Motivating Loyal Bureaucrats in Sequential Agency[1]

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ABSTRACT

We study a two-stage adverse selection model in which a legislature and a bureaucrat make their decisions sequentially. In the first stage, the legislature chooses an amount of transfer to the bureaucrat for setting up and implementing a public project, and also collects information on the public's valuation of the project. In the second stage, using the information from the legislature, the bureaucrat chooses the project size and implements the project. We show that the legislature's transfer to the bureaucrat trades off using the collected information and exploiting the bureaucrat's loyalty to the public. Our result suggests that when the bureaucrat is loyal enough, it is optimal to induce him to make his decision independent of the public's valuation of the project.

JEL Classification: D82, D86, H11, H40

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1 Introduction

A considerable amount of research has been directed at the way public administration is organized and how it functions. Studies in political science have pointed out similarities between the ways projects are conducted in the private and the public sectors.[1] For example, operations in the two sectors are similar in that, just as a private corporation's project is authorized by the board of directors and implemented by the manager in charge, a public project is authorized by the legislative body and implemented by the bureaucrat in charge. At the same time, studies in political economy and public administration have pointed out considerable differences between the two sectors' characteristics.[2]

First, in a private company, members of the board of directors are often the top managers in other business organizations. Thus, they do possess similar expertise and experiences possessed by the top management of the organization. For such a reason, in the agency literature, the board of a firm, representing the shareholders' interest, is treated as "the principal," while the manager is treated as "the agent" who is paid to simply carry out the tasks designed by the principal. For a public project, however, members in the legislature seldom possess the expertise to make judgments on complex attributes of the project as the responsibilities are typically distributed among several entities.[3] Typically, there is a separation between the legislative level of the government which decides the composition of the public good, and the bureaucratic level which regulates the productive sector. For example, resources and spending ministers are often separated, with both affecting the decision-making.[4]

Second, as noted by Wilson (1989), a unifying theme in the study of public organizations is the importance of non-commercial "mission." According to Wilson, such mission-oriented public organizations are frequently staffed by bureaucrats who are motivated by their loyalty to the public—their sense of mission motivates the loyal

[1] See Moe (1990) for a survey.

[2] See Horn (1995).

[3] For example, Niskanen (1971) describes the relationship between a legislature and a bureaucrat as a "bilateral monopoly" game by pointing out that while legislatures have the power of "purse," bureaucrats have the power of "expertise" in carrying out public projects. Sociology literature also makes this point (see Nass (1986)).

[4] See Martimort et. al. (2005).

bureaucrats to make efforts for tasks they are facing. That is, a bureaucrat's loyalty to the public plays a more significant role than a manager's loyalty to the corporate shareholders does. In fact, there are many studies in political science on how bureaucrats make decisions based on non-monetary incentives. Brehm and Gates (1997), for example, conclude that although monetary incentives matter, a bureaucrat's choices are heavily affected by his policy-oriented preferences.

In this paper, we study how to motivate a bureaucrat who is loyal to the public when both the legislature and the bureaucrat play the role of the "principal "at different stages. Specifically, we analyze whether the legislature has to rely on the bureaucrat's loyalty to the public to motivate him and how to use the relevant information regarding the project's value.

We develop a principal-agent framework that incorporates the two critical aspects specific to the public sector mentioned above. First, to incorporate the effect of separation between the legislative and the bureaucratic levels of the government, we allow both the legislature and the bureaucrat to play the role of the "principal "at different stages of the game. In the first stage, the legislature (the principal) offers a menu of transfer payments to the bureaucrat (the agent) to induce him to set up and implement a public project. Once the project is set up, the legislature gathers and aggregates information on the project's value to the public.[5] In the second stage, the bureaucrat (the principal) chooses the potential project sizes to induce the legislature (the agent) to make a truthful report on the aggregated information. Before the transfer payment is made and the project is implemented, the legislature may cancel the project if it expects that the project's net payoff to the public will be negative. Although the legislature is still the Stackelberg leader (since it commits to the transfer to the bureaucrat in the earlier stage), it is the bureaucrat who has the authority to commit to the project size in the later stage.[6]

Second, to incorporate the role of the non-commercial "mission"of the bureaucrat,

[5] As noted by Berg (2018), legislatures, such as city councils, aggregate information from the public before authorizing a project.

[6] In a standard agency model, only one party plays the principal who commits to the entire menu of choices at the outset, and the "selfish" agent's interest is induced to be in line with the principal's. In our model, the bureaucrat also has commitment power, thus becoming the principal in the later stage.

we allow him to have both extrinsic and intrinsic motivation. The standard extrinsic part of the bureaucrat's payoff reflects the difference between the transfer to the bureaucrat and the cost of implementing the project. The intrinsic part reflects the idea that the bureaucrat cares about the public. At the extreme, the bureaucrat can be either fully selfish (does not care about the public at all) or altruistic (fully loyal to the public), and we also consider all the cases in between.

The central message of this paper is as follows. When the bureaucrat is loyal enough, not using all the key information available to the legislature allows it to rely more on the bureaucrat's loyalty to the public, and less on his extrinsic motivation. In other words, by inducing the bureaucrat to make decisions independent of the legislature's acquired information, the legislature can take greater advantage of his loyalty.

As mentioned above, in the first stage, the legislature (whose objective is to maximize the public's welfare) uses the bureaucrat to set up and implement the project by committing to pay him an amount that is related to the project's potential value. After the project setup, the legislature gathers information on the project's value to the public. In the second stage, the bureaucrat commits to the project size contingent on the project value and presents it to the legislature. If the legislature decides not to cancel the project, a report on the gathered information is made to the bureaucrat.[7] To induce the legislature's truthful report, the bureaucrat makes the project sizes contingent on the transfer payment from the legislature, which is also contingent on the project's value to the public. Therefore, if the transfer payment to the bureaucrat is the same regardless of the project's value, the bureaucrat will not differentiate the project size.

According to our result, when the bureaucrat's loyalty level is high, it is optimal to induce the bureaucrat to make his decision independent of the public's valuation of the project. In our model, the bureaucrat's utility consists of two components—selfishness (extrinsic motivation) and loyalty (intrinsic motivation). Using the information of the public's valuation of the project motivates the bureaucrat's selfish component of his utility. Implementing the project is costly, and therefore the bu-

[7]In the second stage, the revelation principle applies to the bureaucrat's problem and thus it is optimal for him to offer the potential project sizes before the legislature's report.

reaucrat's selfishness wants to choose the project size contingent on the public's valuation by extracting that information. Separating the transfers depending on the public's valuation, therefore, motivates the bureaucrat's selfishness in implementing the project. This, however, crowds out the bureaucrat's loyalty, the component in his utility that drives him to implement the project for the public's welfare. When the bureaucrat is loyal enough, the trade-off favors sacrificing the information of the public's valuation to take advantage of the bureaucrat's loyalty to the public. As a result, the legislature pools the transfer payments to the bureaucrat in such a case, and decreases the payment to the minimum level.

Our result is consistent with the empirical observations. As reported by Geys, et al. (2017), although payments to some top bureaucrats depend on the outcome, such an arrangement is still limited in the public sector. Likewise, Horn (1995) notes that bureaucrats are often paid a fixed salary that appears to be only weakly related to outcome.

The remainder of this paper is organized as follows. The studies related to ours are reviewed in the next section. The model is presented in Section 3. In Section 4, we formally present and discuss our key results. Conclusions and remarks are gathered in Section 5. All proofs are relegated to the Appendix.

2 Literature Review

The following papers are those most closely linked to ours. Prendergast (2003) identifies that when consumers of public goods or services cannot be trusted to report errors in their favor, bureaucrats have an incentive to accede to their demands even when it is not efficient. He shows that such problems can be remedied by giving up on incentive payments to bureaucrats. Besley and Ghatak (2005) also demonstrate a similar result. The authors show that public sector incentives are likely to be lower powered because it specializes in more mission-oriented production. Similar to the results in these papers, our study also demonstrates the optimality of transfer payment that is independent of the service provided by the bureaucrat, but for different reasoning. In our study, the non-incentive payment (the pooling payment) to the bureaucrat is to take advantage of his loyalty to the public.

Other studies that consider incentive problems in the public sector include the following papers.[8] Martimort et al. (2005) discuss the role of adverse selection in public good provision. Prendergast (2007) analyzes the link between contractibility and hiring intrinsically motivated public workers. The author shows that a bureaucrat who is biased against the public may lead to more efficient outcomes, depending on the structure of the bureaucracy. Alesina and Tabellini (2007, 2008) examine under what circumstances politicians should centralize or delegate policy tasks to bureaucrats. A more recent study by Khalil et al. (2013) considers a bureaucrat's motivation and fixed budget in contracting inside a bureaucracy where the bureaucrat plays the principal's role.[9]

Our paper is also related to studies that analyze the conditions under which an organization can take advantage of employees whose motivations are in line with the organization's. Kreps (1997) demonstrates that tasks high in intrinsic motivation often involve a high degree of ambiguity. Gibbons (1998) and Holmstrom and Milgrom (1991) show that intrinsic motivation helps overcome the multi-task problem. Murdock (2002) shows that an organization can gain more from intrinsically motivated workers than extrinsically motivated workers, but workers' intrinsic motivation brings benefits to the organization only in a dynamic setting. Prendergast (2008) argues that intrinsically motivated workers may focus too much on the tasks that interest them, and pay insufficient attention to other tasks that are important to the organization. In our paper, a bureaucrat with higher loyalty is always preferred by the public, and our focus is how the bureaucrat's loyalty can be exploited.

In a principal-agent framework, Makris (2009) and Makris and Siciliani (2013) analyze situations in which the agent acts selflessly in dealing with the principal.[10] Their studies show that the outcome in the optimal contract can be distorted in all directions. The cost of a low-productivity agent is underproduction, while the cost of a high-productivity agent is overproduction.[11] Our study highlights the trade-off

[8]Although our focus in this paper is not analyzing organizational structures of public sectors, there are studies analyzing such issues. See, for example, Tirole (1994), Martimort (1996) and Dixit (1997). See Dixit (2002) for a survey in this line of research.

[9]See also Khalil et al. (2019) for a related study.

[10]For related studies, see also Delfgaauw and Dur (2007, 2008) and Barigozzi and Burani (2016).

[11]In an informed principal model, Shin (2017) shows that the cost of using a loyal agent is that

the principal faces when taking advantage of a loyal agent—utilizing information to fine-tune the operation versus paying the agent less for his service. Also, unlike in these studies, in our paper, the principal and the agent switch their roles over different stages.

There are also studies in psychology and psychological contract theory that treat an agent's loyalty as an endogenous variable. The studies examine the crowding out effect of extrinsic rewards on intrinsic motivations, to point out that extrinsic rewards can undermine intrinsic motivations. Earlier studies include Deci (1975), Deci and Ryan (1985) and Frey (1997) that provide the theoretical foundations for the crowding out effect. Rousseau (1995) and, more recently, Benabou and Tirole (2003, 2016) and James (2005) study similar issues in psychological contract theory. These studies identify the conditions under which an employee's intrinsic motivation declines when he receives an extrinsic reward. Like these studies, our paper also sheds light on managing a loyal agent within an organization, but we treat an agent's loyalty to the customers (or shareholders) as an exogenous parameter. In addition, our result requires that the agent in the earlier stage plays the principal's role in the later stage of the game.

Lastly, it is noteworthy that although we use an adverse selection framework, our result complements the traditional wisdom of the moral hazard model.[12] It is implied in the standard moral hazard model that if the risk-averse agent is loyal, or intrinsically motivated, then the principal can share less risk with the agent by reducing the gap between the payments to him. Sharing less risk with the agent allows the principal to decrease the expected payment to the agent. Thus, when the agent is completely loyal, the principal shares no risk with the agent by making a fixed payment to him independent of the outcome. As explained above, in our model, pooling the payments to the bureaucrat allows the legislature to decrease the payment. However, our paper employs an adverse selection model with risk-neutral players, thus not relying on the risk-sharing mechanism.

the principal may need to exaggerate the organization's potential profitability to motivate the agent.

[12] See Arrow (1970), Holmstrom (1979), and Grossman and Hart (1983), among others.

3 Model

In a two-stage principal-agent framework, we model a public organization with a legislature that maximizes the public's welfare and a bureaucrat who sets up and implements a public project. The legislature, representing the public's interest, is the funding authority and decides on the transfer payment to the bureaucrat, and the bureaucrat in turn decides on the size of the project.

The project's value to the public, denoted by v_i, is either v_H (high value) or v_L (low value), and $\Delta v \equiv v_H - v_L > 0$, where $i = H$ with probability $\beta \in (0, 1)$ and $i = L$ with $1 - \beta$. Thus, the expected project value is: $E[v_i] \equiv \beta v_H + (1 - \beta)v_L$. Information on the project value to the public, $i \in \{H, L\}$, is gathered by the legislature, but cannot be directly observed by the bureaucrat. The legislature reports the information it gathered to the bureaucrat. The probability distribution, β, is common knowledge.

In the first stage, the legislature commits to a menu of transfer payments to the bureaucrat, $t_i \geq \underline{t}$, contingent on the legislature's report on the project value $i \in \{H, L\}$, where $\underline{t}$ is the minimum possible amount to be paid. To exaggerate our intuition, we let $\underline{t} = 0$.[13] After t_i is offered, the bureaucrat decides whether or not to participate in the project.

In the second stage, once the bureaucrat sets up the project, the legislature gathers information from the public about the project value $i \in \{H, L\}$. The bureaucrat then commits to a menu of project sizes, $x_i \in \mathbb{R}_+$, contingent on the legislature's announcement on $i \in \{H, L\}$, and presents it to the legislature. The legislature then decides whether to go forward with or cancel the project. If the project is not canceled, the legislature makes an announcement on the project value.

The legislature and the bureaucrat both play the role of the principal and the agent alternately over two stages. In the first stage, the legislature as the principal commits to the transfer payments to the bureaucrat to induce him to set up the project. In the second stage, the bureaucrat as the principal commits to the project sizes to induce the legislature to move forward with the project and to provide a truthful report on the project value. When the legislature chooses t_i in the first stage, it anticipates that the bureaucrat's choice of x_i in the second stage will be his

[13] Our qualitative results hold for $\underline{t}$ not too large.

best-response to the legislature's choice.

The public's gross gain from the project is given by a function $\gamma(x_i, v_i)$, where $\gamma_x > 0$, $\gamma_v > 0$, $\gamma_{xv} > 0$ and $\gamma(0, v_i) = 0$. We let $\gamma(x_i, v_i) \equiv v_i x_i$ for simplicity. The public's ex post payoff is:

$$\pi(x_i, t_i, v_i) = v_i x_i - t_i,$$

since the transfer to the bureaucrat comes from the public's tax payment for the project.

The bureaucrat's cost of implementing the project is given by $c(x_i)$, where $c_x > 0$, $c_{xx} > 0$ and $c(0) = 0$. We let $c(x_i) \equiv x_i^2/2$. The bureaucrat can be someone fully selfish, fully loyal to the public, or somewhere in between. His loyalty level to the public is represented by a parameter $\lambda \in [0, 1]$, where $\lambda = 0$ ($\lambda = 1$) means the bureaucrat is fully selfish (loyal). The bureaucrat's payoff is:

$$u(x_i, t_i, \lambda, \pi) = \underbrace{t_i - x_i^2/2}_{\text{extrinsic payoff}} + \underbrace{\lambda \pi(x_i, t_i, v_i)}_{\text{intrinsic payoff}}.$$

When $\lambda = 0$, the bureaucrat does not care about the public. When $\lambda = 1$, the bureaucrat cares about the public's payoff as much as his own extrinsic payoff.

To make our point, we focus on cases where λ is large enough throughout this paper.[14] More specifically, we assume that the following condition is satisfied.

Condition 1 $\lambda \geq \overline{\lambda}$, *where* $\overline{\lambda} \equiv 2\beta v_L \Delta v / \left[E(v_i)^2 - 2\left(\beta \Delta v\right)^2\right] < 1$.

The timing of the game is summarized as follows:

The First Stage

- The legislature commits to the transfer payments t_i to the bureaucrat.
- The bureaucrat decides whether or not to participate in the project.
- If the bureaucrat participates in and sets up the project, the legislature gathers information on the project value, $i \in \{H, L\}$.

[14]We provide a comprehensive analysis for the entire range of λ as well in Appendix.

The Second Stage

- The bureaucrat commits to the project sizes, x_i, and presents them to the legislature.
- The legislature decides whether to go forward with or cancel the project.
- If the project is not canceled, the legislature makes a report on $i \in \{H, L\}$ to the bureaucrat.
- The transfer payment is made, and the project is implemented.

If the bureaucrat chooses not to participate in the project in the first stage, or the legislature cancels the project in the second stage, then all parties end up with their reservation payoffs, normalized to zero.

In the following section, we move on to analyze the problem to characterize and discuss the outcome in equilibrium—the legislature's transfer payments to the bureaucrat, and the bureaucrat's best response to the legislature's choice.

4 Results and Discussion

We lay out the problems faced by each player in the sequential game. In light of backward induction, we first present the bureaucrat's problem in the second stage, followed by the legislature's problem in the first stage. Note again that the principal-agent relationship between the legislature and the bureaucrat is alternated over the stages.

The Bureaucrat's Problem

Since the revelation principle applies to the bureaucrat's problem, the project sizes, x_i, chosen by the bureaucrat (given t_i set by the legislature in the first stage) must satisfy the following incentive constraints for the legislature's truthful report on the project value:

$$v_H x_H - t_H \geq v_H x_L - t_L, \tag{IC_H}$$

$$v_L x_L - t_L \geq v_L x_H - t_H. \tag{IC_L}$$

The constraints ensure that the public's payoff is higher when the legislature reports truthfully on the project value is made truthfully, thus preventing the legislature from misreporting the project's true value.

The legislature will cancel the project after its evaluation if the public's payoff is expected to be negative. To avoid cancellation of the project, the project sizes chosen by the bureaucrat must satisfy the following positive-payoff constraints:

$$v_H x_H - t_H \geq 0, \tag{PC_H}$$

$$v_L x_L - t_L \geq 0. \tag{PC_L}$$

The bureaucrat's problem in the second stage, $\mathcal{P}^b$, is the following:

$$\mathcal{P}^b : \max_{x_H, x_L} \ \beta \left[t_H - \frac{x_H^2}{2} + \lambda(v_H x_H - t_H) \right] + (1-\beta) \left[t_L - \frac{x_L^2}{2} + \lambda(v_L x_L - t_L) \right],$$

subject to (IC_i) and (PC_i), $i \in \{H, L\}$, where the objective function is the bureaucrat's expected payoff.

The optimal project sizes in the second stage, denoted by x_i^*, are the bureaucrat's best responses to the legislature's choice of the transfer payments—the project sizes in equilibrium depend on the transfers chosen in the first stage, and thus $x_i^* = x_i^*(t_H, t_L)$, $i \in \{H, L\}$.

In the standard screening models, no pooling outcome arises. In this problem, however, the bureaucrat decides how to respond to the transfer payments offered by the legislature in the earlier period, and hence pooling can be the prevailing outcome. The following lemma presents the bureaucrat's response to equal transfer payments from the legislature.

Proposition 1 *In $\mathcal{P}^b$, $x_H^*(t_H, t_L) = x_L^*(t_H, t_L)$ if $t_H = t_L$.*

Proof. See Appendix A. ■

If the legislature offers the same transfer regardless of project value, the bureaucrat's best response is to pool the project sizes. In such a case, the legislature does not fully utilize its valuable information for the public project since the size of the project is independent of its value. Therefore, unless there is a strategic benefit, pooling the potential payments to the bureaucrat simply makes the legislature give up using its valuable information.

In a standard principal-agent model, the agent has an incentive to misrepresent his information only in a certain state ($i \in \{H, L\}$ in our context), thus obtaining a rent only in that certain state. Although the legislature (representing the public) plays the agent's role in the bureaucrat's problem, ultimately the legislature is the Stackelberg leader since it decides on the amount of transfer payments to the bureaucrat in the first stage. In addition, the outcome depends on the bureaucrat's loyalty. Hence, it is possible for the public to obtain a rent regardless of the project's value $i \in \{H, L\}$.

Proposition 2 *Suppose that inducing the legislature's truthful report is an issue in the bureaucrat's problem.*[15] *The public gets a rent when $i = H$, and may or may not get it when $i = L$. If the public gets a rent when $i = L$, the following is true in $\mathcal{P}^b$:*

$$\frac{\partial x_i^*(t_H, t_L)}{\partial t_i} = 0 \text{ if and only if } t_H = t_L.$$

Proof. See Appendix B. ■

If the public obtains a rent in any state of $i \in \{H, L\}$, paying the same amount to the bureaucrat makes the project size insensitive to the amount of the transfer payment. For example, when inducing the legislature's truthful report for $i = H$ is an issue, the project sizes providing a rent to the public in both states of the project's value are:

$$x_H^* = \lambda E[v_i] + (1 - \beta)\frac{t_H - t_L}{v_H} \quad \text{and} \quad x_L^* = \lambda E[v_i] - \beta\frac{t_H - t_L}{v_H}.$$

From the expressions above, if $t_H > t_L$, then $x_H^* > x_L^*$ and x_i^* is increasing in t_i and for any $i \in \{H, L\}$. When the transfers are differentiated, the bureaucrat has more flexibility in inducing the legislature's truthful report. Accordingly, the chosen project size becomes sensitive to the transfer. If, on the other hand, the legislature chooses $t_H = t_L$ in the first stage, then the bureaucrat, who induces the legislature's truthful report by providing a rent to the public regardless of the project's value, will make the project size independent of the transfer: $x_H^* = x_L^* = \lambda E[v_i]$. When the

[15] That is, either (IC_H) or (IC_L) is binding in the bureaucrat's problem.

transfer payments are not differentiated, the bureaucrat has little room to induce the legislature's truthful report. As a result, the chosen project size becomes insensitive to the payment. Thus, with $t_H = t_L$, the legislature relies less on its transfer payment to the bureaucrat, and more on the bureaucrat's loyalty.

Proposition 1 and 2 above lead to the central trade-off faced by the legislature in the first stage. On the one hand, separating the transfer payments to the bureaucrat allows the legislature to fully utilize its information, by fine-tuning the project size according to the realized valuation. On the other hand, pooling the payments induces the loyal bureaucrat to make the project size independent of the transfer payment (in such a case, the project size depends solely on the bureaucrat's loyalty level), which in turn allows the legislature to reduce the payment to the bureaucrat.

The Legislature's Problem

We now move on to the legislature's problem in the first stage. The legislature chooses the transfers, t_H and t_L, rationally anticipating $x_H^*(t_H, t_L)$ and $x_L^*(t_H, t_L)$ in the second stage. The legislature expects that the project sizes chosen by the bureaucrat will bring higher payoff to the public if the legislature reports its evaluation result truthfully.

Also, the legislature's choice of transfer payments to the bureaucrat must induce him to participate in and set up the project. Therefore, the following participation constraint for the bureaucrat must be satisfied in the legislature's problem:

$$E\left[u(x_i^*(t_H, t_L), t_i, \lambda, \pi(x_i^*(t_H, t_L), t_i, v_i))\right]$$
$$= \left\{ \begin{array}{c} \beta\left[t_H - \frac{x_H^*(t_H,t_L)^2}{2} + \lambda\left[v_H x_H^*(t_H, t_L) - t_H\right]\right] + \\ (1-\beta)\left[t_L - \frac{x_L^*(t_H,t_L)^2}{2} + \lambda\left[v_L x_L^*(t_H, t_L) - t_L\right]\right] \end{array} \right\} \geq 0. \qquad (PC)$$

The legislature's problem in the first stage, $\mathcal{P}^l$, is the following:

$$\mathcal{P}^l : \max_{t_H, t_L} \ \beta\left[v_H x_H^*(t_H, t_L) - t_H)\right] + (1-\beta)\left[v_L x_L^*(t_H, t_L) - t_L\right],$$

subject to (PC), where the objective function is the public's expected payoff.

Recall that we are focusing on the parametric value that satisfies Condition 1—the bureaucrat is loyal enough to the public. Combining the legislatures and the bureaucrat's problem, our final result is presented in the following proposition.

Proposition 3 *Suppose Condition 1 holds. Then, in equilibrium* $t_H^* = t_L^* = \underline{t}$ $(= 0)$ *and* $x_H^* = x_L^* = \lambda E[v_i]$.

Proof. See Appendix C. ■

Again, the central trade-off is information versus loyalty, as demonstrated in Proposition 1 and 2. Proposition 3 suggests that, when the bureaucrat is loyal enough to the public, it is optimal to induce him to make his decision independent of the public's valuation of the project. The intuition behind the result is as follows. Since the cost of implementing the project depends on its size, the bureaucrat's selfishness chooses the project sizes such that the public receives a strictly positive rent from the project only when its valuation of the project is high. Thus, the bureaucrat's selfishness is motivated by the benefit from screening the public's valuation of the project, and such a benefit stems from differentiated transfers to him. Put differently, taking advantage of the bureaucrat's selfishness is taking advantage of the acquired information.

The bureaucrat's loyalty to the public, by contrast, drives him to exert a costly effort for implementation with a small transfer payment. Since differentiating transfers (taking advantage of information) motivate the bureaucrat's selfishness, such an arrangement crowds out the bureaucrat's loyalty. Thus, by pooling the transfers, the legislature can take advantage of the bureaucrat's loyalty most effectively. That is, taking advantage of the bureaucrat's loyalty is giving up useful information. When bureaucrat's loyalty level is high enough, the trade-off leans toward sacrificing the useful information—the legislature pools the transfers to the bureaucrat, and reduces it to the minimum level.

5 Conclusion

We analyzed the sequential contracting game between the legislature and the bureaucrat, incorporating two key features in administration of public projects—the bureaucrat's bargaining power due to his expertise and his loyalty to the public. In an early stage of the game, the legislature chooses the transfer payment to the bureaucrat, and in a later stage, the bureaucrat chooses the project size. We have shown that taking advantage of a highly loyal bureaucrat, who is in charge of operation of the project, comes at a cost—loss of information. Exploiting the bureaucrat's loyalty may require the legislature to give up fully utilizing its information about the public's valuation of the project. Our result suggests that, when the bureaucrat's loyalty level is sufficiently high, the legislature may induce pooling the potential outcomes to reduce the payment to the bureaucrat. We assumed in this paper that the legislature gathers information from the public at no cost. An extension to our study for future research, therefore, could be introducing a cost of information gathering, which would lead to an additional incentive problem.

Appendix

Appendix A: Proof of Proposition 1

Combining (IC_H) and (IC_L) in $\mathcal{P}^m$ gives:

$$\frac{t_H - t_L}{v_L} \geqslant x_H - x_L \geqslant \frac{t_H - t_L}{v_H},$$

implying that if $t_H = t_L$, then $0 \geqslant x_H - x_L \geqslant 0$. It follows that $x_H^*(t_H, t_L) = x_L^*(t_H, t_L)$ if $t_H = t_L$. ■

Appendix B: Proof of Proposition 2

We first describe the project sizes $x_H^*(t_H, t_L)$ and $x_L^*(t_H, t_L)$ chosen by the bureaucrat in case $t_H = t_L$. Then we describe the project sizes $x_H^*(t_H, t_L)$ and $x_L^*(t_H, t_L)$ chosen by the bureaucrat in case $t_H > t_L$.

(i) Equal Transfers ($t_H = t_L$): Consider first equal transfers ($t_H = t_L = t$) chosen by the legislature. We proved in Lemma 1 that if $t_H = t_L$, then the bureaucrat will choose equal project sizes, i.e., $x_H = x_L = x$. This implies that the (IC_H) and (IC_L) constraints are automatically satisfied. In addition, the (PC_H) constraint is implied by (PC_L): $v_H x - t > v_L x - t \geqslant 0$. The bureaucrat's optimization problem then simplifies to:

$$\max_x \left\{ t - \beta \frac{x^2}{2} - (1-\beta)\frac{x^2}{2} + \lambda[\beta(v_H x - t) + (1-\beta)(v_L x - t)] \right\},$$

subject to (PC_L): $v_L x - t \geqslant 0$. Labeling μ as the Lagrange multiplier associated with (PC_L) constraint, the optimization problem has the following Lagrangian:

$$\begin{aligned}\mathcal{L} &= t - \beta\frac{x^2}{2} - (1-\beta)\frac{x^2}{2} + \lambda[\beta(v_H x - t) + (1-\beta)(v_L x - t)] + \mu[v_L x - t] \\ &= (1-\lambda)t - \frac{x^2}{2} + \lambda E[v_i]x + \mu[v_L x - t],\end{aligned}$$

which gives the following optimality condition:

$$\frac{\partial \mathcal{L}}{\partial x} = \lambda E[v_i] - x + \mu v_L = 0. \tag{A1}$$

If $\mu > 0$, then the (PC_L) constraint is binding and, as a result, $x^* = t/v_L$. This is the case if $\mu = (x^* - \lambda E[v_i])/v_L > 0$ or, equivalently, if $\lambda < t/(v_L E[v_i])$. If $\mu = 0$, then from $(A1)$ it must be that $x^* = \lambda E[v_i]$. This is the case if (PC_L) is slack, i.e., if $v_L \lambda E[v_i] - t \geqslant 0$, which can be rewritten as $\lambda \geq t/(v_L E[v_i])$.

(ii) **Different Transfers ($t_H \neq t_L$):** Consider next different transfers $(t_H \neq t_L)$ chosen by the legislature. First, (PC_H) is implied by the (IC_H) and (PC_L) since: $v_H > v_L \implies v_H x_L - t_L > v_L x_L - t_L \geqslant 0$. Also, (IC_H) implies $v_H x_H - t_H \geqslant 0$. Thus, (PC_H) is automatically satisfied and can be ignored in the analysis. We will show that, depending on the transfer payments chosen by the legislature, six cases are possible: any two of the three constraints, (PC_L), (IC_H) and (IC_L), may be binding simultaneously, and each of them might be slack. Labeling μ, μ_H and μ_L as the Lagrange multiplier associated with (PC_L), (IC_H) and (IC_L) constraints respectively, the optimization problem has the following Lagrangian:

$$\begin{aligned}\mathcal{L} &= \beta t_H - \beta\frac{x_H^2}{2} + \beta\lambda(v_H x_H - t_H) + (1-\beta)t_L - (1-\beta)\frac{x_L^2}{2} + (1-\beta)\lambda(v_L x_L - t_L) \\ &+ \mu[v_L x_L - t_L] + \mu_H[x_H - x_L - \frac{t_H}{v_H} + \frac{t_L}{v_H}] + \mu_L[\frac{t_H}{v_L} - \frac{t_L}{v_L} - x_H + x_L].\end{aligned}$$

The optimality conditions are:

$$\frac{\partial \mathcal{L}}{\partial x_H} = \beta(\lambda v_H - x_H) + \mu_H - \mu_L = 0, \tag{A2}$$

$$\frac{\partial \mathcal{L}}{\partial x_L} = (1-\beta)(\lambda v_L - x_L) + \mu v_L - \mu_H + \mu_L = 0. \tag{A3}$$

We examine each of six cases below.

Case 1: $\mu_L = \mu = 0$ and $\mu_H > 0$.

Claim 1 *$t_H - t_L > \lambda v_H(v_H - v_L)$, $v_L \lambda E[v_i] \geqslant (1-\beta\frac{v_L}{v_H})t_L + \beta\frac{v_L}{v_H}t_H$ if and only if $\mu_L = \mu = 0$ and $\mu_H > 0$.*

Proof. Suppose$\mu_L = \mu = 0$ and $\mu_H > 0$. Then conditions $(A2)$ and $(A3)$ can be rewritten respectively as:

$$\beta(\lambda v_H - x_H) + \mu_H = 0, \tag{A4}$$

$$(1-\beta)(\lambda v_L - x_L) - \mu_H = 0. \tag{A5}$$

Combining $(A4)$ and $(A5)$ we have $\lambda E[v_i] - \beta x_H - (1-\beta)x_L = 0$. Also, binding (IC_H) implies that $x_H = x_L + (t_H - t_L)/v_H$. Combining the two equation together we have:

$$x_H^*(t_H, t_L) = \lambda E[v_i] + (1-\beta)\frac{t_H - t_L}{v_H} \text{ and } x_L^*(t_H, t_L) = \lambda E[v_i] - \beta\frac{t_H - t_L}{v_H}. \tag{A6}$$

Next, we establish parameters necessary for $\mu_L = \mu = 0 < \mu_H$. From $(A4)$ we have $\mu_H = \beta(x_H - \lambda v_H)$, and form $(A5)$ we have $\mu_H = (1-\beta)(\lambda v_L - x_L)$. Thus, $\mu_H > 0$ is equivalent to $x_L^*(t_H, t_L) < \lambda v_L$ and $x_H^*(t_H, t_L) > \lambda v_H$, which can be rewritten as $t_H - t_L > \lambda v_H(v_H - v_L)$. Condition $\mu = 0$ is equivalent to $v_L x_L^*(t_H, t_L) - t_L \geqslant 0$, which can be rewritten as $v_L \lambda E[v_i] \geqslant (1-\beta\frac{v_L}{v_H})t_L + \beta\frac{v_L}{v_H}t_H$. ■

Case 2: $\mu_L = \mu = \mu_H = 0$.

Claim 2 *$\lambda v_L(v_H - v_L) \leqslant t_H - t_L \leqslant \lambda v_H(v_H - v_L)$ and $t_L \leqslant \lambda v_L^2$ if and only if $\mu_L = \mu = \mu_H = 0$.*

Proof. Suppose $\mu_L = \mu = \mu_H = 0$. Then conditions $(A2)$ and $(A3)$ can be rewritten as:

$$x_H^*(t_H, t_L) = \lambda v_H \text{ and } x_L^*(t_H, t_L) = \lambda v_L.$$

Next, we establish parameters necessary for $\mu_L = \mu = \mu_H = 0$. Condition $\mu = 0$ is equivalent to $t_L \leqslant \lambda v_L^2$. Condition $\mu_L = 0$ is equivalent to $\lambda v_L(v_H - v_L) \leqslant t_H - t_L$. Condition $\mu_H = 0$ is equivalent to $t_H - t_L \leqslant \lambda v_H(v_H - v_L)$. ■

Case 3: $\mu_H = \mu = 0$ and $\mu_L > 0$.

Claim 3 *$t_H - t_L < \lambda v_L(v_H - v_L)$ and $v_L \lambda E[v_i] \geqslant \beta t_H + (1-\beta)t_L$ if and only if $\mu_H = \mu = 0$ and $\mu_L > 0$.*

Proof. Suppose $\mu_H = \mu = 0$ and $\mu_L > 0$. Then conditions $(A2)$ and $(A3)$ are rewritten respectively as:

$$\beta(\lambda v_H - x_H) - \mu_L = 0, \tag{A7}$$

$$(1-\beta)(\lambda v_L - x_L) + \mu_L = 0. \tag{A8}$$

Combining $(A7)$ and $(A8)$ we have $\lambda E[v_i] - \beta x_H - (1-\beta)x_L = 0$. Next, the binding (IC_L) implies $x_H = x_L + (t_H - t_L)/v_L$. Combining the two equations we have:

$$x_H^*(t_H, t_L) = \lambda E[v_i] + (1-\beta)\frac{t_H - t_L}{v_L} \text{ and } x_L^*(t_H, t_L) = \lambda E[v_i] - \beta\frac{t_H - t_L}{v_L}. \tag{A9}$$

Next, we establish parameters necessary for $\mu_H = \mu = 0 < \mu_L$. From $(A7)$ we have $\mu_L = \beta(x_H - \lambda v_H)$, and form $(A8)$ we have $\mu_L = (1-\beta)(\lambda v_L - x_L)$. Thus, $\mu_L > 0$ is equivalent to $x_L^*(t_H, t_L) < \lambda v_L$ and $x_H^*(t_H, t_L) > \lambda v_H$, which can be rewritten as $t_H - t_L < \lambda v_L(v_H - v_L)$. Condition $\mu = 0$ is equivalent to $v_L x_L^*(t_H, t_L) - t_L \geqslant 0$, which can be rewritten as $v_L \lambda E[v_i] \geqslant \beta t_H + (1-\beta)t_L$. ■

Case 4: $\mu_L = 0$, $\mu > 0$ and $\mu_H > 0$.

Claim 4 $\frac{t_H}{v_H} + t_L(\frac{1}{v_L} - \frac{1}{v_H}) > \lambda v_H$ *and* $\beta\frac{t_H}{v_H} + t_L(\frac{1}{v_L} - \frac{\beta}{v_H}) > \lambda E[v_i]$ *if and only if* $\mu_L = 0$, $\mu > 0$ *and* $\mu_H > 0$.

Proof. Suppose $\mu_L = 0$, $\mu > 0$ and $\mu_H > 0$. Then conditions $(A2)$ and $(A3)$ can be rewritten as:

$$\beta(\lambda v_H - x_H) + \mu_H = 0, \tag{A10}$$

$$(1-\beta)(\lambda v_L - x_L) + \mu v_L - \mu_H = 0. \tag{A11}$$

Binding (IC_H) implies $x_H = x_L + (t_H - t_L)/v_H$, and binding (PC_L) implies $x_L = t_L/v_L$. Combining the two equations gives:

$$x_H^*(t_H, t_L) = \frac{t_H}{v_H} + t_L\left(\frac{1}{v_L} - \frac{1}{v_H}\right) \text{ and } x_L^*(t_H, t_L) = \frac{t_L}{v_L}.$$

Next, we establish parameters necessary for $\mu_L = 0$, $\mu > 0$ and $\mu_H > 0$. From $(A10)$ we have $\mu_H = \beta(x_H - \lambda v_H)$, and from $(A11)$ we have $\mu v_L = \mu_H + (1-\beta)(x_L - \lambda v_L)$. Therefore, $\mu_H > 0$ is equivalent to $\frac{t_H}{v_H} + t_L(\frac{1}{v_L} - \frac{1}{v_H}) > \lambda v_H$. Condition $\mu > 0$ is equivalent to $\beta\frac{t_H}{v_H} + t_L(\frac{1}{v_L} - \frac{\beta}{v_H}) > \lambda E[v_i]$. ■

Case 5: $\mu_L = \mu_H = 0$ and $\mu > 0$.

Claim 5 *$t_L > \lambda v_L^2$, $\frac{t_H}{v_H} + t_L(\frac{1}{v_L} - \frac{1}{v_H}) \leqslant \lambda v_H$, $\lambda v_H \leqslant \frac{t_H}{v_L}$ if and only if $\mu_L = \mu_H = 0$ and $\mu > 0$.*

Proof. Suppose $\mu_L = \mu_H = 0 < \mu$. Then conditions $(A2)$ and $(A3)$ can be rewritten as:

$$\beta(\lambda v_H - x_H) = 0, \tag{A12}$$

$$(1-\beta)(\lambda v_L - x_L) + \mu v_L = 0. \tag{A13}$$

Binding (PC_L) implies $x_L = t_L/v_L$. Combining with the $(A12)$ gives:

$$x_H^*(t_H, t_L) = \lambda v_H \text{ and } x_L^*(t_H, t_L) = \frac{t_L}{v_L}.$$

Next, we establish parameters necessary for $\mu_L = \mu_H = 0$ and $\mu > 0$. From $(A13)$ we have $\mu v_L = (1-\beta)(x_L - \lambda v_L)$. Thus, $\mu > 0$ is equivalent to $t_L > \lambda v_L^2$. Conditions $\mu_H = \mu_L = 0$ is equivalent to $\frac{t_H}{v_H} + t_L(\frac{1}{v_L} - \frac{1}{v_H}) \leqslant \lambda v_H$ and $\lambda v_H \leqslant \frac{t_H}{v_L}$. ■

Case 6: $\mu_H = 0$, $\mu_L > 0$ and $\mu > 0$.

Claim 6 *$t_H < \lambda v_L v_H$ and $\lambda v_L E[v_i] < \beta t_H + (1-\beta)t_L$ if and only if $\mu_H = 0$, $\mu_L > 0$ and $\mu > 0$.*

Proof. Suppose $\mu_H = 0$, $\mu_L > 0$ and $\mu > 0$. Then conditions $(A2)$ and $(A3)$ can be rewritten as:

$$\beta(\lambda v_H - x_H) - \mu_L = 0 \tag{A14}$$

$$(1-\beta)(\lambda v_L - x_L) + \mu v_L + \mu_L = 0. \tag{A15}$$

The binding (PC_L) implies $x_L = \frac{t_L}{v_L}$, and the binding (IC_L) implies $x_H = x_L + \frac{(t_H - t_L)}{v_L}$. Combining the two equations together we have:

$$x_H^*(t_H, t_L) = \frac{t_H}{v_L} \text{ and } x_L^*(t_H, t_L) = \frac{t_L}{v_L}.$$

Next, we establish parameters necessary for $\mu_H = 0$, $\mu_L > 0$ and $\mu > 0$. From $(A14)$ we have $\mu_L = \beta(\lambda v_H - x_H)$. Thus, $\mu_L > 0$ is equivalent to $t_H < \lambda v_L v_H$. From $(A15)$ we have $\mu v_L = -(1-\beta)(\lambda v_L - x_L) - \mu_L$. Thus, $\mu > 0$ is equivalent to $\lambda v_L E[v_i] < \beta t_H + (1-\beta)t_L$. ■

Note that only in Cases 1, 3, 4 and 6 either (IC_H) or (IC_L) are binding. Also, (PC_L) is non-binding only in Cases 1 and 3. That is, only relevant cases in which inducing the legislature's truthful report is an issue and the public gets a rent when $i = L$ are Cases 1 and 3. From $(A6)$ and $(A9)$ in the proofs of Claims 1 and 3, $\frac{\partial x_i^*(t_H,t_L)}{\partial t_i} = 0$ if and only if $t_H = t_L$. ■

Appendix C: Proof of Proposition 3

Following the proof of Proposition 2, we will examine the two scenarios (i) when the legislature chooses identical transfers, $t_L = t_H$, and (ii) different transfers, $t_H \neq t_L$, separately. For each of the two cases, we first determine the optimal transfer policy, t_H^* and t_L^*, and the corresponding values of the public's expected payoff. Then, we establish conditions when one transfer policy delivers a higher value of the objective function than the other. Finally, we prove that if $\lambda \geq \overline{\lambda}$, then $t_H^* = t_L^* = 0$ and $x_H^* = x_L^* = \lambda E[v_i]$.

(i) Equal Transfers ($t_H = t_L$): In proving Lemma 2 (Appendix B), we established that if $t_L = t_H = t$, then the bureaucrat chooses the project's size x, where

$$x = \begin{cases} \frac{t}{v_L} & \text{if } \lambda < \frac{t}{v_L E[v_i]}, \\ \lambda E[v_i] & \text{if } \lambda \geqslant \frac{t}{v_L E[v_i]}. \end{cases}$$

The public's expected payoff is then:

$$\left\{ \begin{array}{c} \beta \left[t_H - \frac{x_H^*(t_H,t_L)^2}{2} + \lambda[v_H x_H^*(t_H,t_L) - t_H] \right] + \\ (1-\beta) \left[t_L - \frac{x_L^*(t_H,t_L)^2}{2} + \lambda[v_L x_L^*(t_H,t_L) - t_L] \right] \end{array} \right\} = \begin{cases} \beta(\frac{v_H}{v_L} - 1)t & \text{if } \lambda < \frac{t}{v_L E[v_i]}, \\ \lambda(E[v_i])^2 - t & \text{if } \lambda \geqslant \frac{t}{v_L E[v_i]}. \end{cases}$$

Thus, the bureaucrat's expected payoff becomes:

$$\beta \left[t - \frac{x^2}{2} + \lambda(v_H x - t) \right] + (1-\beta) \left[t - \frac{x^2}{2} + \lambda(v_L x - t) \right]$$
$$= \begin{cases} \left(1 - \lambda + \lambda \frac{E[v_i]}{v_L}\right) t - \frac{t^2}{2v_L^2} & \text{if } \lambda < \frac{t}{v_L E[v_i]}, \\ (1-\lambda)t + \frac{(\lambda E[v_i])^2}{2} & \text{if } \lambda \geqslant \frac{t}{v_L E[v_i]}. \end{cases}$$

The legislature's optimization problem then becomes:

$$\max_t \ t\beta\left(\frac{v_H}{v_L}-1\right)\mathbf{1}_{t\in D_1}+(\lambda E[v_i^2]-t)\mathbf{1}_{t\in D_2}, \text{ where}$$

$$\mathbf{1}_{t\in T}=\begin{cases}1 & \text{if } t\in T,\\ 0 & \text{if } t\notin T,\end{cases}$$

$$D_1\equiv g\{t:\lambda<\frac{t}{v_L E[v_i]},\ \left(1-\lambda+\lambda\frac{E[v_i]}{v_L}\right)t-\frac{t^2}{2v_L^2}\geqslant 0,\ t\geqslant 0\},$$

$$D_2\equiv g\{t:\lambda\geqslant\frac{t}{v_L E[v_i]},\ (1-\lambda)t+\frac{(\lambda E[v_i])^2}{2}\geqslant 0,\ t\geqslant 0\}.$$

Since $D1\cap D2=\varnothing$, we first determine the highest value of the objective function if $t\in D_1$. Then we find the highest value of the objective function if $t\in D_2$. Finally, we compare the two values. We examine each case of $t\in D_1$ and $t\in D_2$ in turn.

Suppose $t\in D_1$. Note tat D_1 is determined by the following inequalities: $t>\lambda v_L E[v_i]$, $t\left[1-\lambda+\lambda E[v_i]/v_L-t/\left(2v_L^2\right)\right]\geqslant 0$ and $t\geqslant 0$. Hence:

$$D_1=\begin{cases}\varnothing & \text{if } \lambda v_L E[v_i]\geqslant 2v_L^2\left(1-\lambda+\lambda\frac{E[v_i]}{v_L}\right),\\ \lambda v_L E[v_i]<t\leqslant 2v_L^2\left(1-\lambda+\lambda\frac{E[v_i]}{v_L}\right) & \text{if } \lambda v_L E[v_i]<2v_L^2\left(1-\lambda+\lambda\frac{E[v_i]}{v_L}\right).\end{cases}$$

Since the objective function is increasing in t for $t\in D_1$, the optimal transfer is given by $t_1^*=2v_L^2(1-\lambda+\lambda E[v_i]/v_L)$, which is relevant if and only if

$$\lambda v_L E[v_i]<2v_L^2(1-\lambda+\lambda E[v_i]/v_L), \tag{A16}$$

or, equivalently, if either

$$\Delta v<\frac{v_L}{\beta} \text{ and } 0\leqslant\lambda<\frac{2v_L}{2v_L-E[v_i]}, \tag{A17}$$

$$\text{or } \Delta v\geq\frac{v_L}{\beta}, \tag{A18}$$

where $(A17)$ and $(A17)$ are derived from solving the inequality in $(A16)$ with respect to λ. The value of the objective function in this case is:

$$2\beta v_L^2\left(1-\lambda+\lambda\frac{E[v_i]}{v_L}\right)\left(\frac{v_H}{v_L}-1\right). \tag{A19}$$

That is, if either $(A17)$ or $(A18)$ holds, then there is a unique optimal transfer chosen by the legislature, $t_1^*=2v_L^2(1-\lambda+\lambda E[v_i]/v_L)$, which yields the expected payoff in $(A19)$.

Suppose now $t \in D_2$. Then clearly the objective function is decreasing in t, so the optimal transfer is $t_2^* = 0$ if

$$\Delta v < \frac{v_L}{\beta} \text{ and } \lambda \geq \frac{2v_L}{2v_L - E[v_i]}. \tag{A20}$$

The value of the objective function is:

$$\lambda (E[v_i])^2. \tag{A21}$$

We now compare the public's expected payoffs in $(A19)$ and $(A21)$. Note that:

$$\lambda E[v_i^2] < 2\beta v_L^2 \left(1 - \lambda + \lambda \frac{E[v_i]}{v_L}\right)\left(\frac{v_H}{v_L} - 1\right), \tag{A22}$$

if and only if either

$$(E[v_i])^2 - 2(\beta\Delta v)^2 \leqslant 0, \text{ or} \tag{A23}$$

$$(E[v_i])^2 - 2(\beta\Delta v)^2 > 0 \text{ and } \lambda < \frac{2\beta v_L \Delta v}{(E[v_i])^2 - 2(\beta\Delta v)^2} \equiv \overline{\lambda}, \tag{A24}$$

where $(A23)$ and $(A24)$ are derived from solving the inequality in $(A22)$ with respect to λ. Therefore, if either $(A23)$ and $(A24)$ holds, then the legislature's optimal transfer payment to the bureaucrat is: $t_1^* = 2v_L^2(1 - \lambda + \lambda E[v_i]/v_L)$.

From $(A20)$and $(A24)$, note that:

$$(E[v_i])^2 - 2(\beta\Delta v)^2 > 0 \Longleftrightarrow \Delta v < \frac{v_L}{(\sqrt{2}-1)\beta},$$
$$\text{where } \frac{v_L}{(\sqrt{2}-1)\beta} > \frac{v_L}{\beta} \text{ for any } \beta.$$

Thus, $t^* = 0$ if $v_L/\beta < \Delta v < v_L/\left[(\sqrt{2}-1)\beta\right]$ and $\lambda \geqslant \overline{\lambda}$, and $t^* = 2v_L^2(1 - \lambda + \lambda E[v_i]/v_L) > 0$ if $\Delta v \geqslant v_L/\left[(\sqrt{2}-1)\beta\right]$.

Finally, it is also optimal to set $t^* = 2v_L^2(1-\lambda+\lambda E[v_i]/v_L) > 0$ if $\Delta v < v_L/\beta$ and $\lambda < \min\{\overline{\lambda},\, 2v_L/\left(2v_L - E[v_i]\right)\}$. Since $\overline{\lambda} < 2v_L/\left(2v_L - E[v_i]\right)$ for all parameters,[16] the last condition simplifies to $\Delta v < v_L/\beta$ and $\lambda < \overline{\lambda}$. Thus, if $\Delta v < v_L/\left[(\sqrt{2}-1)\beta\right]$ and $\lambda \geqslant \overline{\lambda}$, then the optimal transfer is $t^* = 0$, and the corresponding expected payoff to the public is:

$$\pi_A = \lambda(E[v_i])^2.$$

[16] $\frac{2\beta v_L(v_H - v_L)}{(E_i[v_i])^2 - 2\beta^2(v_H - v_L)^2} < \frac{2v_L}{2v_L - E_i[v_i]} \iff (E_i[v_i])^2 - 2\beta^2(v_H - v_L)^2 > \beta(v_H - v_L)[(1+\beta)v_L - \beta v_H] \iff (E_i[v_i])^2 > \beta(v_H - v_L)E_i[v_i] \iff (1-\beta)v_L > -\beta v_L$.

In case either $\Delta v < v_L / \left[(\sqrt{2}-1)\beta\right]$ and $\lambda < \overline{\lambda}$ or $\Delta v \geq v_L / \left[(\sqrt{2}-1)\beta\right]$, then $t^* = 2v_L^2(1-\lambda+\lambda E[v_i]/v_L)$, and the corresponding expected payoff to the public is:

$$\pi_B = 2\beta\Delta v(v_L - \lambda v_L + \lambda E[v_i]).$$

Different Transfers ($t_H \neq t_L$): Since the legislature's optimization problem depends on values of $x_L^*(t_H, t_L)$ and $x_H^*(t_H, t_L)$, we analyze with each of the six cases for $t_H \neq t_L$ in Claim 1 $\sim$ Claim 6 from Appendix B.

Case 1: $\mu_L = \mu = 0$ and $\mu_H > 0$.

The legislature chooses t_H and t_L to maximize:

$$\lambda(E[v_i])^2 - \beta\left[\beta + (1-\beta)\frac{v_L}{v_H}\right]t_H - (1-\beta)\left[1+\beta\left(1-\frac{v_L}{v_H}\right)\right]t_L, \text{ s.t.}$$

$$t_H - t_L > \lambda v_H(v_H - v_L),$$

$$v_L\lambda E[v_i] \geqslant \left(1-\beta\frac{v_L}{v_H}\right)t_L + \beta\frac{v_L}{v_H}t_H,$$

$$\left\{\begin{array}{c} \beta\left[t_H - \frac{\left(\lambda E[v_i]+(1-\beta)\frac{t_H-t_L}{v_H}\right)^2}{2} + \lambda\left(v_H\left(\lambda E[v_i]+(1-\beta)\frac{t_H-t_L}{v_H}\right)-t_H\right)\right] \\ +(1-\beta)\left[t_L - \frac{\left(\lambda E[v_i]-\beta\frac{t_H-t_L}{v_H}\right)^2}{2} + \lambda\left(v_L\left(\lambda E[v_i]-\beta\frac{t_H-t_L}{v_H}\right)-t_L\right)\right] \end{array}\right\} \geq 0,$$

where the last constraint is (PC). Note that the value of the objective function is at most $\lambda(E[v_i])^2 - \beta(\beta + [(1-\beta)v_L/v_H])\varepsilon$, which is achieved if $t_L = 0$ and $t_H = \varepsilon > 0$. This is strictly less than $\pi_B = \lambda(E[v_i])^2$, which is achieved if $t_L = t_H = 0$. Thus, we can disregard Case 1 from the consideration.

Case 2: $\mu_L = \mu = \mu_H = 0$.

The legislature chooses t_H and t_L to maximize:

$$\lambda E[v_i^2] - \beta t_H - (1-\beta)t_L, \text{ s.t.}$$

$$t_L + \lambda v_L(v_H - v_L) \leqslant t_H,$$

$$t_H \leqslant t_L\lambda v_H(v_H - v_L),$$

$$t_L \leqslant \lambda v_L^2,$$

$$(1-\lambda)(\beta t_H + (1-\beta)t_L) + \frac{\lambda E[v_i^2]}{2} \geqslant 0,$$

where the last constraint is (PC). Note that we can ignore the bureaucrat's participation constraint (PC) since it is automatically satisfied. Next, the highest value of the objective function is achieved at:

$$t_L^* = 0 \text{ and } t_H^* = \lambda v_L(v_H - v_L),$$

and the corresponding expected payoff to the public in this case becomes:

$$\pi_D = \lambda(\beta v_H^2 - \beta v_L v_H + v_L^2).$$

Case 3: $\mu_H = \mu = 0$ and $\mu_L > 0$.

The legislature chooses t_H and t_L to maximize:

$$\lambda(E[v_i])^2 - \beta t_H - (1-\beta)t_L + \beta(1-\beta)\left(\frac{v_H}{v_L} - 1\right)(t_H - t_L), \text{ s.t.}$$

$$t_H - t_L < \lambda v_L(v_H - v_L),$$

$$v_L \lambda E[v_i] \geqslant \beta t_H + (1-\beta)t_L,$$

$$(1-\lambda)\left[\beta t_H + (1-\beta)t_L\right] + \lambda\beta(1-\beta)\left(\frac{v_H}{v_L} - 1\right)(t_H - t_L) - \frac{\beta(1-\beta)}{2v_L^2}(t_H - t_L)^2 + \frac{(\lambda E[v_i])^2}{2} \geq 0,$$

where the last constraint is (PC). Note that the objective function is decreasing in t_L and, therefore, $t_L^* = 0$. Next, the objective function is decreasing (increasing) in t_H if $1 - (1-\beta)\left[(v_H/v_L) - 1\right] \geqslant 0$ (< 0) or, equivalently, if $\Delta v \leqslant v_L/(1-\beta)$ $(\Delta v > v_L/(1-\beta))$.

If $\Delta v \leqslant v_L/(1-\beta)$, therefore, the value of the objective function is strictly less than $\lambda(E[v_i])^2$ $(< \pi_B = \lambda(E[v_i])^2)$, which is achieved if $t_L = t_H = 0$. Thus, we can disregard this case from the consideration. If $\Delta v > v_L/(1-\beta)$, then the optimal pricing policy is to set t_H as close to $v_L \lambda E[v_i]/\beta$ as possible, which is Case 2 we considered before. Thus, we can disregard Case 3 from the consideration.

Case 4: $\mu_L = 0$, $\mu > 0$ and $\mu_H > 0$.

The legislature chooses t_H and t_L to maximize:

$$\beta t_L \left(\frac{v_H}{v_L} - 1\right), \text{ s.t.}$$

$$\frac{t_H}{v_H} + t_L\left(\frac{1}{v_L} - \frac{1}{v_H}\right) > \lambda v_H,$$

$$\frac{t_H}{v_H} + t_L\left(\frac{1}{\beta v_L} - \frac{1}{v_H}\right) > \lambda\left[v_H + \frac{(1-\beta)}{\mu}v_L\right],$$

$$\beta t_H + \left(1 + \beta\left[\lambda\left(\frac{v_H}{v_L} - 1\right) - 1\right]\right)t_L - \frac{\beta}{2}\left[\frac{t_H - t_L}{v_H} + \frac{t_L}{v_L}\right]^2 - \frac{(1-\beta)}{2}\left[\frac{t_L}{v_L}\right]^2 \geqslant 0.$$

Consider first a (relaxed) optimization problem of choosing $t_H > t_L$ to maximize function $\beta t_L\left[(v_H/v_L) - 1\right]$ subject to (PC) constraint only. Labeling γ as the Lagrange multiplier associated with the (PC) constraint, the optimization problem has the following Lagrangian:

$$\mathcal{L} = \beta t_L\left(\frac{v_H}{v_L} - 1\right) + .\gamma\left[\begin{array}{c} \beta t_H + \left(1 + \beta\left[\lambda\left(\frac{v_H}{v_L} - 1\right) - 1\right]\right)t_L \\ -\frac{\beta}{2}\left(\frac{t_H - t_L}{v_H} + \frac{t_L}{v_L}\right)^2 - \frac{1-\beta}{2}\left(\frac{t_L}{v_L}\right)^2 \end{array}\right]$$

The optimality conditions are:

$$\frac{\partial\mathcal{L}}{\partial t_H} = \gamma\beta\left[1 - \frac{1}{v_H}\left(\frac{t_H - t_L}{v_H} + \frac{t_L}{v_L}\right)\right] = 0,$$

$$\frac{\partial\mathcal{L}}{\partial t_L} = \beta\left(\frac{v_H}{v_L} - 1\right) + \gamma\left[\begin{array}{c} 1 + \beta\left[\lambda\left(\frac{v_H}{v_L} - 1\right) - 1\right] \\ -\beta\left(\frac{t_H - t_L}{v_H} + \frac{t_L}{v_L}\right)\frac{\Delta v}{v_H v_L} - \frac{1-\beta}{v_L^2}t_L \end{array}\right] = 0.$$

The expression for $\partial\mathcal{L}/\partial t_L = 0$ implies that $\gamma > 0$ and, thus we have:

$$t_H = v_H^2 - t_L\left(\frac{v_H}{v_L} - 1\right). \tag{A25}$$

Binding (PC) implies:

$$\beta t_H + \left(1 + \beta\left[\lambda\left(\frac{v_H}{v_L} - 1\right) - 1\right]\right)t_L - \frac{\beta}{2}\left(\frac{t_H - t_L}{v_H} + \frac{t_L}{v_L}\right)^2 - \frac{1-\beta}{2}\left(\frac{t_L}{v_L}\right)^2 = 0. \tag{A26}$$

Combining $(A25)$ and $(A26)$ together, we have a quadratic equation in t_L:

$$-\frac{1-\beta}{2v_L^2}t_L^2 + \left[1 - \beta - \beta(1-\lambda)\left(\frac{v_H}{v_L} - 1\right)\right]t_L + \frac{\beta v_H^2}{2} = 0,$$

which gives:

$$t_L^* = \frac{v_L - \beta[v_H - \lambda\Delta v] + \sqrt{(v_L - \beta[v_H - \lambda\Delta v])^2 + \beta(1-\beta)v_H^2}}{(1-\beta)/v_L}.$$

Since $t_H^* = v_H^2 - [(v_H/v_L) - 1]\, t_L^*$, this case exists if and only if $v_H^2 - [(v_H/v_L) - 1]\, t_L^* > t_L^*$, or

$$\lambda < \frac{(\Delta v - v_L)}{2\beta \Delta v} \equiv \widehat{\lambda}.$$

Finally, the two constraints we ignored in the relaxed problem are automatically satisfied with t_L^* and t_H^* obtained above. The expected payoff to the public in this case is:

$$\pi_C = \beta \left(\frac{v_H}{v_L} - 1 \right) t_L^*, \qquad (A27)$$

which exists if and only if $\lambda < \widehat{\lambda}$.

Case 5: $\mu_L = \mu_H = 0$ and $\mu > 0$.

The legislature chooses t_H and t_L to maximize:

$$\beta(\lambda v_H^2 - t_H), \text{ s.t.}$$

$$t_L > \lambda v_L^2,$$
$$\frac{t_H}{v_H} + t_L \left(\frac{1}{v_L} - \frac{1}{v_H} \right) \leqslant \lambda v_H,$$
$$t_H \geqslant \lambda v_H v_L,$$
$$\beta \left[t_H - \frac{(\lambda v_H)^2}{2} + \lambda (v_H(\lambda v_H) - t_H) \right] + (1-\beta) \left[t_L - \frac{(t_L/v_L)^2}{2} + \lambda \left(v_L \left(\frac{t_L}{v_L} \right) - t_L \right) \right] \geqslant 0,$$

where the last constraint is (PC). Note that since $t_H \geqslant \lambda v_H v_L$, the value of the objective function is at most $\beta \lambda v_H^2 - \beta \lambda v_H v_L = \beta \lambda (v_H^2 - v_H v_L)$. This is strictly less than $\pi_D = \lambda(\beta v_H^2 - \beta v_L v_H + v_L^2)$ from Case 2. Therefore, we can disregard Case 5 from the consideration.

Case 6: $\mu_H = 0$, $\mu_L > 0$ and $\mu > 0$.

The legislature chooses t_H and t_L to maximize:

$$\beta t_H \left(\frac{v_H}{v_L} - 1 \right), \text{ s.t.}$$

$$t_H < \lambda v_L v_H,$$

$$\lambda v_L E[v_i] < \beta t_H + (1 - \beta) t_L,$$

$$\left\{ \begin{array}{c} \beta \left[t_H - \frac{(t_H/v_L)^2}{2} + \lambda \left(v_H \left(\frac{t_H}{v_L} \right) - t_H \right) \right] + \\ (1-\beta) \left[t_L - \frac{(t_L/v_L)^2}{2} + \lambda \left(v_L \left(\frac{t_L}{v_L} \right) - t_L \right) \right] \end{array} \right\} \geq 0,$$

where the last constraint is (PC). Note that since $t_H < \lambda v_L v_H$, the value of the objective function is at most $\beta\lambda v_H v_L \left[(v_H/v_L) - 1\right] = \beta\lambda(v_H^2 - v_H v_L)$. This is strictly less than $\pi_D = \lambda(\beta v_H^2 - \beta v_L v_H + v_L^2)$ from Case 2. Therefore, we can disregard Case 6 from the consideration.

We have now established conditions when the legislature chooses different transfers ($t_H \neq t_L$) over identical transfer ($t_H = t_L$) in order to maximize the public's expected payoff. The equilibrium value of the public's expected payoff is $\pi = \max\{\pi_A, \pi_B, \pi_C, \pi_D\}$, where:

$$\pi_A = \lambda(E[v_i])^2,$$

$$\pi_B = 2\beta\Delta v(v_L - \lambda v_L + \lambda E[v_i]),$$

$$\pi_C = \beta\Delta v \left[\frac{v_L - \beta[v_H - \lambda\Delta v] + \sqrt{(v_L - \beta[v_H - \lambda\Delta v])^2 + \beta(1-\beta)v_H^2}}{(1-\beta)}\right],$$

$$\pi_D = \lambda(\beta v_H^2 - \beta v_L v_H + v_L^2).$$

The remaining task is to compare the values of π_A, π_B, π_C and π_D and determine conditions when each of them might be higher than the others.

We first compare π_A and π_B when $t_L = t_H$. We established earlier that if $\Delta v < v_L/\left[(\sqrt{2}-1)\beta\right]$ and $\lambda \geqslant \overline{\lambda}$, then $\pi_A > \pi_B$. In case either $\Delta v < v_L/\left[(\sqrt{2}-1)\beta\right]$ and $\lambda < \overline{\lambda}$, or $\Delta v \geq v_L/\left[(\sqrt{2}-1)\beta\right]$, then $\pi_A \leqslant \pi_B$. For $\overline{\lambda}$ to be positive, however, $\Delta v < v_L/\left[(\sqrt{2}-1)\beta\right]$ must hold. Thus, if $\Delta v \geq v_L/\left[(\sqrt{2}-1)\beta\right]$, then $\overline{\lambda} \leq 0$, which in turn implies that $\pi_A \geq \pi_B$ for any λ (at $\Delta v = v_L/\left[(\sqrt{2}-1)\beta\right]$, $\pi_A = \pi_B$).

We next compare π_C and π_D when $t_L \neq t_H$. First we define:

$$\widetilde{\lambda} \equiv \frac{2\beta v_L \Delta v}{\beta(1-2\beta)v_H^2 + \beta(4\beta-1)v_L v_H + v_L^2(1-2\beta^2)}$$

Next, $\pi_D > \pi_C$ is explicitly expressed as:

$$\begin{aligned}&\lambda(\beta v_H^2 - \beta v_L v_H + v_L^2) \\ &> \beta\Delta v \left[\frac{v_L - \beta[v_H - \lambda\Delta v] + \sqrt{(v_L - \beta[v_H - \lambda\Delta v])^2 + \beta(1-\beta)v_H^2}}{(1-\beta)}\right],\end{aligned} \tag{A28}$$

which is simplified as:

$$\lambda > \widetilde{\lambda}.$$

Recall from $(A27)$ that the public's expected payoff is π_C and it exists if and only if $\lambda < \widehat{\lambda}$. Therefore:

$$\lambda < \min\{\widehat{\lambda},\ \widetilde{\lambda}\} \Longrightarrow \pi_C > \pi_D.$$

Finally, we compare $\max\{\pi_A, \pi_B\}$ and $\max\{\pi_C, \pi_D\}$ to find the highest value of the public's expected payoff. That $\pi_D > \pi_A$ is explicitly written as:

$$\lambda(\beta v_H^2 - \beta v_L v_H + v_L^2) > \lambda(E[v_i])^2,$$

which is simplified to:

$$v_H > \frac{2-\beta}{1-\beta} v_L. \tag{A29}$$

Thus, $\pi_D > \pi_A$ if and only if $(A29)$ holds. Next, $\pi_D > \pi_B$ is explicitly expressed as:

$$\lambda(\beta v_H^2 - \beta v_L v_H + v_L^2) > 2\beta\Delta v(v_L - \lambda v_L + \lambda E[v_i]),$$

which can be rewritten as:

$$\Phi > 2\beta v_L \Delta v,$$

where $\Phi \equiv \beta(1-2\beta)v_H^2 + \beta(4\beta - 1)v_L v_H + v_L^2(1-2\beta^2)$. Thus, $\pi_B > \pi_D$ if and only if either :

$$\Phi < 0, \text{ or } \Phi > 0 \text{ and } \lambda < \widetilde{\lambda}.$$

Solving $\Phi < 0$ in v_H, the conditions can be rewritten as follows: $\pi_B > \pi_D$ if and only if either:

$$\beta > \frac{1}{2} \text{ and } \Delta v > \widetilde{v}_L,$$

$$\beta < \frac{1}{2} \text{ and } \lambda < \widetilde{\lambda},$$

$$\text{or } \beta > \frac{1}{2},\ \Delta v < \widetilde{v}_L \text{ and } \lambda < \widetilde{\lambda},$$

where $\widetilde{v}_L \equiv \left[\beta(4\beta-1) + \sqrt{\beta(9\beta-4)} - 2\beta(2\beta-1)v_L\right] / \left[2\beta(2\beta-1)\right]$. We now consider π_C and π_B. That $\pi_C > \pi_B$ is written explicitly as:

$$\beta\Delta v \left[\frac{v_L - \beta[v_H - \lambda\Delta v] + \sqrt{(v_L - \beta[v_H - \lambda\Delta v])^2 + \beta(1-\beta)v_H^2}}{(1-\beta)}\right]$$
$$> 2\beta\Delta v(v_L - \lambda v_L + \lambda E[v_i]),$$

which is simplified as:

$$[2\beta\lambda\Delta v + (\Delta v - 2v_L)]^2 > 0,$$

and this inequality holds for all parameters. Since the relevant set of parameters (when $\pi_C > \pi_B$) for which we consider π_C is when $\lambda < \widehat{\lambda}$, we have $\pi_C > \pi_B$ if and only if $\lambda < \widehat{\lambda}$. Lastly, we consider π_C and π_D. Note that $\pi_C > \pi_D$ if and only if:

$$\beta\Delta v \left[\frac{v_L - \beta[v_H - \lambda\Delta v] + \sqrt{(v_L - \beta[v_H - \lambda\Delta v])^2 + \beta(1-\beta)v_H^2}}{(1-\beta)} \right] > \lambda(\beta v_H^2 - \beta v_L v_H + v_L^2),$$

$\beta < \frac{1}{2}$ and $\lambda < \overline{\lambda}$.

To sum up, we established that:

- $\pi_A > \max\{\pi_B, \pi_C, \pi_D\}$ if and only if $\lambda > \overline{\lambda}$.

- $\pi_B > \max\{\pi_A, \pi_C, \pi_D\}$ if and only if either $\beta \geqslant \frac{1}{2}$ and $\overline{\lambda} \leqslant \lambda < \widehat{\lambda}$, or $\beta < \frac{1}{2}$ and $\lambda < \min\{\overline{\lambda}, \widetilde{\lambda}\}$.

- $\pi_C > \max\{\pi_A, \pi_B, \pi_D\}$ if and only if either $\beta \geqslant \frac{1}{2}$ and $\lambda < \widehat{\lambda}$, or $\beta < \frac{1}{2}$ and $\lambda < \min\{\widehat{\lambda}, \widetilde{\lambda}\}$.

- $\pi_D > \max\{\pi_A, \pi_B, \pi_C\}$ if and only if $\beta < \frac{1}{2}$ and $\max\{\widehat{\lambda}, \widetilde{\lambda}\} \leqslant \lambda < \overline{\lambda}$.

Therefore, if $\lambda \geq \overline{\lambda}$, then $t_H^* = t_L^* = 0$ and $x_H^* = x_L^* = \lambda E[v_i]$. This concludes the proof of Proposition 3. ■

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