that it leads to symmetric information about $z$. Symmetric information is, in turn, valuable because it improves the efficiency of financial intermediation: the optimal symmetric-information contract $\mathcal{C}^{SI}$ allows the firm to credibly pledge more of its expected revenues than the asymmetric-information contract $\mathcal{C}^{AI}$. The key question that arises is, thus, whether a continuation contract that is predicated on symmetric information between bank and firm provides sufficient incentives for banks to actually acquire information.

To answer this question, we ask whether a contract that offers the same repayment schedules as $\mathcal{C}^{SI}$ for every state $z$ provides sufficient information-acquisition incentives. We call this contract the *baseline information-acquisition contract* $\mathcal{C}^{BL}$, and the resulting incentives *baseline information-acquisition incentives*. This contract is of interest since whenever $\mathcal{C}^{BL}$ provides sufficient information-acquisition incentives, it becomes feasible for bank and firm to offer the efficient state-contingent repayment schedules $\tau^{SI}(z)$ in every state $z$.

**Definition 3 (Baseline Information-acquisition Contract)** *Given an optimal symmetric-information contract $\mathcal{C}^{SI}$, the baseline information-acquisition contract $\mathcal{C}^{BL}$ is defined by*

$$\tau^{BL}(\hat{z}, \hat{z}_b) = \tau^{SI}(\hat{z}_b) \qquad \textit{and} \qquad \kappa_1^{BL}(\hat{z}, \hat{z}_b) = \kappa_1^{SI}(\hat{z}_b)$$

*for all $(\hat{z}, \hat{z}_b)$.*

This contract fulfills the firm's truthful-reporting constraint (REV) trivially: since the firm is offered the same repayment schedule and transfer for any report $\hat{z}$, it has no incentives to misreport. Similarly, the contract induces the optimal action in every state: since $\mathcal{C}^{SI}$ satisfies (IC), so does this contract. Hence, $\mathcal{C}^{BL}$ results in the same state-contingent repayment schedules as $\mathcal{C}^{SI}$ as long as banks choose to produce and truthfully reveal information about $z$. What if banks do not produce information? Banks will then find it optimal to report the state that maximizes expected pledgeable income. Since banks must make the reporting decision under ignorance about $z$, the resulting pledgeable income is equivalent to the plegeable income generated by the optimal partial-incentive contract.[6] Proposition 4 states under which conditions it is optimal for a bank to produce and reveal information given $\mathcal{C}^{BL}$.

**Proposition 4 (Information Acquisition and Revelation)** *Under the baseline information-acquisition contract, the incentives to acquire information are given by*

$$\widehat{\Delta T}^* = \Delta T_{PI} \geq \Delta T$$

*where* $\Delta T_{PI} = \min\{\Delta T_D, \Delta T_I\}$. *Given the optimal syndicate structure* $s^*$, *the syndicate acquires information if and only if*

$$c \leq \frac{\widehat{\Delta T}^*}{\left(\sum_{n=1}^{N^*}\left(\frac{1}{\phi_n}\right)\right)}.$$

Proposition 4 states that the incentives to acquire information in the baseline contract are bounded by the value of information in a partial-incentive contract. Why is this the case? Ideally, the firm would like to offer a menu of contracts that provides no transfers to the syndicate if the syndicate shirks. But since the information to be acquired is soft, this is not enforceable. Instead, the firm must provide information-acquisition incentives using repayment schedules that are on the path of play. In the baseline contract, this means that the syndicate cannot be made worse off than in the optimal partial-incentive contract: if the syndicate shirks, it can report any $z$ and guarantee the payoff obtained in a partial-incentive contract. An important upshot of our model then is that a tension arises between providing incentives for overcoming the borrower's moral hazard, and providing incentives for information acquisition by the syndicate.[7]

The next proposition shows that the extent to which the firm can provide incentives to

[6] The proof of Proposition 4 in the Appendix provides a detailed argument.

[7] An important consideration that we neglect in our discussion is whether the firm would like to distort the borrowing contract in order to induce information acquisition by the syndicate. Indeed, it can easily be shown that the firm becomes more information-sensitive from the point of view of the lender if the firm pledges *less* after a realization of low returns, and *more* after high returns in order to make the banks more sensitive to downside risk. This is reminiscent of DeMarzo and Duffie (1999) and Yang and Zeng (2013). While doing so may serve to increase the syndicate's incentives to acquire information, it is clear that *any* distortion of the baseline information-acquisition contract will reduce pledgeable income relative to the full-information baseline. In the interest of parsimony, we therefore abstract from analyzing the firm's security-design problem in more detail, but note that our analysis of the adverse effects of information underprovision may serve as an upper bound of the effects that one can expect to observe in practice.

acquire information may be limited by firm-level volatility. To make our point, we first define a model-consistent measure of informational inefficiency.

**Definition 4 (Informational Inefficiency)** *The informational inefficiency in monitoring at node $n$ is given by*

$$\Phi \equiv \Delta T - s_n^* \widehat{\Delta T}^*.$$

To understand this measure, recall that $\Delta T$ is the value of information to the firm, whereas $s_n^* \widehat{\Delta T}^*$ denotes node $n$'s designated monitor's incentives to acquire information under the optimal contract. When $\Phi$ is large, information is valuable but hard to obtain.

**Proposition 5 (Informational Inefficiency and Volatility)** *Consider a mean-preserving spread of size $\mu$, and let $\Phi(\mu)$ denote the informational inefficiency given $\mu$. Then:*

1. *$\Phi(\mu)$ is strictly increasing in $\mu$ if the optimal contract under asymmetric information is an implementation or a full-incentive separating contract.*
2. *Let the optimal contract under asymmetric information be a full-incentive pooling contract. If the optimal partial-incentive contract is a deterrence contract, $\Phi(\mu)$ is strictly increasing in $\mu$ if and only $1 - s_n^* < \frac{\xi_h(1-2\xi_l)}{\gamma(\xi_h - \xi_l)}$, which is decreasing in $\xi_l$ (cf. Proposition 2). If the optimal partial-incentive contract is an implementation contract, $\Phi(\mu)$ is strictly increasing in $\mu$ if and only if $s_n^* < \frac{\xi_h(1-2\xi_l)}{(1-\gamma)(\xi_h - \xi_l)} - \frac{\gamma}{1-\gamma}$.*
3. *$\Phi(\mu)$ is strictly decreasing in $\mu$ if the optimal contract under asymmetric information is a deterrence contract.*

Firms with valuable growth options (those that are more likely to choose implementation contracts over deterrence contracts, and those that are more likely to choose separating full-incentive contracts over pooling contracts) find it harder to provide information-acquisition incentives relative to the value of information as volatility increases. Furthermore, high-productivity firms, for example those with low $\xi_l$ and, thus, high $\pi_l$, that choose pooling contracts (i.e., firms that prefer implementation to deterrence contracts) find it harder to provide information-acquisition incentives when $s_n^*$ is small and the bank's incentive constraints are tight to begin with. Hence, we find that increases in bank scope, which tend to increase $s_n^*$, are particularly valuable for firms with high productivity and high volatility.

Our model generates a notion of *economies of scope in banking* through endogenous information acquisition with particular implications for high-productivity, high-volatility firms. In the next section, we will argue that it is precisely universal banks that can realize these economies of scope through the breadth of their operations. In terms of our model, enhanced information acquisition translates directly into enhanced efficiency in financial intermediation.

# 5 Empirical Predictions: The Impact of Bank Scope on Firm-level Outcomes

The process of financial deregulation in the United States provides an opportunity to empirically test our model. In particular, we consider the rise of universal banking – as opposed to commercial banking – in the U.S. as a laboratory to study the firm-level effects resulting from changes in the scope of financial intermediation. As in Ang and Richardson (1994), Kroszner and Rajan (1994), and Puri (1996), we take the stance that the move towards universal banking widened the scope of potential interactions between banks and firms, and represented a shock to banks' incentives to acquire information about firms. As we have argued, these arguments are likely to hold particular relevance for firms that operate in multiple industries, or firms that are relatively large and have dispersed operations, as is the case in the sample of COMPUSTAT firms used in Neuhann and Saidi (2013) to evaluate the empirical predictions we outline below. Assumption 4 summarizes our view of universal banking in terms of the model:

**Assumption 4 (Universal Banking vs. Commercial Banking)** *Universal banks have a broader range of expertise than commercial banks. In terms of the model, the advent of universal banking increases $s_n^*$ for all $n$, thereby relaxing the bank's information acquisition incentive constraint.*

The key mechanism that drives differences in firm-level outcomes is as follows: if universal banking serves to reduce information asymmetries, then banks and firms are more likely to reap the value of information, leading to increases in the efficiency of financial intermediation. Our setting allows us to characterize the value of information as a function of firm-level characteristics, such as the production technology. The model therefore generates precise links from firm-level primitives to firm-level outcomes which can be tested in the data.

To generate empirical predictions for universal banking, we consider the following thought experiment. Suppose a firm can switch to a universal bank for a small fixed cost. Which firms are then most likely to switch to universal banks in order to realize gains from information? In the model, it is firms with a high value of information that stand to benefit most from informed lending.

For what kinds of firms is the value of information large? Proposition 2 suggests that information gains are likely to be large for highly volatile and highly productive firms, and small for low-volatility, low-productivity firms. In addition, Proposition 5 suggests that broad monitoring expertise is particularly valuable for highly volatile and highly productive firms, as such firms find it relatively difficult to provide information-acquisition incentives even when information is highly valuable. High-volatility, high productivity firms are therefore most likely to benefit from improvements in the willingness of banks to acquire information about firms.

If the move to universal banking does indeed lead to more information acquisition, our model predicts increases in observed firm-level volatility and productivity for two reasons. First, informed lending increases the pledgeable income of high-productivity, high-volatility firms. Such firms are thus more likely to receive financing under universal banking than under separated banking. Second, informed lending leads to further *endogenous* increases in productivity, since the optimal contract under symmetric information calls for the implementation of the optimal technology in every state of the world. Indeed, because the firm chooses the (productive but risky) growth option whenever it is available, the firm will also exhibit higher volatility upon contracting with an informed lender, such as a universal bank. Our model therefore generates the following empirical predictions.

**Empirical Prediction 1** *Firms that receive financing from universal banks are more volatile.*

**Empirical Prediction 2** *Firms that receive financing from universal banks exhibit higher productivity.*

Furthermore, we can use our framework to speak to the optimal structure of financial syndication. Financial syndication, and most importantly syndicated loans, represents a large fraction of corporate financing in the U.S. The extant theoretical literature focuses on risk sharing between banks as a crucial reason for the existence of such syndicates: if a single bank does not want to take on the risk of providing a large loan to a single firm, it may sell off slices of the loan to other banks in an attempt to diversify its holdings. However, potential asymmetric-information frictions between banks about the quality of the borrower limit the size of syndicates: the lead arranger may need to retain a large share of the loan to credibly signal its quality (see Sufi (2007) and Ivashina (2009), as well as references therein).

Our discussion of a firm's optimal monitoring structure provides an alternative explanation for the widespread existence of syndicates: banks may form syndicates to make use of a more diverse set of monitoring expertise. The limits to the size of syndicates in our model are then driven by coordination failures among banks. As a testable prediction, our model implies that such syndicates will be smaller in the presence of a universal bank, since universal banks themselves possess a wide range of monitoring expertise.Our model delivers the following implication in this regard:

**Empirical Prediction 3** *Syndicates that include a universal bank are smaller than syndicates that do not.*

# 6 Conclusion

We present a framework to analyze financial intermediation in the presence of moral hazard and asymmetric information about the nature of this model hazard. We characterize the optimal contract, and show that the value of this contract depends on firm-level volatility and productivity, even if increases in volatility are mean-preserving. We then analyze the same setting, but under the assumption of symmetric information about the nature of moral hazard. The effects of volatility on the value of the optimal contract are shown to be substantially weaker under symmetric information. Indeed, we show that information is particularly valuable for firms that are highly volatile and simultaneously highly productive. We extend the model to incorporate endogenous information acquisition by syndicates of banks. In our model, coordination failures within syndicates may lead to substantial underinvestment in information acquisition when the borrower requires the expertise of multiple distinct banks to be monitored efficiently. We show that increases in the scope of banking ease coordination frictions between banks, and allow firms to capture gains from informed lending more easily.

When evaluating the potential impact of increasing bank scope on overall welfare, we focus on firm-level, rather than bank-level, outcomes. Our findings point towards potentially important efficiency gains from increasing bank scope. While recent policy considerations are dominated by concerns about bank size, we propose to expand the debate to include scope in addition to bank size, given that many large banks are simultaneously active in a wide array of financial markets.

Our analysis speaks to the importance of interaction among financial intermediaries in driving firm-level outcomes. While we concentrate only on banks, in particular universal banks versus stand-alone commercial and investment banks, similar mechanisms may be at play when taking a broader view of financial intermediation. For example, hedge funds, money-market mutual funds, and other shadow-banking institutions now represent a substantial fraction of the U.S. financial industry in general and short-term corporate finance in particular. Against this background, a full understanding of corporate financing and its real effects may require an understanding of the interplay of different classes of financial institutions subject to distinct regulatory environments. We therefore view our paper as contributing to a system-based understanding of the financial sector in its relationship to the real economy at the firm level.

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# A Appendix

## A.1 Optimal Contract under Symmetric Information and Moral Hazard

This section provides proofs of the lemmas used to characterize the optimal contract under symmetric information and moral hazard.

### A.1.1 Proof of Lemma 1

A pure-equity contract is a contract that satisfies $\tau = \alpha X$ for some $\alpha \in [0, 1]$. For a given pure-equity contract, the deterrence constraint (DET) reads:

$$(1-\alpha)pX \geq (1-\alpha)q^l X.$$

Since $pX > q^l X$, this inequality is satisfied for any $\alpha \in [0, 1]$.

### A.1.2 Proof of Lemma 2

Suppose that the bank does not want to implement the growth option for any $\hat{z}$. Then $\kappa_1(\hat{z}) = 0$ for all $\hat{z}$ is optimal. Next, suppose that the bank wants to implement the growth option for some $\hat{z}$. To prove the lemma, suppose that $\{\tau(\hat{z}), \kappa_1(\hat{z})\}$ satisfies (IMP) but $\kappa_1(\hat{z}) > k_1$. If the bank were to offer $k_1$ instead of $\kappa_1(\hat{z})$, (IMP) would still be satisfied, and the firm would have sufficient capital to implement the growth option. Since $k_1 < \kappa_1(\hat{z})$, offering $k_1$ improves the banks realized payoff by $\kappa_1(\hat{z}) - k_1 > 0$. Offering $\kappa_1(\hat{z}) > k_1$ can therefore not be optimal.

### A.1.3 Proof of Lemma 3

To satisfy (IMP), the bank must provide wages such that the expected wages under $q^h$ are larger than the expected wages under $p$ by at least $k_1$. Clearly, (IMP) is binding at the optimum, and the bank provides incentives of exactly $k_1$. Suppose the bank wants to provide incentives by paying wage $w_i$ after output realization $i$. To satisfy (IMP), we must have $w_i = \frac{k_1}{q_i^h - p_i}$. This results in expected wage payments given by

$$w_i = k_1 \frac{q_i^h}{q_i^h - p_i}.$$

Assumption 2 implies that

$$\frac{q_3^h}{q_3^h - p_3} < \min\left\{\frac{q_1^h}{q_1^h - p_1}, \frac{q_2^h}{q_2^h - p_2}\right\}.$$

Thus, it is cheapest to provide incentives by offering wages in state 3 only, and the bank must offer $w_3 = k_1 \frac{q_3^h}{q_3^h - p_3}$ to the firm.

## A.2 Optimal Contract under Asymmetric Information and Moral Hazard

In this section, we fully characterize the optimal contract under asymmetric information and moral hazard. Recall that the optimal contract is the solution to the following program:

$$T = \max_{\{\tau(\cdot),\kappa_1(\cdot)\}} \quad \sum_z \Pr(z)\left[Q^*(z)\tau(\hat{z}^*) - \kappa_1(\hat{z}^*(z)\right] \tag{P}$$

$$\text{s.t} \quad (i) \quad \text{for every } (z, \hat{z})$$

$$a^*(z,\hat{z}) = \arg\max_a \quad Q(a,z,\hat{z})\left(X - \tau(\hat{z})\right) + \kappa_1(\hat{z}) - c(a,z) \tag{IC}$$

$$(ii) \quad \text{for every } z$$

$$\hat{z}^*(z) = \arg\max_{z'} \quad Q(a^*(z,z'),z,z')\left(X - \tau(z')\right) + \kappa_1(z') - c(a^*(z,z'),z) \tag{REV}$$

$$(iii) \quad \tau(z) \leq X \quad \text{for every } z. \tag{LL}$$

We solve this problem by first deriving the optimal contract within each contract class depicted in Figure 1, and then characterize which contract class is optimal. Throughout, we sometimes ease notation by specializing (IC). In particular, we say that the pair $\{\tau, \kappa\}$ provides incentives to implement the growth option if $\kappa \geq k_1$ and

$$q^h(X - \tau) \geq p(X - \tau) + \kappa, \tag{IMP}$$

and that $\{\tau, \kappa\}$ provides incentives to deter the gamble if

$$p(X - \tau) \geq q^l(X - \tau). \tag{DET}$$

To further simplify notation, we denote the optimal contract within each contract class by an asterisk throughout the Appendix. Finally, recall that Lemma 2 states that $\kappa_1^*(z) \leq k_1$ for all $z$.

### A.2.1 Optimal Implementation Contract

In an implementation contract, the bank provides incentives to implement the growth option, but does not provide incentives to deter the gamble. Since we want to implement the growth option, we have that $\kappa_1(h) = k_1$, and since we are considering an implementation contract,

$\{\tau(h), k_1\}$ satisfies (IMP) but not (DET), and $\{\tau(l), \kappa_1(l)\}$ does not satisfy (DET).

First, suppose that $\{\tau(l), \kappa_1(l)\}$ satisfies (IMP). Then it must be the case that $\kappa_1(l) = k_1$, since the growth option cannot be implemented otherwise. Since $\{\tau(h), \kappa_1(h)\}$ and $\{\tau(l), \kappa_1(l)\}$ both satisfy (IMP) but not (DET), the firm always chooses the same action in every state. Since (REV) requires that the firm's report maximize the firm's payoff given its action, we must have $q^h\tau(l) = q^h\tau(h)$ and $q^l\tau(l) = q^l\tau(h)$. Otherwise the firm would always prefer to report the state in which its expected wages are higher. Using the latter condition, program (P) can be specialized to:

$$T = \max_{\tau(h)} \quad \gamma\left(q^h\tau(h) - k_1\right) + (1-\gamma)\left(q^l\tau(h) - k_1\right) \tag{P'}$$

$$\text{s.t} \quad q^h(X - \tau(h)) \geq p(X - \tau(h)) + k_1, \tag{1}$$

where (1) will be binding at the optimum. Let $\tau^*$ denote the solution to this program. Since $p_2 \geq q_2^h > 0$, it must be the case that $\tau_2^* = X_2$. We then ask whether the bank prefers to pay wages to the firm in state 1 or in state 3. If the bank pays wages in state 1, providing $\Delta$ units of incentives requires wages of $\frac{\Delta}{q_1^h - p_1}$. The expected cost of providing $\Delta$ units of incentives using wage payments in state 1 is thus $\Delta\frac{\gamma q_1^h + (1-\gamma)q_1^l}{q_1^h - p_1}$. By the analogous argument, the cost of providing $\Delta$ units of incentives using wage payments in state 3 is $\Delta\frac{\gamma q_3^h + (1-\gamma)q_3^l}{q_3^h - p_3}$. As such, it is cheaper to provide incentives in state 3 than in state 1 if and only if

$$\frac{\tilde{q}_3}{q_3^h - p_3} < \frac{\tilde{q}_1}{q_1^h - p_1}. \tag{2}$$

We now show that this condition is always satisfied. Assumption 2 implies that

$$\frac{q_3^h}{q_3^h - p_3} < \frac{q_1^h}{q_1^h - p_1}.$$

Since $\tilde{q}_3 < q_3^h$ and $\tilde{q}_1 > q_1^h$, it follows that

$$\frac{\tilde{q}_3}{q_3^h - p_3} < \frac{q_3^h}{q_3^h - p_3} < \frac{q_1^h}{q_1^h - p_1} < \frac{\tilde{q}_1}{q_1^h - p_1}.$$

Hence, (2) is always satisfied given Assumption 2, so we have $\{\tau^*(l), \kappa_1^*(l)\} = \{\tau^*(h), \kappa_1^*(h)\} = \{\tau^{SI}(h), k_1\}$.

Next, suppose that $\{\tau(l), \kappa_1(l)\}$ does not satisfy (IMP). The binding revelation constraint in state $l$ is then given by

$$q^l(X - \tau(l)) + \kappa_1(l) = q^l(X - \tau(h)) + k_1. \tag{3}$$

Since $\{\tau(h), k_1\}$ satisfies (IMP), we can again specialize Program (P) to (P'). Equation (3) implies that we again have $\{\tau^*(l), \kappa_1^*(l)\} = \{\tau^*(h), \kappa_1^*(h)\} = \{\tau^{SI}(h), k_1\}$ whenever (2) is satisfied, which we have shown to be the case. This completes the proof.

### A.2.2 Optimal Deterrence Contract

In a deterrence contract, the bank provides incentives to deter the gamble, but does not provide incentives to implement the growth option. Recall from the symmetric-information case that $\tau = X$ provides incentives to deter the gamble. Hence, the contract $\{X, X, 0, 0\}$ deters the gamble in every state of the world. By the limited-liability constraint $\tau \leq X$, we also know that $\{\tau^*(l), \kappa_1^*(l)\} = \{\tau^*(h), \kappa_1^*(h)\} = \{X, 0\}$ is the deterrence contract that maximizes pledgeable income.

### A.2.3 Optimal Full-incentive Pooling Contract

We look for a pooling contract in which $\{\tau, \kappa_1\}$ is offered in every state of the world, and satisfies both (DET) and (IMP). Since this is a pooling contract, truth-telling constraints are irrelevant. Given that we want to implement the growth option in the high state, we must have $\kappa_1 = k_1$. The contracting problem can then be stated as:

$$
\begin{aligned}
T = \max_{\tau} \quad & \gamma \left(q^h \tau - k_1\right) + (1-\gamma)\left(p\tau - k_1\right) && \text{(P")} \\
\text{s.t} \quad & q^h(X-\tau) \geq p(X-\tau) + k_1 && (4) \\
& p(X-\tau) \geq q^l(X-\tau) && (5) \\
& \tau \leq X. && (6)
\end{aligned}
$$

As before, we let $\tau^*$ denote the solution to this program.

**Lemma 11** *The implementation constraint* (4) *and the deterrence constraint* (5) *are binding.*

**Proof:** Suppose first that (4) is not binding. Since $\tau = X$ violates (4), we must have $\tau_i < X_i$ for at least one $i$. Suppose $\tau_1 < X_1$, $\tau_3 < X_3$, or both. Then the bank can improve its payoff by increasing $\tau_1$ until $\tau_1 = X_1$, $\tau_3$ until $\tau_3 = X_3$, or both, holding $\tau_2$ constant. Now suppose that $\tau_1 = X_1$ and $\tau_3 = X_3$. Then the bank can improve its payoff by increasing $\tau_2$ until $\tau_2 = X_2$. This scheme does not violate (5), and lowers the firm's expected wages. Since $\tau = X$ violates (4), (4) must be binding. Next, suppose that (5) does not bind. Since $p_2 > q_2^h$, the bank will satisfy (4) by offering wages only after $X_1$ or $X_3$. But this violates (5), and hence (5) cannot be slack. ■

It is easy to show that the bank will never offer wages in state 1. Assumption 2 implies that

$$
\frac{\gamma q_3^h + (1-\gamma)p_3}{q_3^h - p_3} < \frac{\gamma q_1^h + (1-\gamma)p_1}{q_1^h - p_1}.
$$

Therefore, it is cheaper to satisfy (4) by offering wages in state 3 than in state 1. Since $q_3^l - p_3 < q_1^l - p_1$, paying any given wage in state 3 rather than state 1 also relaxes (5).

To maximize pledgeable income, calibrate the optimal full-incentive pooling contract from $\tau = X$, noting that (5) holds while (4) is violated at $\tau = X$. Given $\tau_1 = X_1$, to satisfy (4), we must reduce $\tau_3$. Reducing $\tau_3$ while holding the remaining elements of $\tau$ fixed violates (5). Hence, we must reduce $\tau_2$ simultaneously. The cheapest way to do so is such that (5) holds exactly. Differentiating (5) yields the requirement:

$$\frac{\partial \tau_2}{\partial \tau_3} = \xi_l.$$

We then choose the change in $\tau_3$ such that (4) holds with equality. The smallest possible change is precisely $\Delta$. This completes the proof.

### A.2.4 Optimal Full-incentive Separating Contract

We now characterize the optimal full-incentive separating contract. A full-incentive separating contract consists of a menu $\{\tau(h), \kappa_1(h), \tau(l), \kappa_1(l)\}$ in which $\{\tau(h), \kappa_1(h)\}$ satisfies (IMP) and $\{\tau(l), \kappa_1(l)\}$ satisfies (DET). We begin by showing that a contract in which $\{\tau(h), \kappa_1(h)\}$ also satisfies (DET) cannot improve upon a full-incentive pooling contract.

**Lemma 12 (Partial Payoff Equivalence of Pooling and Separating Contracts)** *Let* $\{\tau(h), \kappa_1(h)\}$ *satisfy both* (IMP) and (DET) *in a full-incentive separating contract. Then the maximum attainable payoff is the same as in a full-incentive pooling contract.*

**Proof:** Since $\tau(h), \kappa_1(h)$ satisfies (DET), the revelation constraint in state $l$ is given by

$$p(X - \tau(l)) \geq p(X - \tau(h)) + \kappa_1.$$

Since this constraint must bind in equilibrium, we have that

$$p\tau(l) = p\tau(h) - \kappa_1. \tag{7}$$

Note that there always exists a pure-equity $\tau(l)$ that delivers this value and satisfies (DET). Next, we must pick $\tau(h)$ to be the highest-value repayment schedule that satisfies (IMP) and (DET). From the previous section, we know that this is the optimal full-incentive pooling contract. Computing expected values given (7) delivers the desired result. ■

Hence, full-incentive separating contracts cannot improve upon full-incentive pooling contracts whenever $\{\tau(h), \kappa_1(h)\}$ satisfies both (IMP) *and* (DET). Since satisfying (DET) in isolation is costless, it is also never optimal to require $\{\tau(l), \kappa_1(l)\}$ to satisfy (IMP). We therefore consider separating contracts where $\{\tau(h), \kappa_1(h)\}$ satisfies (IMP) but not (DET), and $\{\tau(l), \kappa_1(l)\}$ satisfies (DET) but not (IMP). We can, thus, restrict attention to contracts in which $\kappa_1(h) = k_1$ and $\kappa_1(l) = 0$.

Pledgeable income then is the solution to the program:

$$
\begin{aligned}
T = \max_{\tau(h),\tau(l)} \quad & \gamma\left(q^h\tau(h) - k_1\right) + (1-\gamma)p\tau(l) \\
\text{s.t} \quad & q^h(X - \tau(h)) \geq p(X - \tau(h)) + k_1 && (8) \\
& p(X - \tau(l)) \geq q^l(X - \tau(l)) && (9) \\
& p(X - \tau(l)) \geq q^l(X - \tau(h)) + k_1 && (10) \\
& q^h(X - \tau(h)) \geq p(X - \tau(l)) && (11) \\
& \tau(l) \leq X \quad \text{and} \quad \tau(h) \leq X, && (12)
\end{aligned}
$$

where (10) and (11) denote the truth-telling constraints in states $l$ and $h$, respectively, while (8) and (9) denote the respective incentive constraints.

**Lemma 13** *The truth-telling constraint* (10) *is binding.*

**Proof:** Since $\tau(h) = X$ does not satisfy (8), we must have that $\tau_i(h) < X_i$ for at least one $i$. Given this fact, $\tau(l) = X$ does not satisfy (10). Hence $\tau_i(l) < X_i$ for at least one $i$. Now suppose (10) is slack, and consider adjusting $\tau(l)$ upwards according to the scheme presented in the proof of Lemma 11. This scheme does not violate (9), relaxes (11), does not impact any other constraint, and increases the bank's payoff. Hence, (10) must be binding. ■

Since (10) is binding, use (10) in (11) to give

$$q^h(X - \tau(h)) \geq q^l(X - \tau(h)) + k_1. \tag{13}$$

Combining (13) and (8) yields

$$q^h(X - \tau(h)) \geq \max\left\{q^l(X - \tau(h)), p(X - \tau(h))\right\} + k_1. \tag{14}$$

Equation (14) can be thought of as the incentive constraint of a firm that is supposed to choose the growth option over both the old technology and the risky gamble. It arises because the bank is uninformed about $z$. How does the bank choose $\tau(h)$ to satisfy this constraint at the lowest cost? Our parametric assumptions on the distribution functions imply that

$$q_3^h > \max\{p_3, q_3^l\} \quad \text{and} \quad q_i^h < \max\{q_i^l, p_i\} \quad \text{for } i = 1, 2.$$

Hence, the bank is unable to satisfy (14) by providing wages in either state 1 or state 2 only. We now show that the bank is also unable to provide incentives to the firm by offering wages in states 1 and 2 jointly. To this end, suppose the bank were to offer $w_1$ in state 1 and $w_2$ in state 2. Efficiency dictates that $w_1$ and $w_2$ be chosen such that $q_1^l w_1 + q_2^l w_2 = p_1 w_1 + p_2 w_2$, or $w_1 = \frac{p_2 - q_2^l}{q_1^l - p_1} w_2$. The constraint (14) can then be written as:

$$\left(\frac{q_1^h(p_2 - q_2^l) + q_2^h(q_1^l - p_1)}{q_1^l - p_1}\right) w_2 \geq \left(\frac{p_1(p_2 - q_2^l) + p_2(q_1^l - p_1)}{q_1^l - p_1}\right) w_2 + k_1.$$

It is thus infeasible to satisfy (14) by jointly offering wages in states 1 and 2 if

$$(q_1^h - p_1)(p_2 - q_2^l) < (p_2 - q_2^h)(q_1^l - p_1),$$

which is equivalent to

$$\frac{q_3^l - p_3}{q_1^l - p_1} < \frac{q_3^h - p_3}{q_1^h - p_1}.$$

By Assumption 1, the LHS is strictly smaller than 1, and the RHS is strictly greater than 1. Hence, the bank cannot provide incentives to the bank by offering wages in states 1 and 2. Instead, the bank pays the firm only in state 3. Since $q_3^l > p_3$, we have

$$\tau^*(h) = \begin{bmatrix} X_1 \\ X_2 \\ X_3 - \frac{k_1}{(q_3^h - q_3^l)} \end{bmatrix}.$$

Since (10) is binding, $\tau^*(l)$ is the pure-equity contract that satisfies

$$\tau^*(l) = pX - q^l(X - \tau^*(h)) - k_1.$$

This completes the proof.

## A.3 Proof of Proposition 2

The arguments for full-incentive separating contracts are omitted here, but are provided in the main text.

### A.3.1 Implementation Contract

The value of information conditional on a mean-preserving spread of size $\mu$ is

$$\begin{aligned}
\Delta_I(\mu) &= \pi_l + W_I^{AI}(\mu) - W^{SI}(\mu) \\
&= \pi_l + (1-\gamma)k_1 + (\tilde{q}_3 + \mu)\left(\frac{k_1}{q_3^h - p_3}\right) - \gamma(q_3^h + \mu)\left(\frac{k_1}{q_3^h - p_3}\right) \\
&= \pi_l + (\tilde{q}_3 - \gamma q_3^h)\left(\frac{k_1}{q_3^h - p_3}\right) + \mu(1-\gamma)\left(\frac{k_1}{q_3^h - p_3}\right).
\end{aligned}$$

Since $\gamma \in (0, 1)$ and $q_3^h > p_3$, $\Delta_I(\mu)$ is strictly increasing in $\mu$.

### A.3.2 Deterrence Contract

The value of information conditional on a mean-preserving spread of size $\mu$ is

$$\begin{aligned}\Delta_D(\mu) &= \pi_h - W^{SI}(\mu)\\ &= \pi_h - \gamma(q_3^h + \mu)\left(\frac{k_1}{q_3^h - p_3}\right).\end{aligned}$$

Since $\gamma \in (0,1)$ and $q_3^h > p_3$, $\Delta_D(\mu)$ is strictly decreasing in $\mu$.

### A.3.3 Full-incentive Pooling Contract

The value of information conditional on a mean-preserving spread of size $\mu$ is

$$\begin{aligned}\Delta_P(\mu) &= W_P^{AI}(\mu) - W^{SI}(\mu)\\ &= \left((\hat{q}_2 - 2\mu)\xi_l + (\hat{q}_3 + \mu)\right)\omega_P + (1-\gamma)k_1 - \gamma(q_3^h + \mu)\left(\frac{k_1}{q_3^h - p_3}\right)\\ &= \left(\hat{q}_2\xi_l + \hat{q}_3\right)\omega_P + (1-\gamma)k_1 - \gamma q_3^h\left(\frac{k_1}{q_3^h - p_3}\right) + \mu\left((1-2\xi_l)\omega_p - \gamma\left(\frac{k_1}{q_3^h - p_3}\right)\right).\end{aligned}$$

It immediately follows that

$$\frac{\partial\Delta_P(\mu)}{\partial\mu} = (1-2\xi_l)\omega_p - \gamma\left(\frac{k_1}{q_3^h - p_3}\right).$$

Recall that

$$\xi_l \equiv \frac{q_3^l - p_3}{p_2 - q_2^l} \in \left(0, \frac{1}{2}\right) \quad \text{and} \quad \omega_P \equiv \frac{k_1}{(q_3^h - p_3) - \xi_l(p_2 - q_2^h)}.$$

Hence, $\frac{\partial\Delta_P(\mu)}{\partial\mu} > 0$ if and only if

$$\begin{aligned}&(1-2\xi_l)\left(\frac{k_1}{(q_3^h - p_3) - \xi_l(p_2 - q_2^h)}\right) > \gamma\left(\frac{k_1}{q_3^h - p_3}\right)\\ \Leftrightarrow&(1-2\xi_l) > \gamma\left(\frac{(q_3^h - p_3) - \xi_l(p_2 - q_2^h)}{q_3^h - p_3}\right)\\ \Leftrightarrow&(1-2\xi_l) > \gamma\left(1 - \xi_l\left(\frac{p_2 - q_2^h}{q_3^h - p_3}\right)\right).\end{aligned}$$

Analogously to $\xi_l$, define $\xi_h = \frac{q_3^h - p_3}{p_2 - q_2^h}$, and note that $\xi_h \in \left(\frac{1}{2}, 1\right)$ since $q^h X > pX$. Then $\frac{\partial\Delta_P(\mu)}{\partial\mu} > 0$ if and only if

$$\gamma < \gamma^*(\xi_l, \xi_h) \equiv \frac{\xi_h(1-2\xi_l)}{\xi_h - \xi_l}.$$

Since $\xi_h \in \left(\frac{1}{2}, 1\right)$ and $\xi_l \in \left(0, \frac{1}{2}\right)$, it is easy to verify that $\gamma^*(\xi_l, \xi_h)$ is strictly decreasing in $\xi_l$. Furthermore, $\gamma^*(\xi_l, \xi_h)$ is also strictly decreasing in $\xi_h$, and $\gamma^*(\xi_l, \xi_h) \in (0,1)$.

## A.4 Proof of Proposition 3

Recall that there exists a unique designated monitor for each node $n \in \mathcal{N}^*$. Without loss of generality, refer to this bank as bank $n$. To provide monitoring incentives at every node in $\mathcal{N}^*$, $s$ must be such that

$$c \leq \phi_n s_n \widehat{\Delta T} \quad \text{for all } n$$

or, equivalently,

$$c \leq \min_n \{\phi_n s_n\} \widehat{\Delta T}.$$

To relax this constraint, the bank chooses $s^* = \arg\max_s \phi_n s_n$. A necessary condition for a maximum is that $s_n \phi_n = s_{n'} \phi_{n'}$ for all $n, n' \in \mathcal{N}^*$. Imposing $\sum_n s_n = 1$ then yields (S*).

## A.5 Proof of Proposition 4

Suppose first that there exists a bank that exerts monitoring effort at $n^*$, so that $z$ is fully revealed to the syndicate of banks. Since offering $\tau^{SI}(z)$ maximizes each bank's expected income in state $z$, $\hat{z}_b^*(z) = z$ satisfies every bank's truth-telling constraint (TT). The expected payoff from acquiring information under $\mathcal{C}^{BL}$, gross of the monitoring cost, is therefore

$$V^{BL}(\theta^I) = T^{SI}.$$

Suppose now that no informative signal is produced. What is the optimal reporting strategy? If the bank announces $\hat{z}_b = h$, the firm is offered $\tau^{SI}(h)$ in every state of the world. The resulting payoff to the syndicate of banks is exactly $T_I^{AI}$, the pledgeable income under a partial-incentive implementation contract. If, instead, the bank announces $\hat{z}_b = l$, the firm is offered $\tau^{SI}(l)$ in every state of the world, and the bank receives expected income $T_D^{AI}$, the pledgeable income under a partial-incentive deterrence contract. The optimal reporting strategy for the bank maximizes its expected payoff. The expected payoff to the syndicate is now

$$V^{BL}(\theta^{NI}) = \max\{T_D^{AI}, T_I^{AI}\}.$$

The baseline information incentives are thus equal to

$$\widehat{\Delta T}^* = V^{BL}(\theta^I) - V^{BL}(\theta^{NI}).$$

By the definition of $\mathcal{C}^{BL}$, this implies that

$$\widehat{\Delta T}^* = \min\{\Delta T_D, \Delta T_I\}.$$

Bank $j$ therefore exerts effort at node $n$ if and only if

$$c \leq \phi_n s_j \min\{\Delta T_D, \Delta T_I\}.$$

## A.6 Proof of Proposition 5

Fix a given node $n$, and simplify notation by letting $s = s_n^*$ and $\widehat{\Delta T} = \widehat{\Delta T}^*$. Recall that

$$\Phi = \Delta T - s\widehat{\Delta T}.$$

By the definition of $\Delta T$ and $\widehat{\Delta T}$ under the optimal contract, we have that

$$\Phi = (1-s)T^{SI} + sT^{AI}_{PI} - T^{AI}_{*}.$$

Analogously to the proof of Proposition 2, define

$$\Phi(\mu) = (1-s)T^{SI}I(\mu) + sT^{AI}_{PI}(\mu) - T^{AI}_{*}(\mu).$$

1. Suppose that the optimal contract under asymmetric information is a pooling contract (either deterrence or implementation). Then we have that

   $$\Phi(\mu) = (1-s)(T^{SI}I(\mu) - T^{AI}_{*}(\mu)).$$

   By the proof of Proposition 2, it follows that $\Phi(\mu)$ is strictly increasing if the optimal contract is an implementation contract, and strictly decreasing if the optimal contract is a deterrence contract.

2. Suppose that the optimal contract under asymmetric information is a full-incentive separating contract.

   (a) Suppose the optimal partial-incentive contract is a deterrence contract. Following the proof of Proposition 2, we can write

   $$\Phi(\mu) = \chi + \mu\left[\frac{k_1}{q_3^h - q_3^l} - (1-s)\gamma\frac{k_1}{q_3^h - p_3}\right],$$

   where $\chi$ does not depend on $\mu$. Since $q_3^l > p_3$, $\gamma < 1$, and $s \leq 1$, the term in square brackets is strictly positive.

   (b) Suppose the optimal partial-incentive contract is an implementation contract. Following the proof of Proposition 2, we can write

   $$\Phi(\mu) = \chi + \mu\left[\frac{k_1}{q_3^h - q_3^l} - ((1-s)\gamma + s)\frac{k_1}{q_3^h - p_3}\right],$$

   where $\chi$ does not depend on $\mu$. Since $q_3^l > p_3$, $\gamma < 1$, and $s \leq 1$, the term in square brackets is strictly positive.

3. Suppose the optimal contract under asymmetric information is a full-incentive pooling contract.

(a) Suppose the optimal partial-incentive contract is a deterrence contract. Following the proof of Proposition 2, we can write

$$\Phi(\mu) = \chi + \mu \left[ (1 - 2\xi_l)\omega_P - (1 - s)\gamma \frac{k_1}{q_3^h - p_3} \right],$$

where $\chi$ does not depend on $\mu$. From the proof of Proposition 2, the term in square brackets is strictly positive if and only if $(1-s) < \frac{\gamma^*(\xi_l,\xi_h)}{\gamma}$, with $\gamma^*(\xi_l, \xi_h) = \frac{\xi_h(1-2\xi_l)}{\xi_h-\xi_l}$.

(b) Suppose the optimal partial-incentive contract is an implementation contract. Following the proof of Proposition 2, we can write

$$\Phi(\mu) = \chi + \mu \left[ (1 - 2\xi_l)\omega_P - ((1 - s)\gamma + s) \frac{k_1}{q_3^h - p_3} \right],$$

where $\chi$ does not depend on $\mu$. From the proof of Proposition 2, the term in square brackets is strictly positive if and only if $(1 - s)\gamma + s < \gamma^*(\xi_l, \xi_h)$. This can be rearranged to give the desired result.