Pareto-Improving Inefficiency

by

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Abstract

We examine the effects of a systematic increase in the agent's operating costs in a simple agency setting with moral hazard. We show that either the principal's profit or the agent's profit can increase as the agent's costs increase. The combined profit of the two parties also can increase. Perhaps most surprisingly, the principal's profit and the agent's profit can both increase simultaneously as the agent's costs rise. In this sense, increased inefficiency can be Pareto-improving under plausible conditions.

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1 Introduction.

It seems natural to presume that a systematic increase in a supplier's operating costs would harm either the supplier or the buyer or both parties in a procurement relationship. This presumption typically is correct when contracting frictions are absent. However, when common contracting frictions prevail, a supplier can secure greater profit as his costs increase systematically. Aggregate surplus (the sum of the buyer's profit and the supplier's profit) also can increase as the agent's costs increase. Perhaps most surprisingly, a systematic increase in the supplier's costs can increase the profit of both the buyer and the supplier simultaneously. In this sense, increased inefficiency can be Pareto improving.

We develop these conclusions in a simple moral hazard setting where a buyer (or, more generally, a principal) hires a supplier (or, more generally, an agent) to operate her project. For example, the principal might own a promising technology and the agent might be an entrepreneur who is hired to develop the technology into a viable commercial product. To motivate the agent to supply unobservable effort, the principal promises the agent a share of the payoff that arises when the project succeeds but pays the agent nothing if the project fails.

When increased inefficiency causes the agent's marginal cost to rise, the principal must promise the agent a higher payment for success in order to secure any specified success probability. Despite the higher cost of promoting success, the principal will not allow the equilibrium success probability to decline substantially when success is sufficiently valuable for the principal. Consequently, increased inefficiency can enhance the agent's profit by inducing an increase in his expected payment that exceeds the corresponding increase in his total cost. However, the relatively high payment for success will reduce the principal's profit. Therefore, although increased inefficiency that raises the agent's marginal cost may increase aggregate surplus, it will not increase the profit of both the principal and the agent.

Increased inefficiency can enhance the profit of both parties when the agent's marginal cost declines as his total cost rises. The principal gains in this case because the agent labors more diligently under any specified reward structure as incremental effort becomes less onerous to deliver. Furthermore, the resulting rise in the equilibrium probability of success can increase the agent's expected payment by more than the associated increase in his total cost of production. In this case, increased inefficiency will generate greater profit for both the principal and the agent.

The systematic increase in the agent's costs that we consider can take many forms in practice. For example, work rules or safety standards imposed by a labor union or by government regulation can increase operating costs. In addition, training programs to which workers must devote considerable time and effort can increase their total operating costs.

Our study is not the first to suggest that cost increases can be beneficial. Gelman and Salop (1983), for example, show that a competitor can reduce the intensity of price competition and thereby increase his profit by limiting his ability to produce large levels of output. Such a capacity limit can be viewed as an intentional increase in the marginal cost of production beyond a specified level of output. Similarly, Joskow and Kahn (2002) observe that an electricity producer can benefit by withholding electricity from the market. Such withholding of supply also can be viewed as the intentional implementation of a substantial increase in marginal cost beyond the desired output level. Anant et al. (1995) identify conditions under which a producer will employ an inefficient production technology in order to induce the government to reduce the ad valorem tax that it imposes on the producer. Other authors demonstrate the competitive benefits that a firm can derive from choosing inefficient locations and/or transport costs (e.g., Gupta et al., 1994, 1995), or that a candidate can secure by deliberately tarnishing his political reputation (Fletcher and Slutsky, 2008).

Although our study is related to its predecessors, our study differs in at least two respects. First, we analyze the potential benefit of a systematic increase in operating costs in a standard agency model where a principal designs a contract for an agent. Thus, we do not presume a particular form of market interaction among agents (e.g., Bertrand price competition, a market-clearing price for electricity, ad valorem taxation, Hotelling spatial competition, or standard election contests). Instead, we analyze fully optimal contracts between a principal and an agent in a canonical moral hazard setting. Second, we emphasize the increases in aggregate surplus and the Pareto gains that increased inefficiency can provide. While an action such as limiting electricity supply typically will increase the equilibrium price of electricity and thereby harm consumers, the cost increases in our model can benefit all contracting parties under plausible conditions.[1]

The analysis proceeds as follows. Section 2 describes the key elements of our simple agency model. Section 3 presents our primary conclusions. Section 4 illustrates our main findings in a special setting of interest. Section 5 concludes.

2 The Model.

We consider the interaction between two risk-neutral parties – a principal and an agent. The principal hires the agent to operate a project. The project either succeeds or fails. Success generates value $V > 0$ while failure produces no value for the principal. The agent will work for the principal as long as he anticipates non-negative profit from doing so. The agent's profit is the difference between the payment (T) he receives from the principal and the personal cost he incurs working for the principal.

The agent can increase the probability $p \in [0, 1]$ that the project succeeds by incurring greater personal cost. We will denote by $C(p, \cdot)$ the personal cost the agent incurs when he implements success probability p. The agent can secure a zero probability of success at no personal cost, so $C(0, \cdot) = 0$. However, the agent's cost increases with p at an increasing

[1] In standard agency settings where the agent is risk averse and payments from the principal to the agent are not restricted, the principal often secures increased expected profit while the agent continues to receive his reservation level of expected utility as the agent's operating cost declines. Thus, the strict Pareto gains that can arise in our model (with a risk neutral agent and limited liability concerns) typically do not arise in such standard agency settings.

rate for $p > 0$. Formally, $C_p(0,\cdot) \geq 0$, with strict inequality for $p > 0$.[2] Furthermore, $C_{pp}(p,\cdot) > 0$ for all $p \in [0,1]$. To ensure an interior equilibrium probability of success ($p \in (0,1)$), we also assume that $C_p(0,\cdot)$ is sufficiently small and $C_p(1,\cdot)$ is sufficiently large.[3] In addition, we assume that the principal's equilibrium expected profit is a concave function of p.[4]

The principal cannot observe the agent's effort supply. To motivate the agent to deliver effort, the principal delivers the minimum possible payment ($T = 0$) to the agent when the project fails, but promises a strictly positive payment ($T > 0$) when the project succeeds. The minimum (zero) payment might reflect either the agent's limited wealth or legal limits on the agent's liability, for example (Sappington, 1983).

The principal chooses the payment for success (T) to maximize her expected profit:

$$\Pi^P \;=\; p\,[\,V - T\,]. \tag{1}$$

Given the promised payment, the agent chooses the success probability ($p \in (0,1)$) to maximize his expected profit:[5]

$$\Pi^A \;=\; p\,T - C(p,\cdot). \tag{2}$$

We introduce the parameter $k \in [\underline{k},\overline{k}]$ to index the agent's cost of achieving success probability p. Higher values of k imply a higher cost of achieving every positive success probability. Formally, $C_k(p,k) > 0$ for all $k \in [\underline{k},\overline{k}]$ and for all $p \in (0,1]$.[6] We will say that "increased inefficiency" arises as $k \in (\underline{k},\overline{k})$ increases.[7] For simplicity, we take the value

[2] Here and throughout the ensuing analysis, subscripts on functions denote partial derivatives.

[3] Sufficient conditions are $\lim_{p\to 0} C_p(p,\cdot) = 0$ and $\lim_{p\to 1} C_p(p,\cdot) = \infty$.

[4] The principal's equilibrium expected profit will be a strictly concave function of p if $2\,C_{pp}(\cdot) + p\,C_{ppp}(\cdot) > 0$ for all $p \in [0,1]$. The key requirement is that $C_{ppp}(\cdot)$ be positive or sufficiently small in absolute value.

[5] Because $T \geq 0$ and $C(0,\cdot) = 0$, the agent can always secure non-negative expected profit by choosing $p = 0$.

[6] No restrictions are placed on cross partial derivatives (e.g., $C_{pk}(\cdot)$) at this point. Additional structure will be considered as the analysis proceeds.

[7] As the ensuing analysis will make clear, the term "increased inefficiency" will denote a marginal increase in k. We employ the term "inefficiency" here in a first-best sense. Inefficiency is present when the agent's total cost exceeds its minimum feasible level for all $p \in (0,1]$. As we demonstrate below, the elevated cost

of k (and thus the prevailing cost structure) to be determined exogenously at the outset of the interaction between the principal and the agent.[8]

The interaction between the principal and the agent proceeds as follows. First, the agent's cost structure (including the exogenous value of k) is determined. Then the principal specifies the payment for success (T). Next, the agent chooses his preferred success probability (p). Finally, the outcome of the project (success or failure) is observed, and the promised payment is delivered to the agent.

3 Findings.

Once k, and thus the agent's cost function, is determined, the agent maximizes his expected profit by increasing the success probability, p, up to the point at which his marginal cost of expanding p is equal to the promised reward for success, T. Formally, from equation (2):[9]

$$p \;=\; \arg\max_{\widetilde{p}} \{\, \widetilde{p}\, T - C(\widetilde{p}, k) \} \quad \Rightarrow \quad T \;=\; C_p(p, k). \tag{3}$$

Equations (2) and (3) imply that the agent's equilibrium profit can be written as:

$$\Pi^A \;=\; p\, C_p(p, k) - C(p, k). \tag{4}$$

Differentiating equation (4) reveals that the rate at which the agent's profit increases as k increases is:

$$\frac{d\Pi^A}{dk} \;=\; p\, C_{pp}(\cdot)\, \frac{dp}{dk} \,+\, p\, C_{pk}(p, k) \,-\, C_k(p, k). \tag{5}$$

To determine how changes in the agent's operating costs affect the principal's profit, notice from equations (1) and (3) that the principal's equilibrium profit can be written as:

$$\Pi^P \;=\; p\,[\, V - C_p(p, k)\,]. \tag{6}$$

can increase the profit of the principal, the agent, or both in the (second-best) setting under consideration.

[8] Although we take the prevailing cost structure to be exogenous, our analysis of the impact of increased inefficiency on the profits of the contracting parties identifies the party or parties that would favor or oppose the corresponding changes in the cost structure.

[9] For expositional simplicity, we do not explicitly note the dependence of the equilibrium success probability on k.

Because the principal's equilibrium expected profit is a concave function of p, equation (6) implies that the profit-maximizing success probability for the principal is determined by:

$$\frac{\partial \Pi^P}{\partial p} = 0 \quad \Leftrightarrow \quad V = C_p(p,k) + p\, C_{pp}(p,k). \tag{7}$$

Equation (7) implies that the principal's equilibrium marginal cost of increasing p is $C_p(\cdot) + p\, C_{pp}(\cdot)$. As this marginal cost increases (respectively, decreases), the equilibrium success probability declines (respectively, increases). Formally, totally differentiating the expression in equation (7) provides:[10]

$$\frac{dp}{dk} = -\, \frac{C_{pk}(\cdot) + p\, C_{ppk}(\cdot)}{2\, C_{pp}(\cdot) + p\, C_{ppp}(\cdot)} \lesseqgtr 0 \quad \text{as} \quad C_{pk}(\cdot) + p\, C_{ppk}(\cdot) \gtreqless 0. \tag{8}$$

Equations (5) and (8) imply that the rate at which the agent's profit varies with k is:

$$\frac{d\Pi^A}{dk} = -\, p\, C_{pp}(\cdot) \left[\frac{C_{pk}(\cdot) + p\, C_{ppk}(\cdot)}{2\, C_{pp}(\cdot) + p\, C_{ppp}(\cdot)} \right] + p\, C_{pk}(\cdot) - C_k(\cdot). \tag{9}$$

Similarly, differentiating equation (6) provides the rate at which the principal's profit varies with k:

$$\frac{d\Pi^P}{dk} = -\, p\, C_{pk}(\cdot) + [\, V - C_p(\cdot) - p\, C_{pp}(\cdot)\,] \frac{dp}{dk} = -\, p\, C_{pk}(\cdot). \tag{10}$$

The last equality in equation (10) follows from equation (7).

Now consider the impact of increased inefficiency on aggregate surplus, W, which is the sum of the agent's profit and the principal's profit. Adding equations (9) and (10) provides:

$$\frac{dW}{dk} = -\, p\, C_{pp}(\cdot) \left[\frac{C_{pk}(\cdot) + p\, C_{ppk}(\cdot)}{2\, C_{pp}(\cdot) + p\, C_{ppp}(\cdot)} \right] -\, C_k(\cdot). \tag{11}$$

Equations (9), (10), and (11) allow us to specify conditions under which increased inefficiency enhances the profit of the principal and/or the agent. The conditions are relatively simple in the standard textbook setting where the agent's cost is a quadratic function of p

[10] For expositional simplicity, we use $C(\cdot)$ to denote $C(p,k)$ in the ensuing analysis.

for each k (so $C_{ppp}(\cdot) = 0$), as Observations 1 – 4 reveal.[11]

Observation 1. Suppose $C_{ppp}(\cdot) = 0$. Then $\dfrac{d\Pi^A}{dk} > 0$ if $C_{pk}(\cdot) > \dfrac{2}{p} C_k(\cdot) + p\, C_{ppk}(\cdot)$.

Proof. From equation (9), when $C_{ppp}(\cdot) = 0$:

$$\frac{d\Pi^A}{dk} = \frac{p}{2} C_{pk}(\cdot) - p^2 C_{ppk}(\cdot) - C_k(p,k) > 0 \;\Leftrightarrow\; C_{pk}(\cdot) > \frac{2}{p} C_k(\cdot) + p\, C_{ppk}(\cdot). \quad \blacksquare$$

Observation 1 reveals that the agent can profit from increased inefficiency if his marginal cost rises sufficiently rapidly relative to his total cost (i.e., if $\frac{\partial}{\partial k} C_p(\cdot)$ is sufficiently large relative to $\frac{\partial}{\partial k} C(\cdot)$).[12] As the agent's marginal cost increases, the principal must raise the payment for success to induce the agent to deliver a specified success probability. Therefore, the agent's expected payment can increase by more than his total cost increases if the principal does not induce too pronounced a reduction in the equilibrium success probability, p. The reduction in p will be relatively small when increased inefficiency reduces the curvature of the agent's cost function (so $\frac{\partial}{\partial k} C_{pp}(\cdot) \leq 0$), and thereby diminishes the rate at which the agent's marginal cost declines as p declines.[13,14]

Although increased inefficiency that elevates the agent's marginal cost can augment his profit, it will never increase the principal's profit, as Observation 2 reports.[15]

Observation 2. $\dfrac{d\Pi^P}{dk} \gtreqless 0$ as $C_{pk}(\cdot) \lesseqgtr 0$.

[11] Alternative settings are considered in Observation 2, section 4, and footnotes #14, 17, and 18. In the ensuing Observations, the derivatives $\frac{d\Pi^A}{dk}$, $\frac{d\Pi^P}{dk}$, and $\frac{dW}{dk}$ are all evaluated at the equilibrium success probability, p.

[12] Observation 1 also reveals that the agent can profit from increased inefficiency that reduces his marginal cost, provided $C_{ppk}(\cdot)$ is negative and sufficiently large in absolute value. Observation 4 considers this possibility in more detail. The sufficient condition cited in Observation 1 is also a necessary condition when $C_{ppp}(\cdot) = 0$. The same is true of the sufficient condition cited in Observation 3.

[13] Recall from equation (8) that the equilibrium success probability, p, increases as k increases if $\frac{\partial}{\partial k} \{C_p(\cdot) + p\, C_{pp}(\cdot)\} < 0$.

[14] Equation (9) also implies that $\frac{d\Pi^A}{dk} > 0$ if $C_{pk}(\cdot) > \frac{2}{p} C_k(\cdot)$, $C_{ppk}(\cdot) \leq 0$, and $C_{ppp}(\cdot) \geq 0$.

[15] The proof of Observation 2 follows directly from equation (10).

Observation 2 indicates that increased inefficiency enhances the principal's profit if and only if the agent's marginal cost declines as his total cost increases. The reduced marginal cost reduces the incremental compensation required to induce the agent to increase the success probability, and thereby increases the principal's profit.

Observation 3 identifies a setting in which increased inefficiency enhances aggregate surplus.

Observation 3. Suppose $C_{ppp}(\cdot) = 0$. Then $\frac{dW}{dk} > 0$ if $-C_{pk}(\cdot) > \frac{2}{p} C_k(\cdot) + p\, C_{ppk}(\cdot)$.

Proof. From equation (11), when $C_{ppp}(\cdot) = 0$:

$$\frac{dW}{dk} = -\frac{p}{2} C_{pk}(\cdot) - p^2 C_{ppk}(\cdot) - C_k(p,k) > 0 \quad \Leftrightarrow \quad -C_{pk}(\cdot) > \frac{2}{p} C_k(\cdot) + p\, C_{ppk}(\cdot). \quad \blacksquare$$

Observation 3 reports that when the agent's cost is a quadratic function of p, aggregate surplus increases as inefficiency increases if: (i) the agent's marginal cost and the curvature of his cost function decline (so $\frac{\partial}{\partial k} C_p(\cdot) < 0$ and $\frac{\partial}{\partial k} C_{pp}(\cdot) \leq 0$); and (ii) the reduction in the agent's marginal cost is sufficiently pronounced relative to the increase in the agent's total cost (so $|\frac{\partial}{\partial k} C_p(\cdot)|$ is large relative to $\frac{\partial}{\partial k} C(\cdot)$). The relatively pronounced reduction in the agent's marginal cost and the reduction in the curvature of his cost function leads the principal to induce a higher equilibrium success probability, p.[16] The increase in p enhances the expected payoff from the project $(p\,V)$ by more than it raises the agent's total cost under the specified conditions.[17]

It remains to determine if increased inefficiency can enhance the profit of both the principal and the agent simultaneously. Observation 4 describes a setting in which such Pareto

[16] A reduction in the agent's marginal cost enables the principal to secure any specified success probability, p, with a smaller payment for success. A reduction in the curvature of the agent's cost function reduces the rate at which the agent's marginal cost increases as p increases. Both effects render an increase in p more profitable for the principal.

[17] Equation (11) also implies that $\frac{dW}{dk} > 0$ if $C_{pk}(\cdot) < 0$, $C_{ppk}(\cdot) \leq 0$, $C_{ppp}(\cdot) \leq 0$, and $|C_{pk}(\cdot)| > \frac{2}{p} C_k(\cdot) + p\, C_{ppk}(\cdot)$.

gains arise.[18]

Observation 4. Suppose $C_{ppp}(\cdot) = 0$. Then $\dfrac{d\Pi^A}{dk} > 0$ and $\dfrac{d\Pi^P}{dk} > 0$ if $C_{pk}(\cdot) < 0$,

$$C_{ppk}(\cdot) < 0, \text{ and } p\,|C_{ppk}(\cdot)| > |C_{pk}(\cdot)| + \frac{2}{p}\,C_k(\cdot).$$

Observation 4 reports that increased inefficiency can increase the profit of both the principal and the agent if it lowers the agent's marginal cost and reduces the curvature of his cost function sufficiently. The reduced marginal cost and reduced curvature of the agent's cost function ensure that the principal induces the agent to implement a higher success probability. (Recall equation (8).) Under the specified conditions, the corresponding increase in the agent's expected payment exceeds the increase in his costs. Consequently, the agent, like the principal, secures higher profit.[19]

4 An Example.

The analytic conditions presented in section 3 are endogenous because they reflect the equilibrium success probability, p. To identify exogenous conditions under which increased inefficiency can be advantageous for the agent and/or the principal and to illustrate the magnitude of the potential gains from increased inefficiency, it is helpful to impose additional structure on the problem. Consider the following simple cost function:

$$C(p,k) = p^{\frac{1}{k}}, \text{ where } k \in (0,1). \tag{12}$$

When $k = \frac{1}{2}$ in this setting, the agent's cost takes the familiar quadratic form, $C(p,\cdot) = p^2$. As Figure 1 illustrates, the agent's cost function shifts upward and becomes flatter as k increases.[20] In particular, the agent's marginal cost of delivering p rises for the smaller

[18] The proof of Observation 4 follows directly from Observations 1 and 2. It is readily verified that the conclusion in Observation 4 continues to hold if $C(\cdot)$ is not quadratic, provided $C_{ppp}(\cdot) \leq 0$.

[19] Recall from Observation 2 that when $C_{pk}(\cdot) > 0$, the principal's profit declines as k increases, and so the Pareto gains identified in Observation 4 cannot arise. However, W can increase as k increases when $C_{pk}(\cdot) > 0$. As Observation 3 reports, this is the case when $C_{ppk}(\cdot) < 0$ and $p\,|C_{ppk}(\cdot)| > C_{pk}(\cdot) + \frac{2}{p}C_k(\cdot)$.

[20] Formally, $C_k(p,k) = -\left[\frac{1}{k^2}\right] p^{\frac{1}{k}} \ln p > 0$ for all $p \in (0,1)$ when $C(\cdot)$ is as specified in equation (12). Furthermore, $C_{pk}(p,k) = -\left[\frac{1}{k^2}\right] p^{\frac{1-k}{k}} \left[1 + \frac{\ln p}{k}\right] \gtreqless 0$ as $p \lesseqgtr \exp\{-k\}$.

values of p and declines for the larger values of p as k increases.

Observation 5 summarizes the impact of increased inefficiency on the principal's profit (Π^P), the agent's profit (Π^A), and aggregate surplus ($W = \Pi^P + \Pi^A$) when the agent's cost function is as specified in equation (12) and when k and V are such that $p \in (0,1)$ in equilibrium.[21]

Observation 5. Suppose the agent's cost function is as specified in equation (12). Then:

(i) $\frac{d\Pi^A}{dk} < 0$, $\frac{d\Pi^P}{dk} < 0$, and $\frac{dW}{dk} < 0$ if $V < \frac{1}{k^2} \exp\left\{-\left(\frac{1-k}{k}\right)\right\}$;

(ii) $\frac{d\Pi^A}{dk} > 0$, $\frac{d\Pi^P}{dk} < 0$, and $\frac{dW}{dk} < 0$ if $V \in (\frac{1}{k^2} \exp\{-\left(\frac{1-k}{k}\right)\}, \frac{1}{k^2} \exp\{-\frac{2[1-k]}{1+k}\})$;

(iii) $\frac{d\Pi^A}{dk} > 0$, $\frac{d\Pi^P}{dk} < 0$, and $\frac{dW}{dk} > 0$ if $V \in (\frac{1}{k^2} \exp\{-\frac{2[1-k]}{1+k}\}, \frac{1}{k^2} \exp\{-[1-k]\})$; and

(iv) $\frac{d\Pi^A}{dk} > 0$, $\frac{d\Pi^P}{dk} > 0$, and $\frac{dW}{dk} > 0$ if $V \in (\frac{1}{k^2} \exp\{-[1-k]\}, \frac{1}{k^2})$.[22]

Corollary. Suppose k is initially $\frac{1}{2}$, so $C(p, \frac{1}{2}) = p^2$ in the setting of equation (12). Then in equilibrium, as k increases marginally above $\frac{1}{2}$: (i) Π^A, Π^P, and W all decline if $V < 1.47$; (ii) Π^A increases, Π^P declines, and W declines if $V \in (1.47, 2.05)$; (iii) Π^A increases, Π^P declines, and W increases if $V \in (2.05, 2.43)$; and (iv) Π^A, Π^P, and W all increase if $V \in (2.43, 4)$.

The conclusions recorded in Observation 5 and its corollary reflect the following considerations. In the setting of equation (12), the principal optimally induces a higher success probability (p) when success generates greater value (i.e., when V is larger).[23] Therefore, when V is small, p will be small, and so increased inefficiency increases the agent's marginal

[21] The equilibrium success probability is 1 when $V \geq \frac{1}{k^2}$ in this setting.

[22] The proof of Observation 5 is presented in the Appendix.

[23] From equation (7), the equilibrium success probability is determined by $V = C_p(p,k) + p\, C_{pp}(p,k)$. It is readily verified that $\frac{\partial}{\partial p}\{C_p(\cdot) + p\, C_{pp}(\cdot)\} = \left[\frac{1-k}{k^3}\right] p^{\frac{1-2k}{k}} > 0$ for all $k \in (0,1)$ in the setting of equation (12). Therefore, p increases as V increases in this setting.

cost of delivering p. The increase in the agent's marginal cost harms the principal because she must now promise a larger reward for success to induce the agent to deliver a given success probability. When V is sufficiently small, the principal optimally responds to the agent's higher marginal cost by inducing a smaller success probability.[24] The reduction in p serves to reduce the agent's profit since, due to the convexity of his cost function, the agent secures positive profit on all inframarginal units of p. Consequently, increased inefficiency reduces the profit of both the principal and the agent when V is sufficiently small.

When V is intermediate in magnitude, the principal optimally increases the payment for success (T) as the agent's marginal cost rises. She does so in order to avoid too pronounced a reduction in the (moderately valuable) success probability. The higher payment increases the agent's profit. However, when V (and thus p) is sufficiently small that increased inefficiency raises the agent's marginal cost, the higher payment to the agent outweighs the greater expected payoff from the project ($p\,V$), and so the principal's profit declines.

As V (and thus p) becomes larger, increased inefficiency does not increase the agent's marginal cost substantially. Consequently, the agent's profit rises by more than the principal's profit declines as inefficiency increases, and so aggregate surplus increases.

When V is sufficiently large, the principal induces a relatively large success probability, and so increased inefficiency reduces the agent's marginal cost of delivering p. The reduction in the agent's marginal cost benefits the principal, as she can now secure a given success probability with a smaller payment for success. (Recall Observation 2.) The principal optimally induces a higher p as the agent's marginal cost declines. The larger equilibrium success probability generates higher profit for the agent, and so Pareto gains arise.

Figure 2 illustrates how the profits of the principal and the agent change as k increases

[24] It is readily verified that $C_p(\cdot)$ and $C_{pp}(\cdot)$ both increase as k increases when V (and thus p) is sufficiently small in the setting of equation (12). Therefore, since the equilibrium p is determined by $V = C_p(p,k) + p\,C_{pp}(p,k)$ (from equation (7)), p must decline as k increases, holding V constant.

in the setting of equation (12) for different values of k and V. The profit of the principal and the profit of the agent both rise as k increases in the region marked P^+ in Figure 2. V (and thus the equilibrium p) is relatively large in this region, and so an increase in k reduces the agent's marginal cost as it raises his total cost.[25] The principal's profit declines as k rises in the other three regions in Figure 2, where the agent's equilibrium marginal cost increases as k increases. The decline in the principal's profit is less than the increase in the agent's profit, as so aggregate surplus increases, in the region of moderately large values of V marked W^+. The decline in the principal's profit exceeds the corresponding increase in the agent's profit, and so aggregate surplus declines, in the region of smaller V values labelled W^-. The profit of the principal and the profit of the agent both decline as k increases in the region of the smallest V values labelled P^- in Figure 2.

Table 1 provides more detailed information about the effects of increased inefficiency in the setting of equation (12). The table reveals how an increase in k from $k = 0.50$ to $k = 0.55$ affects the equilibrium probability of success (p), the payment for success (T), the agent's profit (Π^A), the principal's profit (Π^P), and aggregate surplus (W) for $V = 1$, 2, and 3.[26] When $V = 1$, the increased inefficiency reduces the agent's profit by more than 8% and reduces the principal's profit by more than 16%. These profit reductions reflect in part the lower success probability that the principal induces as the agent's marginal cost rises. When $V = 2$, the increased inefficiency raises the agent's profit by 7.1% and reduces the principal's profit by 2.6%, resulting in a 0.6% increase in aggregate surplus. When $V = 3$, the increased inefficiency raises the agent's profit by more than 17% and augments the principal's profit by more than 6%, and thereby enhances aggregate surplus by approximately 10%. These Pareto gains reflect in part the higher equilibrium success probability that is optimally induced when increased inefficiency reduces the agent's marginal cost as it increases his total cost.

[25] The equilibrium success probability is 1 in the region above the curve that forms the upper boundary of the region marked P^+ in Figure 2.

[26] The column headings $\Delta\Pi^A$, $\Delta\Pi^P$, and ΔW in Table 1 denote the changes in the agent's profit, the principal's profit, and aggegate surplus, respectively, as k increases from 0.50 to 0.55.

5 Conclusions.

We have shown that a systematic increase in operating costs can be advantageous for the principal, for the agent, or for both parties in a standard agency setting. A cost increase that elevates the agent's marginal cost can benefit the agent by compelling the principal to promise a larger reward for success in order to ensure that the agent's increased costs do not reduce the equilibrium probability of success unduly. However, the increase in the agent's marginal cost harms the principal because it requires her to promise a larger payment for success in order to ensure any desired success probability.

In contrast, a systematic increase in total cost that entails a reduction in marginal cost can enhance the profit of both the principal and the agent. The principal can gain because as the incremental cost of securing success declines, the agent will implement a higher success probability for any given reward structure. The agent also gains when the increased equilibrium success probability raises the agent's expected payment by more than it increases his costs.

Although these findings may be somewhat counterintuitive, they are not entirely surprising in light of the principle of the second best (Lipsey and Lancaster, 1956). This principle states that institutional imperfections (which stem from the moral hazard problem in the present setting) can render changes that would otherwise be universally detrimental (i.e., systematic increases in operating costs) advantageous for some or all contracting parties.[27] However, the particular application of the theory of the second best that we have analyzed may not be fully appreciated. Indeed, the traditional focus on efficiency and cost minimization in procurement and other contracting settings suggests that the potential for cost increases to produce increases in aggregate surplus and even Pareto gains may not be widely

[27] It is readily verified that systematic increases in the agent's operating cost would always harm the principal in our model if the agent's effort supply (or, equivalently, the probability of success) were contractable. Thus, the possibility of Pareto gains from increased inefficiency arises because of the contracting frictions created by the moral hazard problem in our model.

recognized.

Our analysis suggests caution when assessing the merits of structural changes in procurement and other agency relationships. A change that is certain to increase the costs of achieving any specified level of performance might appear to be counterproductive. However, as we have demonstrated, such a change can enhance welfare, and might even generate Pareto gains.[28] Our analysis also indicates that the welfare implications of a change in operating costs typically will vary with the details of the change (e.g., its impact on marginal costs) and the environment in which the change takes place (e.g., the principal's valuation of success).

Our analysis has proceeded in the context of a simple agency setting. Future research that derives corresponding conditions in richer settings would be valuable. Relevant alternative settings include those in which realized performance is a continuous variable, the agent's activities are multidimensional, and the principal contributes to the production process. Team settings with multiple agents also warrant investigation, as do settings in which the principal and the agent(s) bargain over the terms of the contract, including the details of the working environment (e.g., the value of k in the $C(p,k)$ cost function). Future research also might address the impact of proposed structural changes in agency settings where adverse selection concerns compound moral hazard considerations. We suspect that our key qualitative conclusions will persist in these alternative environments. However, the details of the conclusions remain to be specified.

[28] Our analysis also is readily employed to identify conditions under which improved efficiency (i.e., a reduction in the cost of achieving any specified success probability) can be detrimental to the principal, to the agent, or to both parties.

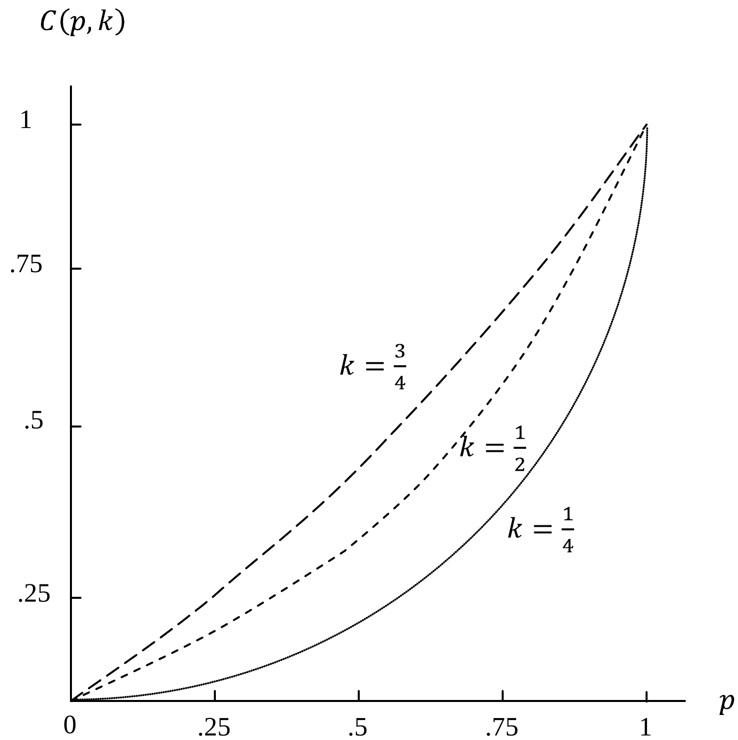
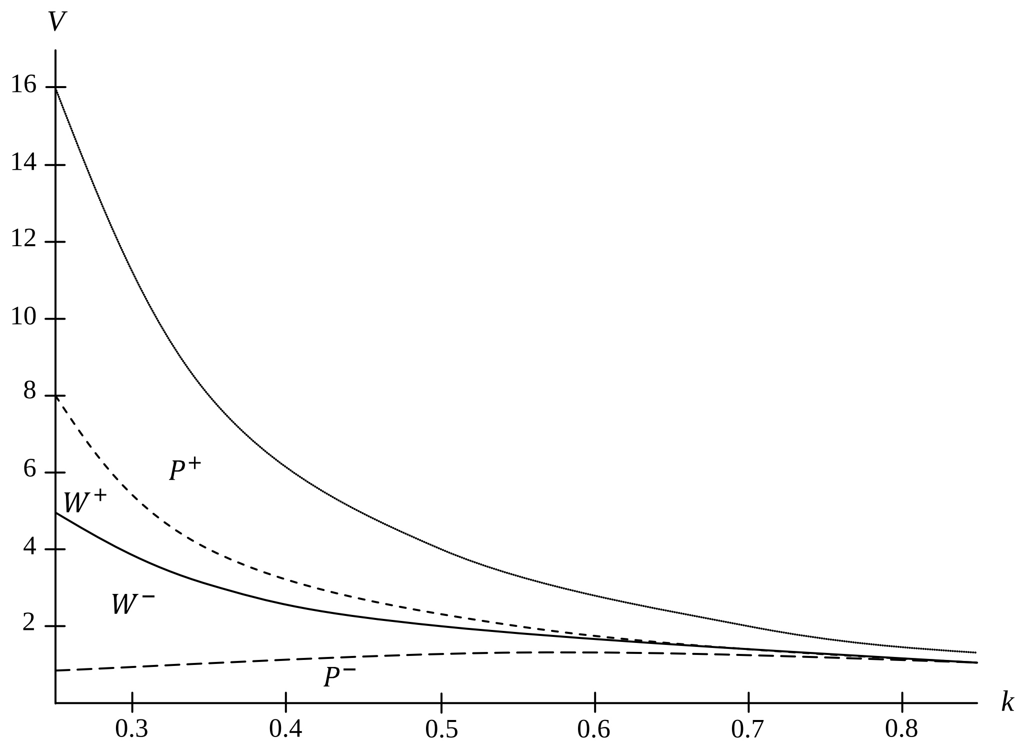


Figure 1. The Agent's Costs when $C(p,k) = p^{1/k}$.



P^+ = region in which Π^A, Π^P, and W all increase as k increases.
W^+ = region in which Π^A and W increase while Π^P declines as k increases.
W^- = region in which Π^A increases while Π^P and W decline as k increases.
P^- = region in which Π^A, Π^P, and W all decline as k increases.

Figure 2. Impacts of Increased Inefficiency when $C(p,k) = p^{1/k}$.

V	k	p	T	Π^A	$\Delta\Pi^A$	Π^P	$\Delta\Pi^P$	W	ΔW
1.0	0.50	0.25	0.50	0.0625		0.1250		0.1875	
1.0	0.55	0.23	0.55	0.0574	- 8.2%	0.1044	-16.5%	0.1618	-13.7%
2.0	0.50	0.50	1.00	0.2500		0.5000		0.7500	
2.0	0.55	0.54	1.10	0.2678	+ 7.1%	0.4870	- 2.6%	0.7548	+ 0.6%
3.0	0.50	0.75	1.50	0.5625		1.1250		1.6875	
3.0	0.55	0.89	1.65	0.6594	+17.2%	1.1990	+ 6.6%	1.8584	+10.1%

Table 1. The Effects of Increased Inefficiency when $C(p,k) = p^{1/k}$.

Appendix

Proof of Observation 5.

Differentiation of equation (12) provides:

$$C_p(p,k) \;=\; \left[\frac{1}{k}\right] p^{\frac{1-k}{k}}; \;\; C_k(p,k) \;=\; -\left[\frac{1}{k^2}\right] p^{\frac{1}{k}} \,\ln p; \;\; C_{pp}(p,k) \;=\; \left[\frac{1-k}{k^2}\right] p^{\frac{1-2k}{k}}; \qquad \text{(A1)}$$

$$C_{pk}(p,k) \;=\; -\left[\frac{1}{k^2}\right] p^{\frac{1-k}{k}} \left[1+\frac{\ln p}{k}\right]; \quad C_{ppp}(p,k) \;=\; \left[\frac{(1-k)\,(1-2k)}{k^3}\right] p^{\frac{1-3k}{k}}; \qquad \text{(A2)}$$

$$C_{ppk}(p,k) \;=\; -\left[\frac{1}{k^4}\right] p^{\frac{1-2k}{k}} \left[k+(1-k)\,(k+\ln p)\right]. \qquad \text{(A3)}$$

Equation (A2) implies:

$$C_{pk}(p,k) \;\gtreqless 0 \quad \Leftrightarrow \quad 1+\frac{\ln p}{k} \;\lesseqgtr\; 0 \quad \Leftrightarrow \quad p \;\lesseqgtr\; \exp\{-k\}. \qquad \text{(A4)}$$

Because Π^P is a concave function of p (and so $2\,C_{pp}(\cdot)+p\,C_{ppp}(\cdot) > 0$), equation (9) implies:

$$\begin{aligned} \frac{d\Pi^A}{dk} \;&\overset{s}{=}\; -\,p\,C_{pp}(\cdot)\left[C_{pk}(\cdot)+p\,C_{ppk}(\cdot)\right]+\left[2C_{pp}(\cdot)+p\,C_{ppp}(\cdot)\right]\left[p\,C_{pk}(\cdot)-C_k(\cdot)\right] \\ &=\; C_{pp}(\cdot)\left[\,p\,C_{pk}(\cdot)-2\,C_k(p,k)-p^2C_{ppk}(\cdot)\,\right] \\ &\qquad\qquad +\; p\,C_{ppp}(\cdot)\left[\,p\,C_{pk}(\cdot)-C_k(p,k)\,\right]. \end{aligned} \qquad \text{(A5)}$$

Equations (A1) – (A3) imply:

$$\begin{aligned} C_{pp}(\cdot)\left[\,p\,C_{pk}(\cdot)-2\,C_k(p,k)-p^2C_{ppk}(\cdot)\,\right] \;&=\; \left[\frac{1-k}{k^2}\right] p^{\frac{1-2k}{k}} \left[-\left(\frac{1}{k^2}\right) p^{\frac{1}{k}} \left(1+\frac{\ln p}{k}\right)\right. \\ &\left.+\;\left(\frac{2}{k^2}\right) p^{\frac{1}{k}}\,\ln p+\left(\frac{1}{k^4}\right) p^{\frac{1}{k}}\,(k+[1-k][k+\ln p])\right] \\ =\; \left[\frac{1-k}{k^2}\right] p^{\frac{2[1-k]}{k}} &\left[-\frac{1}{k^2}-\frac{1}{k^3}\ln p+\frac{2}{k^2}\ln p+\frac{1}{k^3}+\frac{1-k}{k^3}+\frac{1-k}{k^4}\ln p\right] \\ =\; \left[\frac{1-k}{k^5}\right] p^{\frac{2[1-k]}{k}} &\left[\left(2k-2+\frac{1}{k}\right)\ln p+2-2k\right]; \quad \text{and} \end{aligned} \qquad \text{(A6)}$$

$$p\,C_{ppp}(\cdot)\left[\,p\,C_{pk}(\cdot)-C_k(p,k)\,\right]$$

$$=\; \left[\frac{(1-k)\,(1-2k)}{k^3}\right] p^{\frac{1-2k}{k}} \left[-\left(\frac{1}{k^2}\right) p^{\frac{1}{k}} \left(1+\frac{\ln p}{k}\right)+\left(\frac{1}{k^2}\right) p^{\frac{1}{k}}\,(\ln p)\right]$$

$$= \left[\frac{(1-k)(1-2k)}{k^5}\right] p^{\frac{2[1-k]}{k}} \left[\left(1-\frac{1}{k}\right)\ln p - 1\right]$$

$$= \left[\frac{1-k}{k^5}\right] p^{\frac{2[1-k]}{k}} \left[\left(1-2k-\frac{1}{k}+2\right)\ln p - 1 + 2k\right]. \tag{A7}$$

Equations (A5) – (A7) imply:

$$\frac{d\Pi^A}{dk} > 0 \;\Leftrightarrow\; \left[2k-2+\frac{1}{k}+1-2k-\frac{1}{k}+2\right]\ln p + 2 - 2k - 1 + 2k > 0$$

$$\Leftrightarrow\; 1+\ln p > 0 \;\Leftrightarrow\; p > \exp\{-1\}. \tag{A8}$$

To express these conclusions in terms of exogenous parameters, notice that equations (7) and (A1) imply that the equilibrium success probability in the present setting is determined by:

$$V = \left[\frac{1}{k}\right] p^{\frac{1-k}{k}} + \left[\frac{1-k}{k^2}\right] p^{\frac{1-k}{k}} = \left[\frac{1}{k}\right] p^{\frac{1-k}{k}} \left[1+\frac{1-k}{k}\right] = \left[\frac{1}{k^2}\right] p^{\frac{1-k}{k}}$$

$$\Rightarrow\; p = \left[k^2 V\right]^{\frac{k}{1-k}}. \tag{A9}$$

Equation (A9) implies that the equilibrium p is less than 1 if $V < \frac{1}{k^2}$. Equation (A9) also implies that:

$$p > \exp\{-1\} \;\Leftrightarrow\; \left[k^2 V\right]^{\frac{k}{1-k}} > \exp\{-1\} \;\Leftrightarrow\; V > \frac{1}{k^2}\exp\{-\left[\frac{1-k}{k}\right]\}; \text{ and} \tag{A10}$$

$$p > \exp\{-k\} \;\Leftrightarrow\; \left[k^2 V\right]^{\frac{k}{1-k}} > \exp\{-k\} \;\Leftrightarrow\; V > \frac{1}{k^2}\exp\{-[1-k]\}. \tag{A11}$$

From equation (11):

$$\frac{dW}{dk} = \frac{-p\,C_{pk}(\cdot) - p^2\,C_{ppk}(\cdot)}{2 + p\,C_{ppp}(\cdot)/C_{pp}(\cdot)} - C_k(p,k). \tag{A12}$$

(A1) and (A2) imply:

$$2 + \frac{p\,C_{ppp}(\cdot)}{C_{pp}(\cdot)} = 2 + \frac{\left[\frac{(1-k)(1-2k)}{k^3}\right] p^{\frac{1-2k}{k}}}{\left[\frac{1-k}{k^2}\right] p^{\frac{1-2k}{k}}} = 2 + \frac{1-2k}{k} = \frac{1}{k}. \tag{A13}$$

(A2) and (A3) imply:

$$-p\,C_{pk}(\cdot) - p^2\,C_{ppk}(\cdot) = \left[\frac{1}{k^2}\right] p^{\frac{1}{k}} \left[1+\frac{\ln p}{k}\right] + \left[\frac{1}{k^4}\right] p^{\frac{1}{k}} \left[k + (1-k)(k+\ln p)\right]$$

$$= \frac{p^{\frac{1}{k}}}{k^4}\left[k^2\left(1+\frac{\ln p}{k}\right) + k + (1-k)(k+\ln p)\right]$$

$$= \frac{p^{\frac{1}{k}}}{k^4}\left[k^2 + k\ln p + k + k + \ln p - k^2 - k\ln p\right] \;=\; \frac{p^{\frac{1}{k}}\left[2k + \ln p\right]}{k^4}. \tag{A14}$$

(A1) and (A12) – (A14) imply:

$$\frac{dW}{dk} \;=\; \frac{p^{\frac{1}{k}}\left[2k + \ln p\right]}{k^3} + \left[\frac{1}{k^2}\right] p^{\frac{1}{k}}\;\ln p \;=\; \frac{p^{\frac{1}{k}}}{k^3}\left[2k + (1+k)\ln p\right]. \tag{A15}$$

(A9) and (A15) imply:

$$\frac{dW}{dk} \;\gtreqless\; 0 \;\text{ as }\; 2k + [1+k]\ln\left[k^2 V\right]^{\frac{k}{1-k}} \;\gtreqless\; 0 \;\Leftrightarrow\; \ln\left[k^2 V\right]^{\frac{k}{1-k}} \;\gtreqless\; -\frac{2k}{1+k}$$

$$\Leftrightarrow\; \ln\left[k^2 V\right] \;\gtreqless\; -\frac{2[1-k]}{1+k} \;\Leftrightarrow\; k^2 V \;\gtreqless\; \exp\left\{-\frac{2[1-k]}{1+k}\right\}$$

$$\Leftrightarrow\; V \;\gtreqless\; \frac{1}{k^2}\exp\left\{-\frac{2[1-k]}{1+k}\right\}. \tag{A16}$$

Conclusions (i) – (iv) in the Observation follow from equations (A4), (A8), (A10), (A11), and (A16).

To ensure the identified intervals for V are well-defined, notice that:

$$-\left[\frac{1-k}{k}\right] \;<\; -\frac{2[1-k]}{1+k} \;<\; -(1-k). \tag{A17}$$

The first inequality in (A17) holds because:

$$-\left[\frac{1-k}{k}\right] \;<\; -\frac{2[1-k]}{1+k} \;\Leftrightarrow\; \frac{2[1-k]}{1+k} \;<\; \frac{1-k}{k} \;\Leftrightarrow\; 2k[1-k] \;<\; 1-k^2$$

$$\Leftrightarrow\; k^2 - 2k + 1 \;>\; 0 \;\Leftrightarrow\; (k-1)^2 \;>\; 0.$$

The second inequality in (A17) holds because:

$$-\frac{2[1-k]}{1+k} \;<\; -(1-k) \;\Leftrightarrow\; 1-k \;<\; \frac{2[1-k]}{1+k} \;\Leftrightarrow\; 1-k^2 \;<\; 2-2k$$

$$\Leftrightarrow\; k^2 - 2k + 1 \;>\; 0 \;\Leftrightarrow\; (k-1)^2 \;>\; 0. \qquad \blacksquare$$

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