Regulating a Risk-Averse Firm under Incomplete Information

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Abstract

We examine the optimal regulatory policy for a risk-averse firm when the firm is imperfectly informed about its efficiency parameter for a project at the time of contracting. The firm's risk aversion shifts the optimal regulatory policy from a fixed-price contract to a cost-plus contract. The optimal regulatory policy entails undereffort by an inefficient firm as in Lafont and Tirole (1986) and the effort distortion increases as the firm becomes more risk-averse. Further, the regulator benefits from sequential contracting with the firm where the firm chooses contract terms gradually as it acquires information, albeit the benefit diminishes as the firm becomes more risk-averse.

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1 Introduction

We examine the optimal regulatory policy for a risk-averse firm under incomplete and asymmetric information. The information environment considered here is one in which neither the firm nor the regulator initially knows with certainty the firm's efficiency parameter for a project. After the regulator and the firm have negotiated a contract, the firm can discover its efficiency parameter before choosing its cost reduction effort. The regulator can observe the firm's output and production cost but not its efficiency parameter and its cost reduction effort. Therefore, we study a situation with both adverse selection and moral hazard for a risk-averse firm.

Laffont and Tirole (1986) (L&T henceforth) examine the optimal regulatory policy for a risk-neutral firm who is perfectly and privately informed about its efficiency parameter for a project at the time of contracting. Our analysis differ from L&T in two dimensions. First, we examine a situation where both the regulator and the firm are imperfectly informed about the firm's efficiency parameter at the time of contracting. We model a sequential contracting process where the firm chooses contract terms gradually over time as it discovers more information about its efficiency parameter. Second, we examine the optimal regulatory policy for a risk-averse firm. Therefore, we extend L&T to situations requiring a simultaneous treatment of moral hazard, adverse selection, and risk-sharing, such as the regulation of small firms.

Dai et al (2006) study how owners optimally contract with risk-neutral managers who are privately, but imperfectly informed of market conditions at the time of contracting. They show that the owner's ability to benefit from a manager's expertise depends on the contracting sequence employed. When all contract terms are negotiated after the manager has completed his forecast of market conditions, the owner may benefit little or not at all from a manager's expertise. On the other hand, when contract terms are determined gradually as the manager acquires information about market conditions, the owner always benefits from a manager's expertise. In contrast to Dai et al (2006), we examine a sequential contracting process for a risk-averse manager. Since the sequential contracting process subjects a manager to uncertainties at the time of contracting, it is interesting to study the regulator's preference for contracting sequence when the manager becomes risk-averse.

Laffont and Rochet (1998) (L&R henceforth) analyze a similar information environment to ours for a risk-averse firm. In their model, the contract is also offered and signed before the firm discovers its efficiency parameter. However, the firm in their model can reject the contract after observing its efficiency parameter, which makes their model equivalent to one that the firm is perfectly informed at the time of contracting. Therefore, their model excludes the benefit of sequential contracting.

Sappington (1982) examines the optimal regulatory strategy to promote cost reduction in a similar information environment but for a risk-neutral firm. Salanié (1990) studies optimal contracting with a risk-averse agent subject to adverse selection. In contrast, we study a situation with both adverse selection and moral hazard for a risk-averse firm. Our analysis permits direct comparisons with L&T and L&R. The comparisons demonstrate the effects of risk-aversion and sequential contracting.

We show that the firm's risk-aversion shifts the optimal regulatory policy from a fixed-price contract to a cost-plus contract. The optimal regulatory policy entails undereffort by an inefficient firm and the effort distortion increases as the firm becomes more risk-averse. Further, as the firm becomes more risk-averse, the effort distortion converges to, but is always smaller than, that in L&R . The finding demonstrates that the regulator benefits from sequential contracting, where the firm chooses contract terms gradually as it acquires information, even when firms are risk-averse. However, the benefit does diminish as the firm becomes more risk-averse. This result extends the finding by Dai et al. (2006) to settings with risk-averse managers.

We present the model in Section 2. Section 3 provides our analysis of the optimal regulatory policy. Section 4 demonstrates the regulator's preference for contracting sequence using a constant absolute risk-aversion utility function. Section 5 discusses the main findings and concludes the paper with future research directions.

2 Elements of the model

An utilitarian regulator wishes to realize a public project with social value S. A single firm can realize the project, at a total cost $C = \beta - e$, where β is the firm's efficiency parameter for the project and e is its manager's effort. The manager's disutility of effort is $\psi(e)$ with $\psi'(e) > 0$, $\psi''(e) > 0$, and $\psi'''(e) > 0$. The total production cost is observable by the regulator and is reimbursed to the firm by the regulator, as in L&T and L&R. The firm is also compensated by a net monetary transfer t in addition to the reimbursement of cost. The firm's manager is risk-averse and his utility function is $U = u(\pi)$, where $u' > 0$, $u'' < 0$, and $\pi \equiv t - \psi(e)$.

At the outset, neither the regulator nor the firm knows exactly the firm's efficiency parameter, β. However, both of them know β belongs to the two point support $\{\underline{\beta}, \overline{\beta}\}$ with $\overline{\beta} > \underline{\beta}$ and $\Pr(\beta = \underline{\beta}) = v$ (therefore $\Pr(\beta = \overline{\beta}) = 1 - v$). We assume that S is sufficiently large so that it is worth realizing the project regardless of the firm's efficiency parameter. After contracting with the regulator and before determining its cost reduction effort, the firm privately discovers its β for the project.

With incomplete information regarding β, the regulator offers a contract menu specifying a list of transfer-cost pairs that are contingent upon the firm's later announcement of its efficiency parameter, $\widehat{\beta}$, namely $\{t(\underline{\beta}), C(\underline{\beta})\}$ for $\widehat{\beta} = \underline{\beta}$ and $\{t(\overline{\beta}), C(\overline{\beta})\}$ for $\widehat{\beta} = \overline{\beta}$. As is well known, according to the revelation principle, we can restrict our attention to a truth-telling mechanism that $\widehat{\beta} = \beta$ is the firm's optimal strategy. For notation simplicity, let $\underline{t} \equiv t(\underline{\beta})$, $\underline{C} \equiv C(\underline{\beta})$, $\bar{t} \equiv t(\overline{\beta})$, and $\overline{C} \equiv C(\overline{\beta})$.

We assume that the regulator can raise public fund only through a distortionary mechanism. $\lambda > 0$ denote the shadow cost of public funds. The expected consumer surplus is $S - (1+\lambda)[v(\underline{t}+\underline{C}) + (1-v)(\bar{t}+\overline{C})]$. The certainty equivalent of the risk-averse manager's profit is $CE \equiv u^{-1}[vu(\underline{\pi}) + (1-v)u(\overline{\pi})]$. We aggregate the expected consumer surplus with the certainty equivalent of the manager's profit to obtain the expected social welfare:

$$\begin{aligned} W &= S - (1+\lambda)[v(\underline{t}+\underline{C}) + (1-v)(\bar{t}+\overline{C})] + u^{-1}[vu(\underline{\pi}) + (1-v)u(\overline{\pi})] \qquad (1) \\ &= S - (1+\lambda)\{v[\underline{\pi} + \psi(\underline{\beta} - \underline{C}) + \underline{C}] + (1-v)[\overline{\pi} + \psi(\overline{\beta} - \overline{C}) + \overline{C}]\} \\ &\quad + u^{-1}[vu(\underline{\pi}) + (1-v)u(\overline{\pi})]. \end{aligned}$$

The timing of the model is as follows: 1) The regulator and the firm signs a contract menu which specifies a list of transfer-cost pairs that are contingent upon the manager's later announcement, $\widehat{\beta}$. 2) After signing the contract, the firm discovers its efficiency parameter β for the project. 3) The firm announces its efficiency parameter $\widehat{\beta}$ and takes the transfer-cost pair depending on its announcement. 4) The firm determines it cost reduction effort and the production takes place. 5) The total cost is observed and exchange takes place based on the contract. It is noteworthy that, in contrast to L&T, we specify the contracting as a sequential process. The firm initially signs a contract menu contingent upon its later announcement of its efficiency parameter. Then, after discovering its efficiency parameter, the firm chooses a transfer-cost pair from the initial contract menu depending on its announcement.

3 The Optimal regulatory policy

The manager will participate in a contract if and only if his expected utility from the contract is nonnegative. Therefore, the regulatory policy must satisfy the incentive rationality condition

$$E(U) = vu(\underline{\pi}) + (1 - v)u(\overline{\pi}) \geqslant 0. \tag{2}$$

To guarantee the manager truthfully reveal the firm's efficiency parameter for the project, the transfer-cost pair designed for a type $\underline{\beta}$ (respectively a type $\overline{\beta}$) firm must be the one preferred by a type $\underline{\beta}$ (respectively a type $\overline{\beta}$) firm. Notice that $e = \beta - C$. Therefore, the regulatory policy must also satisfy the following incentive compatibility conditions:

$$\underline{\pi} = \underline{t} - \psi(\underline{\beta} - \underline{C}) \geqslant \bar{t} - \psi(\underline{\beta} - \overline{C}), \text{ and} \tag{3}$$

$$\overline{\pi} = \bar{t} - \psi(\overline{\beta} - \overline{C}) \geqslant \underline{t} - \psi(\overline{\beta} - \underline{C}). \tag{4}$$

Define $\phi(e) \equiv \psi(e) - \psi(e - \Delta\beta)$ where $\Delta\beta \equiv \overline{\beta} - \underline{\beta}$. Since $\psi''(e) > 0$ and $\psi'''(e) > 0$, it can be readily shown that $\phi' > 0$ and $\phi'' > 0$. The incentive compatibility conditions can be rewritten as

$$\underline{\pi} \geqslant \overline{\pi} + \phi(\overline{\beta} - \overline{C}), \text{ and} \tag{5}$$

$$\overline{\pi} \geqslant \underline{\pi} - \phi(\overline{\beta} - \underline{C}). \tag{6}$$

The regulator wishes to maximize the expected social welfare under incentive rationality and incentive compatibility conditions. Therefore, the regulator's optimization problem is

$$\underset{\{\underline{C},\overline{C},\underline{\pi},\overline{\pi}\}}{Max}\ W = S - (1+\lambda)\{v[\underline{\pi} + \psi(\underline{\beta} - \underline{C}) + \underline{C}] + (1-v)[\overline{\pi} + \psi(\overline{\beta} - \overline{C}) + \overline{C}]\}$$

$$+ u^{-1}[vu(\underline{\pi}) + (1-v)u(\overline{\pi})] \tag{7}$$

subject to conditions (2), (5) and (6). Since $\bar{t} - \psi(\underline{\beta} - \overline{C}) > \bar{t} - \psi(\overline{\beta} - \overline{C}) = \overline{\pi}$, an efficient firm ($\beta = \underline{\beta}$) can always mimic an inefficient one ($\beta = \overline{\beta}$) with a lower effort and capture information rent. As explained below, any rent captured by the efficient firm is costly to the regulator. Therefore, condition (5) must be binding at the optimum. We momentarily neglect condition (6), and we later check that the solution of the maximization under conditions (2) and (5) satisfies condition (6). Therefore, the regulator's optimization problem can be rewritten as

$$\underset{\{\underline{C},\overline{C},\overline{\pi}\}}{Max}\, W = S - (1+\lambda)\{v[\overline{\pi} + \phi(\overline{\beta} - \overline{C}) + \psi(\underline{\beta} - \underline{C}) + \underline{C}] + (1-v)[\overline{\pi} + \psi(\overline{\beta} - \overline{C}) + \overline{C}]\}$$
$$+ u^{-1}[vu(\overline{\pi} + \phi(\overline{\beta} - \overline{C})) + (1-v)u(\overline{\pi})] \tag{8}$$

subject to condition (2).

Before proceeding to the solution of the regulator's optimization problem (8), it is useful to characterize, as a benchmark, the optimal regulatory policy when the firm is risk-neutral. When the firm is risk-neutral, the regulator optimally offers the firm a fixed transfer payment $t^* = v\left(\psi(\underline{\beta} - \underline{C}) + \underline{C}\right) + (1-v)\left(\psi(\overline{\beta} - \overline{C}) + \overline{C}\right)$ regardless of the realization of its efficiency parameter. The fixed transfer payment equals the firm's expected cost of completing the project, which guarantees the firm's participation. Given the fixed transfer payment, the firm chooses the optimal amount of effort to reduce the cost of the project. Consequently, the firm delivers the efficient level of effort regardless of the realization of its efficiency parameter. Therefore, the optimal regulatory policy possesses the following features:

$$E(U) = vu(\underline{\pi}) + (1-v)u(\overline{\pi}) = 0 \tag{9}$$

$$\psi'(\underline{e}) = 1, \text{ and} \tag{10}$$

$$\psi'(\overline{e}) = 1. \tag{11}$$

Notice that, when the firm is risk-neutral, it captures no information rent from its private information about the efficiency parameter.

However, when the firm is risk-averse, the solution to the regulator's optimization problem has the following properties:

$$E(U) = vu(\underline{\pi}) + (1-v)u(\overline{\pi}) = 0, \tag{12}$$

$$\psi'(\underline{e}) = 1, \text{ and} \tag{13}$$

$$(1-v)[1-\psi'(\overline{e})] = [1-H]\, v\phi'(\overline{e}), \tag{14}$$

where $H \equiv 1/[(1-v) + v\frac{u'(\overline{\pi})}{u'(\overline{\pi}+\phi(\overline{e}))}]$.

Equation (12) indicates that, in contrast to L&T and L&R, the firm in expectation receives no rent from its private information.

Note that $u'(\overline{\pi}) > u'(\overline{\pi} + \phi(\overline{e}))$ and $H < 1$ because $u'' < 0$. Consequently, equation (14) shows $\psi'(\overline{e}) < 1$. Therefore, equations (13) and (14) suggest that, under the optimal regulatory policy, an efficient firm delivers an efficient level of effort but an inefficient firm delivers a less than efficient level of effort.

This qualitative property of optimal regulatory policy is similar to those in L&T and L&R. However, the intuitions behind these outcomes are profoundly different. In L&R, the firm is privately informed about its efficiency parameter at the time of contracting. An efficient firm can always mimic an inefficient firm and capture information rent. The rent $\phi(\overline{e})$ is an increasing function of the effort level required from an inefficient firm. Therefore, the regulator faces a trade-off between production efficiency and rent extraction. To reduce the costly rent, the regulator optimally lowers the effort level required from an inefficient firm. In L&R, the firm can reject the initial contract after observing its efficiency parameter, which makes their model equivalent to one that the firm is perfectly informed at the time of contracting. Hence, the regulator balances production efficiency and rent extraction as in L&T except that the information rent for a risk-averse firm is more socially costly than that for a risk-neutral firm. Consequently, the optimal regulatory policy entails a larger effort distortion in L&R than that in L&T.

In this model, at the time of contracting the firm shares the same incomplete information with the regulator about the firm's efficiency parameter. Consequently, although an efficient firm can capture ex post information rent by mimicking an inefficient firm, the regulator can fully extract the expected information rent at the time of contracting by adjusting the level of the transfer payments $\underline{t}$ and $\overline{t}$. Note that only the difference between the two payments affects the manager's decision to truthfully reveal its efficiency parameter. Therefore, the manager's ex post information rent would be costless for the regulator and efficient outcomes would be achieved as shown earlier, should the manager be risk-neutral. However, when the manager is risk-averse, the optimal regulatory policy must balance production efficiency and risk-sharing.

Equation (14) demonstrates the intuition. Raising $\overline{e}$ by δe will increase production efficiency by $(1-v)[1-\psi'(\overline{e})]\delta e$, but will also increase an efficient firm's ex post information rent by $\phi'(\overline{e})\delta e$. When the manager is risk-averse, the regulator can only reduce the expected transfer payment by $v\phi'(\overline{e})H\delta e$ in order to keep the manager's expected utility non-negative. As a result, the regulator's welfare decreases by $[1-H]\,v\phi'(\overline{e})\delta e$. At the optimum, the regulator's marginal benefit of raising $\overline{e}$ must equal her marginal cost of doing so, which yields equation (14).

Note that when the firm is risk-neutral, i.e., $u''=0$, $u'(\overline{\pi})=u'(\overline{\pi}+\phi(\overline{e}))$ and $H=1$. Consequently, $v\phi'(\overline{e})H\delta e = v\phi'(\overline{e})\delta e$, in other words, the regulator can fully recover the manager's expected ex post information rent by reducing the expected transfer payment by exactly $v\phi'(\overline{e})\delta e$. In that case, the right-hand side of equation (14) becomes 0 and the firm always delivers the efficient level of effort. On the other hand, when the firm becomes more risk-averse, i.e., u'' decreases, $u'(\overline{\pi})/u'(\overline{\pi}+\phi(\overline{e}))$ increases and H decreases. Consequently, the right-hand side of equation (14) increases and the inefficient firm delivers a smaller effort under the optimal regulatory policy. When the firm becomes infinitely risk-averse, H converges to 0. Consequently, equation (14) converges to $\psi'(\overline{e}) = 1 - \phi'(\overline{e})v/(1-v)$.

Note that $\psi'(\overline{e}) = 1-\phi'(\overline{e})v\lambda/(1-v)(1+\lambda)$ in L&T.* Therefore, when the firm becomes infinitely risk-averse, the outcome converges to the one in L&T as if the regulator in L&T places no value on the manager's utility. This is because of the following two effects. First, when the manager becomes infinitely risk-averse, he participates in the contract only if he is guaranteed nonnegative utility regardless of the realization of the efficiency parameter. Therefore, the optimal regulatory policy converges to one where the firm is perfectly informed about its efficiency parameter at the time of contracting. Second, the manager's ex post information rent becomes a complete waste for both the manager and the regulator when the manger becomes infinitely risk-averse. Therefore, the outcome converges to one where the regulator places no value on the firm's rent.

Note that the neglected condition (6) is satisfied by this solution. The condition can be written as $\overline{\pi} \geqslant \overline{\pi} + \phi(\overline{\beta} - \overline{C}) - \phi(\overline{\beta} - \underline{C})$ or $0 \geqslant \phi(\overline{\beta} - \overline{C}) - \phi(\overline{\beta} - \underline{C})$ which is true since $\overline{e} < \underline{e}$ from equations (13) and (14). We summarize the properties of the optimal regulatory policy in Proposition 1.

Proposition 1 *Under the optimal regulatory policy: (1) The manager receives no information rent in expectation; (2) An efficient firm delivers an efficient level of effort; (3) An inefficient firm delivers a less than efficient level of effort, and the effort distortion increases as the firm becomes more risk-averse.*

*See Laffont and Tirole (1986) for detailed analysis.

4 Preference for Contracting Sequence

An interesting example of risk-averse utility function is the constant absolute risk-aversion (CARA) utility function: $u(x) = (1 - e^{-\rho x})/\rho$ with $\rho > 0$. The CARA parameterization allows us to study the change in the optimal regulatory policy when the firm's degree of risk-aversion changes. In addition, it provides a direct comparison between our model and L&R. The comparison demonstrates the effect of sequential contracting.

With the CARA utility function, equation (14) becomes

$$\psi'(\bar{e}) = 1 - \frac{v}{1-v}\phi'(\bar{e})\left[1 - \frac{1}{v + (1-v)e^{\rho\phi(\bar{e})}}\right]. \qquad (15)$$

Differentiating equation (15) with respect to $\bar{e}$, ρ, and $\Delta\beta$ provides $\partial\bar{e}/\partial\rho < 0$ and $\partial\bar{e}/\partial\Delta\beta < 0$. Hence, the effort distortion for an inefficient firm increases as its manager becomes more risk-averse or the firm becomes relatively more inefficient.

As ρ converges to 0, i.e., the firm becomes less risk-averse, $\psi'(\bar{e})$ converges to 1. The regulatory policy converges to a fixed price contract. On the other hand, as ρ converges to infinity, i.e., the firm becomes infinitely risk-averse, $\psi'(\bar{e})$ decreases and converges to $1 - v\phi'(\bar{e})/(1-v)$, and the regulatory policy shifts towards a cost-plus contract, i.e., a less powerful incentive scheme.

A direct comparison between our model and L&R demonstrates the effect of sequential contracting. It can be shown that the effort distortion in our model converges to, but is always smaller than, that in L&R as ρ converges to infinity.

Proposition 2 *The effort distortion for an inefficient firm converges to, but is always smaller than, that in L&R as the firm becomes more risk-averse.*

Proof. In L&R, the effort level for the inefficient firm is determined by the following equation:

$$\psi'(e) = 1 - \frac{v}{1-v}\phi'(e)\left[\frac{\lambda}{1+\lambda} + \frac{1}{1+\lambda}\left(1 - \frac{1}{v+(1-v)e^{\rho\phi(e)}}\right)\right].^{\dagger} \tag{16}$$

Since $\rho > 0$, $e^{\rho\phi(\overline{e})} > 1$. Therefore, $1 > \frac{1}{v+(1-v)e^{\rho\phi(\overline{e})}} > 0$ and

$$\begin{aligned}\frac{\lambda}{1+\lambda} + \frac{1}{1+\lambda}\left(1 - \frac{1}{v+(1-v)e^{\rho\phi(e)}}\right) &> \frac{\lambda+1}{1+\lambda}\left(1 - \frac{1}{v+(1-v)e^{\rho\phi(e)}}\right) \\ &> 1 - \frac{1}{v+(1-v)e^{\rho\phi(e)}}.\end{aligned} \tag{17}$$

Then a direct comparison of equations (15) and (16) shows $\psi'(\overline{e}) > \psi'(e)$, i.e., the effort distortion for the inefficient firm is larger in L&R. As ρ increases, $1 - 1/(v+(1-v)e^{\rho\phi(\overline{e})})$ increases, the difference between the effort distortions in the two models shrinks. When $\rho \to \infty$, $1 - 1/(v+(1-v)e^{\rho\phi(\overline{e})})$ converges to 1. Consequently, $\psi'(\overline{e})$ converges to $\psi'(e)$ as $\rho \to \infty$. ■

Proposition 2 shows that the optimal regulatory policy entails a smaller effort distortion when the regulator is able to contract sequentially with the firm so that the firm chooses contract terms gradually as it acquires information. Therefore, the regulator benefits from sequential contracting. However, the benefit of sequential contracting diminishes as the firm becomes more risk-averse. When the manager becomes infinitely risk-averse, to ensure his participation he must be guaranteed a nonnegative utility for all realizations of its efficiency parameter. In this case, the benefit of sequential contracting disappears and the outcome becomes equivalent to those in L&R.

[†]See Laffont and Rochet (1998) for detailed analysis.

5 Conclusion

We examine the optimal regulatory policy for a risk-averse firm when the firm is imperfectly informed about its efficiency parameter for a project at the time of contracting. The regulator benefits from sequential contracting with the firm where the firm chooses contract terms gradually as it acquires information, even when the firm is risk-averse. However, the benefit does diminish as the firm becomes more risk-averse. Therefore, we extend Dai *et al.* (2006) to settings with risk-averse managers.

Our central insights also shed light on other contractual relationships that require a simultaneous treatment of adverse selection, moral hazard, and profit sharing, such as sharecropping, insurance, managerial compensation, *etc.* For example, buyers of automobile insurance typically do not have perfect information about their risks of being in an accident, which could depend on weather conditions, road conditions, traffic conditions, etc., when they purchase their auto insurances. They determine the amount of care to exert after they purchase their insurance contracts and are better informed about their potential risks.

Our study abstract from several factors that could be included in future research. First, although the firm's information about its efficiency parameter is imperfect at the time of contracting, the firm could be better informed than the regulator. In that case, the optimal regulatory policy must screen the firm not only by its efficiency parameter but also by its information at the time of contracting regarding its efficiency parameter. Second, we derive the optimal regulatory policy under the assumption that the regulator has perfect information regarding the firm's risk-preference. When the regulator has imperfect information about the firm's risk-aversion, the firm conceivably will try to manipulate the regulator's perception of both its risk-aversion and its efficiency parameter . The optimal regulatory policies in these situations merit further investigation.

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