Regulating a manager whose empire-building preferences are private information*

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Abstract. We determine the optimal contract for the government (principal) to regulate a manager (agent) who has a taste for empire-building that is her private information. We find that output is distorted upward when the manager's taste for running large firms is weak, downward when it is strong, and equals a reference output when it is intermediate (in this case, the participation constraint is binding). We also determine an endogenous reference output (equal to the expected output, which depends on the reference output), and find that the response of output to cost is null in the short-run (in which the reference output is fixed), whenever the manager's type is in the intermediate range, and negative in the long-run (after the adjustment of the reference output to equal expected output).

Keywords: Procurement, Regulation, Adverse selection, Empire-building, Reservation utility.

JEL Classification Numbers: D82, H42, H51, I11.

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1 Introduction

Behavior of managers within firms is more complex than profit maximization.[1] Its immediate determinants include: salary, security, status, power, prestige, social service and professional excellence (Niskanen, 1971; Brehm and Gates, 1997; Prendergast, 2007). An observed willingness to manage a firm without significant monetary incentives should be attributed to these non-monetary factors (Wilson, 1989).

The motivations of managers were synthesized and formalized by Williamson (1974), who concluded that, in addition to a preference for profit, managers also display a preference for expenses in staff and emoluments. Such preference for expenditure may accentuate the business cycle, by inducing a systematic accumulation of staff and emoluments during prosperity, with divestment frequently becoming necessary during adversity.

The empire-building motive is well documented (Donaldson, 1984), and has been emphasized by Jensen (1986, 1993) as an origin of excess investment and output: "*Managers have incentives to cause their firms to grow beyond the optimal size. Growth increases managers' power by increasing the resources under their control.*"

But this tendency of managers towards empire-building has not been accounted for in the standard theory of regulation under asymmetric information (Baron and Myerson, 1982; Guesnerie and Laffont, 1984; Maskin and Riley, 1984; Laffont and Tirole, 1986). There, it is assumed that the managers' objective is the maximization of the monetary transfers that they receive, net of the monetary value of the effort that they exert. We believe that extending the theory of regulation to incorporate the empire-building bias of managers will have a positive effect on the design of procurement contracts. Recently, Borges and Correia-da-Silva (2011) contributed in this direction, by extending the model of Laffont and Tirole (1986) to allow the manager of the firm to have a tendency for empire-building, modeled as a preference for high output.[2]

[1] Empirical evidence of deviations from profit-maximization was provided by Chetty and Saez (2005) and by Brown, Liang and Weisbenner (2007), who studied the response of corporations to the 2003 dividend tax cut in the USA.

[2] The preference for high output is equivalent to the preference for staff considered by Williamson (1974).

The intrinsic difficulty in the observation of managers' preferences motivates us to pursue this line of research by studying the case in which the empire-building preference of the manager is unobservable by the government. In this paper, we consider a model in which the government (principal) offers a contract to the manager of a firm (agent) that has an unobservable preference for high output.[3] The model can be straightforwardly adapted to deal with the case of owners of a firm offering a contract to the manager of the firm.

We model the preference for empire-building as a utility premium that is proportional to the difference between the contracted output and a reference output (it will actually be a utility penalty whenever the contracted output is lower than the reference output). The immediate effect of this bias is that the manager becomes willing to accept a lower payment if the contracted output is relatively high, and will demand a greater payment if it is relatively low. The government will, then, contract a higher output if the manager has a strong preference for empire-building and a lower output if this preference is weak.

An increase in the manager's preference for empire-building may lead to an increase or a decrease in the manager's attainable utility, depending on whether the contracted output is higher or lower than the reference output. This implies that the informational rent may not be monotonic (Jullien, 2000; Laffont and Martimort, 2002)[4] and, therefore, interior types may have a null rent or be excluded from trade. What we find is that output is distorted above the perfect information level when the preference for output is weak and above it when it is strong. For intermediate values of the preference for output, output equals its reference level. The participation constraint is actually binding for these intermediate types, while the lower and higher types benefit from informational rents.

The reference output should be seen as a typical output level, that the manager associates with neither a utility premium nor a utility penalty. It may be natural to keep the reference output fixed when we estimate the short-run effects of an exogenous shock. But it is equally natural to consider an endogenous reference output, which may change in response to exogenous shocks, especially if we are interested in estimating the long-run effects of

[3]More precisely, the government offers an incentive compatible set of contracts, one for each possible type of manager.

[4]The informational rent coincides with the manager's attainable utility, because in the case of perfect information the manager's attainable utility is null (the participation constraint is binding).

these shocks. We do this by making the reference output equal to the expected output of the firm with respect to the probability distribution of manager's types (notice that this expected value depends on the reference output itself).

The consideration of an endogenous reference output is useful to improve our understanding of the response of output to a change in the production cost. For example, if we suppose that the manager's type is in the "intermediate" range (over which the participation constraint is binding), we find that: in the short-run (in which the reference output is fixed), output does not respond to small variations in cost; while in the long-run (after the adjustment of the reference output to equal the expected output), the sensitivity of output to cost becomes negative.

Of course that we are not the first to investigate the effects of deviations from profit-maximizing behavior. The early managerial discretion models (Baumol, 1959; Marris, 1963; Williamson, 1974) aimed to investigate the implications of various hypotheses concerning the objective functions of managers, explicitly recognizing that these may not coincide with profit-maximization. Baumol (1959) argued that some firms maximize sales subject to a profit constraint, thus producing more than if they operated as profit-maximizers. These firms respond to external shocks in a very different way. For example, if there is an increase in fixed costs or if a lump-sum tax is imposed, a firm whose managers have a preference for staff will reduce its output, staff employment and other perquisites.

A recent strand of literature is taking into account the preference of managers for empire-building.[5] The focus in this literature has been to develop models of financial structure based on the desire to curb management's empire-building tendencies, assuming that firms are owned by shareholders who don't observe cash-flows or investment decisions. The empire-building bias is typically incorporated by assuming managerial private benefits of control (Grossman and Hart, 1988) that are either proportional to investment (Hart and Moore, 1995) or to the gross output from investment (Stulz, 1990).

It is worthwhile to compare our results with those of the early managerial discretion models and of the models of optimal financial structure. Our result that output is an increasing

[5] See, for example, the works of Stulz (1990), Hart and Moore (1995), Harris and Raviv (1996), Li and Li (1996), Zwiebel (1996), Arya, Baldenius and Glover (1999) and Kanniainen (2000).

function of the manager's preference for output is in line with managerial discretion theory, but results from a quite different mechanism. Instead of being the straightforward implication of managerial discretion over output, it follows from the manager's participation constraint: a larger output yields a larger utility to the manager who, then, becomes willing to accept a lower monetary transfer. Our result differs, however, from those in the literature on optimal financial structure, where empire-building tendencies do not necessarily lead to an empirical prediction of overinvestment (or overproduction) on average.[6] Relatively to the sensitivity of output to cost, we find that, unlike what is predicted by managerial discretion models, increases in marginal cost have no effect on output (as long as the reference output is kept fixed).

The paper is organized as follows. Section 2 describes the model and section 3 analyzes the benchmark case of complete information. In section 4, we derive the optimal incentive scheme and provide the general results. Section 5 presents an illustration for quadratic social value functions and an uniform distribution over types (with an exogenous reference output and with an endogenous reference output). Finally, Section 6 offers some concluding remarks.

2 The model

We consider a model of procurement in which the government (principal) delegates to a firm (agent) the provision of a public good. The manager of the firm cares about profit, t, but also about the output level, q. The manager's utility function is:

$$U = t + \delta \left(q - q_{ref} \right),$$

where δ, the marginal utility of output to the manager, is a private information parameter, drawn according to a probability distribution over an interval $\left[\underline{\delta}, \overline{\delta}\right]$, with strictly positive density, $f(\delta) > 0$, and monotone hazard rates, $\frac{d}{d\delta}\left[\frac{f(\delta)}{1-F(\delta)}\right] > 0$ and $\frac{d}{d\delta}\left[\frac{f(\delta)}{F(\delta)}\right] < 0$ (where $F(\delta)$ denotes the cumulative distribution function). The reference output, q_{ref}, may be

[6] These models predict overinvestment when the free cash-flow is higher than expected, and underinvestment when it is lower.

interpreted as a "normal" output, such that producing this output neither implies a utility increase nor a utility penalty.[7]

The manager accepts to participate if and only if $U(\delta) \geq 0,\ \forall \delta \in \left[\underline{\delta}, \overline{\delta}\right]$.

The production cost is $C = \beta q$, where the marginal cost, $\beta > 0$, is observable by the government. The social value of output is $S(q)$, with marginal social value being strictly positive and decreasing, $S'(q) > 0$ and $S''(q) < 0$, for any $q \in [0, \overline{q})$. We also set $S(0) = 0$ and $S'(\overline{q}) = 0$ (where $\overline{q}$ can be interpreted as fully covering the needs of the population).

The government finances the public good provision using a distortionary mechanism (taxes, for example), so that the social cost of raising one unit of money is $1 + \lambda$, with $\lambda > 0$. The welfare of consumers is the difference between the social value of the public good and the cost of financing its provision, $S(q) - (1 + \lambda)(t + C)$. In the model of Laffont and Tirole (1986, 1993) and, more generally, in the regulation literature, the government is assumed to maximize the sum of the consumers' welfare with the utility of the firm. With the incorporation of an empire-building tendency, it becomes natural to consider two possibilities:

(i) social welfare, $W(\delta)$, is the sum of the consumer's welfare with the utility of the firm (this case corresponds to setting $k = 0$, below);

(ii) social welfare, $W(\delta)$, is the sum of the consumer's welfare with the profit of the firm, while the empire-building component of the manager's utility is excluded (corresponds to setting $k = 1$, below).

We also allow for intermediate cases (any $k \in (0, 1)$, below).

The problem of the government (maximization of expected social welfare) is:

$$\max_{q,t} \int_{\underline{\delta}}^{\overline{\delta}} \left[S(q) - (1 + \lambda)(t + C) + U - k\delta(q - q_{ref})\right] f(\delta)\, d\delta \tag{1}$$

subject to

$$U \geq 0. \tag{2}$$

[7] In Section 5.2, we propose an endogenous determination of this reference level of output.

3 The case of complete information

As a benchmark, we study the case in which there is no asymmetry of information between the government and the firm (the government is able to observe δ).

The problem of the government can be written as:

$$\max_{q,U} \{S(q) - (1+\lambda)\beta q - \lambda U + (1+\lambda-k)\,\delta\,(q - q_{ref})\} \tag{3}$$

subject to

$$U \geq 0.$$

We make the following assumptions for the problem to be well-behaved.

Assumption 1.

(i) $\lambda > 0$;

(ii) $\forall q \in [0, \overline{q})\,,\ S''(q) < 0$;

(iii) $S'(0) > (1+\lambda)(\beta - \underline{\delta}) + k\underline{\delta}$;

(iv) $\beta > \frac{1+\lambda-k}{1+\lambda}\overline{\delta}$.

Assumption *(i)* guarantees that the participation constraint is binding, *(ii)* ensures that the second order condition is satisfied, *(iii)* ensures a positive output level, and *(iv)* is necessary for the equilibrium output to be lower than $\overline{q}$.

With $\lambda > 0$, the objective function is strictly decreasing in U, therefore the participation constraint is binding. We can replace $U = 0$ in the objective function and then solve for q. The corresponding first-order condition is:

$$S'(q) = (1+\lambda)(\beta - \delta) + k\delta. \tag{4}$$

And the second order condition is: $S''(q) < 0$.

Since the participation constraint is binding, $U_c^*(\delta) = 0$ and the net transfer is:

$$t_c^*(\delta) = \delta \left[q_{ref} - q_c^*(\delta) \right].$$

Observe that the net transfer, t_c^*, is positive (negative) if and only if the optimal output, q_c^*, is lower (higher) than the reference output, q_{ref}.

The optimality condition (4) equates the marginal benefit of output to consumers, $S'(q)$, and the social marginal cost. Using this condition, the optimal output level, q_c^*, can be determined. It is clear that when the regulator cares about the non-monetary component of the manager's utility ($k = 0$), the level of output is higher and the net monetary transfer is lower than when she does not care ($k = 1$). Observe also that the optimal output level is an increasing function of the preference for output parameter, even when the regulator does not care at all about the utility that the manager derives from output ($k = 1$). This occurs because increasing the output implies an increase in the non-monetary component of the manager's utility, decreasing, therefore, the monetary transfer which is necessary to induce participation.

We also find that the social welfare is increasing (decreasing) with the intensity of the empire-building preference, δ, if and only if the optimal output, q_c^*, is higher (lower) than the reference output, q_{ref}. Applying the Envelope Theorem:

$$\frac{dW_c^*}{d\delta} = \frac{\partial W_c^*}{\partial \delta} = (1 + \lambda - k) \left(q_c^* - q_{ref} \right).$$

Since q_c^* is increasing in δ, we conclude that social welfare, W_c^*, is a convex function of δ:

$$\frac{d^2 W_c^*}{d\delta^2} > 0.$$

In the following section, we determine the optimal procurement contract in the presence of an unobservable empire-building tendency.

4 The optimal incentive scheme

In the asymmetric information case, the government does not know the manager's marginal utility of output, δ. At the moment of contracting, the government only knows the prior probability distribution of δ.

Thanks to the Revelation Principle, we can restrict (without loss of generality) our attention to incentive compatible direct revelation mechanisms.[8]

The timing of the game is the following:

(1) nature chooses the preference for output of the manager, $\delta \in \left[\underline{\delta}, \overline{\delta}\right]$;

(2) the government offers a contract to the manager, $[q(\tilde{\delta}), t(\tilde{\delta}]$, specifying a level of output and a net payment that depend on the preference for output that is to be announced by the manager, $\tilde{\delta}$;

(3) the manager either accepts the contract, announces a type, $\tilde{\delta}$, produces $q(\tilde{\delta})$ and receives the net transfer $t(\tilde{\delta})$ or rejects the contract and receives a null payoff.

In this section we will consider that if the manager rejects the contract, the government receives a large negative payoff. The government is, therefore, forced to participate.[9]

4.1 The firms's optimization problem

The government offers a contract to the manager such that she receives a net transfer $t(\tilde{\delta})$ when she produces the output level $q(\tilde{\delta})$, and has to pay an extreme penalty, $t(\tilde{\delta}) = -\infty$, if she produces an output level that is different from $q(\tilde{\delta})$.

[8] By the revelation principle (Myerson, 1979), given a Bayesian Nash equilibrium of a game of incomplete information, there exists a direct mechanism that has an equivalent equilibrium where the players truthfully report their types. A direct-revelation mechanism is said to be incentive compatible if, when each individual is expecting the others to be truthful, then he has interest in being truthful.

[9] In the light of Proposition 5, it will be clear that the government obtains a positive payoff for all types $\delta \in \left[\underline{\delta}, \overline{\delta}\right]$ if and only if the parameter q_{ref} is below a certain threshold.

For any $\delta \in \left[\underline{\delta}, \overline{\delta}\right]$, truthful revelation must maximize the utility of the firm:

$$\delta \in arg \max_{\tilde{\delta} \in \left[\underline{\delta}, \overline{\delta}\right]} \left\{ t(\tilde{\delta}) + \delta \left[q(\tilde{\delta}) - q_{ref} \right] \right\}. \tag{5}$$

Let $V(\delta)$ be the firm's value function (attainable utility as a function of δ):

$$V(\delta) = \max_{\tilde{\delta} \in \left[\underline{\delta}, \overline{\delta}\right]} \left\{ t(\tilde{\delta}) + \delta \left[q(\tilde{\delta}) - q_{ref} \right] \right\} = t(\delta) + \delta \left[q(\delta) - q_{ref} \right].$$

If announcing $\tilde{\delta} \neq \delta$ is not optimal (5), then the output, transfer and value functions are almost everywhere differentiable (see Appendix A.1).

From the Envelope Theorem, we obtain the first-order incentive compatibility constraint:

$$V'(\delta) = q(\delta) - q_{ref}, \tag{6}$$

which tells us that the derivative of the value function with respect to δ is equal to the output level.

Integrating, we obtain:

$$V(\delta) = V(\underline{\delta}) + \int_{\underline{\delta}}^{\delta} q(\gamma) d\gamma - \left(\delta - \underline{\delta}\right) q_{ref}. \tag{7}$$

The second incentive compatibility constraint is derived from the second order condition of utility maximization (see Appendix A.2):[10]

$$q'(\delta) \geq 0, \ \forall \delta \in \left[\underline{\delta}, \overline{\delta}\right]. \tag{8}$$

It implies that the output level is increasing with the manager's preference for output.

[10]In Appendix A.3 we show that the first and second incentive compatibility constraints, (6) and (8), are equivalent to truth-telling (5).

4.2 The government's optimization problem

The objective of the government is to maximize expected social welfare, $E_\delta\left[W(\delta)\right]$:

$$\max_{q(\delta),V(\delta)} \int_{\underline{\delta}}^{\overline{\delta}} \left\{S\left[q(\delta)\right] - (1+\lambda)\beta q(\delta) - \lambda V(\delta) + (1+\lambda-k)\,\delta\left[q(\delta) - q_{ref}\right]\right\} f(\delta)\; d\delta, \tag{9}$$

subject to, for all $\delta \in \left[\underline{\delta}, \overline{\delta}\right]$,

$$V(\delta) \geq 0, \tag{10}$$

$$V'(\delta) = q(\delta) - q_{ref},$$

$$q'(\delta) \geq 0.$$

We start by solving a relaxed problem in which condition (8) is ignored. Later, we will check that the solution of this relaxed problem is the solution of the general problem (Appendix B.2).

Incorporating the participation constraint in the objective function, the problem becomes:[11]

$$\max_{q(\delta),V(\delta)} \int_{\underline{\delta}}^{\overline{\delta}} \left\{S\left[q(\delta)\right] - (1+\lambda)\beta q(\delta) - \lambda V(\delta) + (1+\lambda-k)\delta\left[q(\delta) - q_{ref}\right]\right\} f(\delta) + $$
$$+\eta(\delta)\lambda V(\delta)\; d\delta, \tag{11}$$

subject to, for all δ,

$$V'(\delta) = q(\delta) - q_{ref},$$

where $\eta(\delta)$ satisfies $\eta(\delta) \geq 0$ and $\eta(\delta)\lambda V(\delta) = 0$. Notice that $\eta(\delta)\lambda$ is the Lagrangian multiplier associated to the participation constraint of type δ.[12]

We define $\zeta(\delta) = \int_{\underline{\delta}}^{\delta} \eta(s)ds$. It is shown in the proof of Proposition 1 that η is a probability distribution on $\left[\underline{\delta}, \overline{\delta}\right]$, and that, therefore, $\zeta(\delta)$ is a c.d.f. on $\left[\underline{\delta}, \overline{\delta}\right]$.

[11] See Basov (2005), pages 124-126.

[12] The participation constraint must be binding for some δ, otherwise the government could increase expected social welfare by reducing the transfer to the manager (across all types) without violating the participation constraint.

Lemma 4.1.

The output level is such that:

$$S'\left[q(\delta)\right] - (1+\lambda)(\beta - \delta) - k\delta + \lambda \frac{F(\delta) - \zeta(\delta)}{f(\delta)} = 0. \tag{12}$$

Proof. See Appendices B.1 and B.2. □

Observe, from the incentive compatibility conditions (6) and (8), that $V(\delta)$ is a convex function. Since the reservation utility is linear in δ, it follows that the participation constraint is binding over an interval, that we denote by $[\delta_0, \delta_1]$.[13]

For $\delta \in [\delta_0, \delta_1]$, from the first incentive compatibility constraint (6), we have $q(\delta) = q_{ref}$ and $t(\delta) = 0$.

Proposition 1 (Output and net transfer).

The participation constraint (10) binds at $[\delta_0, \delta_1]$, *where* $\underline{\delta} \leq \delta_0 \leq \delta_1 \leq \overline{\delta}$.

(i) For $\delta < \delta_0$, *the output is distorted upwards,* $q(\delta) > q_c^*(\delta)$, *and the monetary transfer is positive,* $t(\delta) > 0$*;*

(ii) For $\delta_0 \leq \delta \leq \delta_1$, *the output is equal to the reference output,* $q(\delta) = q_{ref}$, *and the monetary transfer is null,* $t(\delta) = 0$*;*

(iii) For $\delta > \delta_1$, *the output is distorted downwards,* $q(\delta) < q_c^*(\delta)$, *and the monetary transfer is negative,* $t(\delta) < 0$*;*

Proof. See Appendix B.3. □

The output level is strictly increasing with δ over the two intervals $[\underline{\delta}, \delta_0]$ and $\left[\delta_1, \overline{\delta}\right]$, being constant and equal to q_{ref} in $[\delta_0, \delta_1]$. When the output level is strictly increasing, the monetary transfer, $t(\delta)$, is strictly decreasing.

[13] This includes, for example, the case in which the participation constraint is only binding at one of the extremes of the interval ($\delta_0 = \delta_1 = \underline{\delta}$ or $\delta_0 = \delta_1 = \overline{\delta}$).

The distortion of output results, obviously, from the need to induce truth-telling. We found that if the manager happens to have a relatively strong preference for high output, contracted output is below the perfect information level. This means that it would be preferable to “pay” more in output and less in money. But notice that in this case the participation constraint binds for lower types and the principal must avoid that the higher types mimic the lower. Paying more in output to type δ would make it even more costly to prevent type $\delta+\epsilon$ from mimicking type δ. Of course that this argument no longer holds at $\delta=\overline{\delta}$, and this is why distortion disappears for the highest type (see Figures 1, 2 and 3 in the next section).

5 Characterizing the optimal contract

In this section, we characterize the optimal contract in the case of a quadratic social value function of output and a uniform distribution over types.

5.1 Exogenous reference output

In order to illustrate our general results, we now assume that the social value of output is $S(q)=\alpha q-\frac{1}{2}q^2$ and that δ is uniformly distributed on $[0,1]$.

With complete information, the solution is:

$$\begin{aligned} q_c^*(\delta) &= \alpha-(1+\lambda)\beta+(1+\lambda-k)\delta, \\ t_c^*(\delta) &= \delta(q_{ref}-q_c^*). \end{aligned}$$

Assumption 1 (iii), which in this case is $\alpha>(1+\lambda)\beta$, ensures that the complete information output is always positive.

The participation constraint binds if and only if $\delta\in[\delta_0,\delta_1]$, with (Appendix C.1):

$$\delta_0=\max\left\{0,\frac{q_{ref}-\alpha+(1+\lambda)\beta}{1+2\lambda-k}\right\} \text{ and } \delta_1=\min\left\{\frac{q_{ref}-\alpha+(1+\lambda)\beta+\lambda}{1+2\lambda-k},1\right\}.$$

The analytical expressions for output, net transfer and the manager's utility are presented in Appendices C.2 and C.3.

Qualitatively, the solution is characterized by the following propositions.

Proposition 2 (The intermediate reference output case).

When $q_{ref} \in [\alpha - (1+\lambda)\beta, \alpha - (1+\lambda)\beta + 1 + \lambda - k]$*, we find that (see Figure 1):*

(i) for $\delta \in [\delta_0, \delta_1]$*, there is bunching, with* $q(\delta) = q_{ref}$*,* $t(\delta) = 0$ *and* $V(\delta) = 0$ *(binding participation constraint);*

(ii) for $\delta \in [0, \delta_0)$*, output is distorted upwards,* $q(\delta) > q_c^*$*, and the monetary transfer is positive,* $t(\delta) > 0$*;*

(iii) for $\delta \in (\delta_1, 1]$*, output is distorted downwards (*$q(\delta) < q_c^*$*) and the monetary transfer is negative,* $t(\delta) < 0$*.*

Proof. See Appendices C.2 and C.3. □

When δ increases from 0 to 1, the output level first increases (until δ_0), being larger than the complete information output, then it is constant (between δ_0 and δ_1), and then increases again, being lower than the complete information optimal output.

The following propositions describe what happens when the reference output q_{ref} is outside the interval defined in Proposition 2.

Proposition 3 (The large reference output case).

When $q_{ref} > \alpha + (1+\lambda)(1-\beta) - k$*, there is bunching at the top (see Figure 2):*

(i) for $\delta \in [\delta_0, 1]$*, there is bunching, with* $q(\delta) = q_{ref}$*,* $t(\delta) = 0$ *and* $V(\delta) = 0$ *(binding participation constraint);*

(ii) for $\delta \in [0, \delta_0)$*, output is distorted upwards,* $q(\delta) > q_c^*$*, and the monetary transfer is positive,* $t(\delta) > 0$*.*

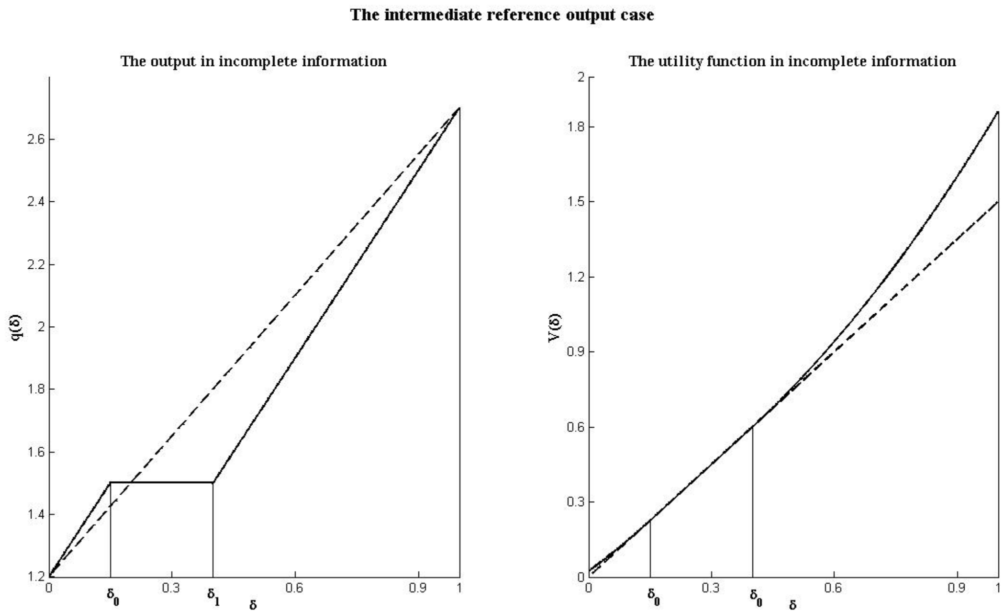

Figure 1: The output and the utility function of the firm with $k = 0$, $\alpha = 3$, $\lambda = 0.5$, $\beta = 1.2$, $q_{ref} = 1.5$, $\delta_0 = 0.15$, $\delta_1 = 0.4$.

Proof. See Appendix C.2. □

Proposition 4 (The small reference output case).

When $q_{ref} < \alpha - (1 + \lambda)\beta$, there is bunching at the bottom (see Figure 3):

(i) for $\delta \in [0, \delta_1]$, there is bunching, with $q(\delta) = q_{ref}$, $t(\delta) = 0$ and $V(\delta) = 0$ (binding participation constraint);

(ii) for $\delta \in (\delta_1, 1]$, output is distorted downwards, $q(\delta) < q_c^*$, and the monetary transfer is negative, $t(\delta) < 0$.

Proof. See Appendix C.3. □

The figures illustrated the case in which the government incorporates the non-monetary component of the manager's utility in the welfare function ($k = 0$). If the government does not care about the preference for empire-building ($k = 1$), the interval over which the

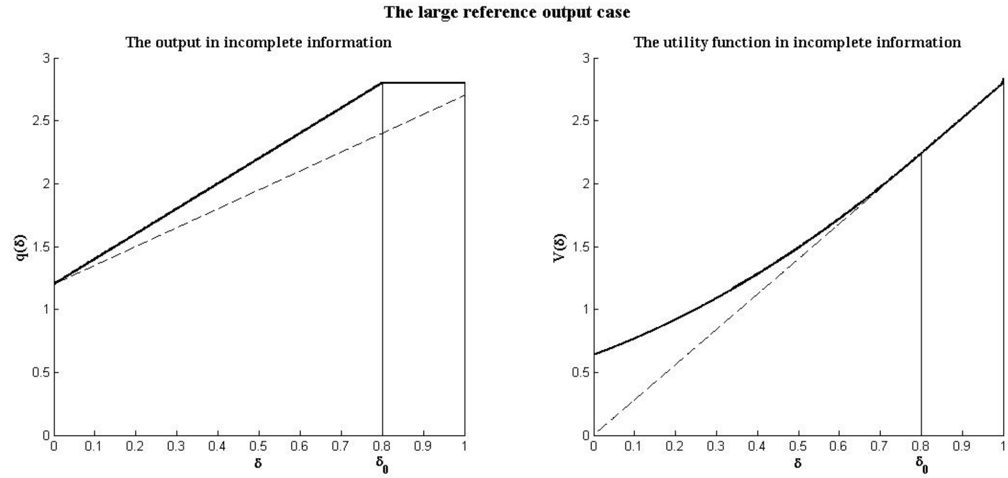

Figure 2: The output and the utility function of the firm with $k = 0$, $\alpha = 3$, $\lambda = 0.5$, $\beta = 1.2$, $q_{ref} = 2.8$, $\delta_0 = 0.8$.

output is constant and the participation constraint of the manager is binding moves to the right and, outside this interval, the output and the manager's utility are lower.

We can use our results to study how the output responds to changes in cost, for a given reference output level. An increase in marginal cost, β, entails a reduction of the output level both when the manager's marginal utility is low ($\delta \in [0, \delta_0]$) and when it is high ($\delta \in [\delta_1, 1]$). However, for intermediate values ($\delta \in [\delta_0, \delta_1]$), output does not change in response to (small) changes in cost.

Finally, we show that a sufficient condition for social welfare, $W(\delta)$, to be positive for all $\delta \in [0, 1]$ (which implies that the regulator is happy to offer a contract to all possible types) is that the reference output is not larger than twice the optimal output in the absence of empire-building tendencies.

Proposition 5 (The government's participation constraint).

If $q_{ref} \leq 2\left[\alpha - (1 + \lambda)\beta\right]$, *then the social welfare is positive,* $W(\delta) > 0$, *for all* $\delta \in [0, 1]$.

Proof. See Appendix C.4. □

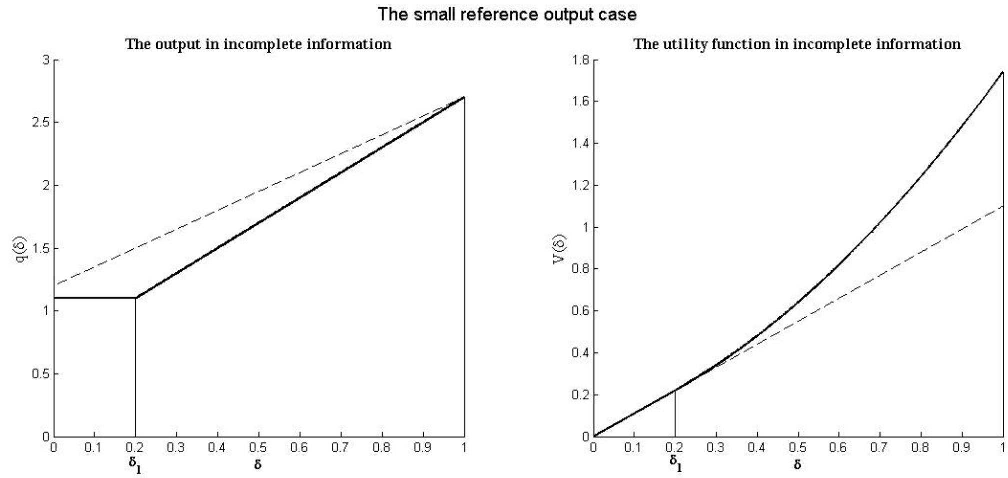

Figure 3: The output and the utility function of the firm with $k = 0$, $\alpha = 3$, $\lambda = 0.5$, $\beta = 1.2$, $q_{ref} = 1.1$, $\delta_1 = 0.2$.

In Figure 4, we observe that if the government cares about the managerial empire-building utility ($k = 0$), the social welfare increases with δ. If the government disregards the managerial empire-building utility in the welfare function (i.e., when k increases), the social welfare increases in $\delta \in [0, \delta_0)$, is constant in $\delta \in [\delta_0, \delta_1]$, and increases again in $\delta \in (\delta_1, 1]$.

5.2 Endogenous reference output

Until now, we considered that the reference output was exogenous. Remember that the reference output determines the (type-dependent) reservation utility. It is natural to assume that this reference output is the expected output of the population of firms, with respect to the managers' types.[14] Since this expected value depends on the reference output itself, the equilibrium value of the reference output is to be determined by stipulating that the reference output should equal the expected output, $q_{ref} = E_\delta [q(\delta)]$.

With quadratic social value of output and a uniform distribution over types, whenever the reference output is assumed to take an intermediate value (an assumption to be checked

[14] This is in the spirit of Kőszegi and Rabin (2006), where the reference point of an agent corresponds to her rational expectation about a certain outcome.

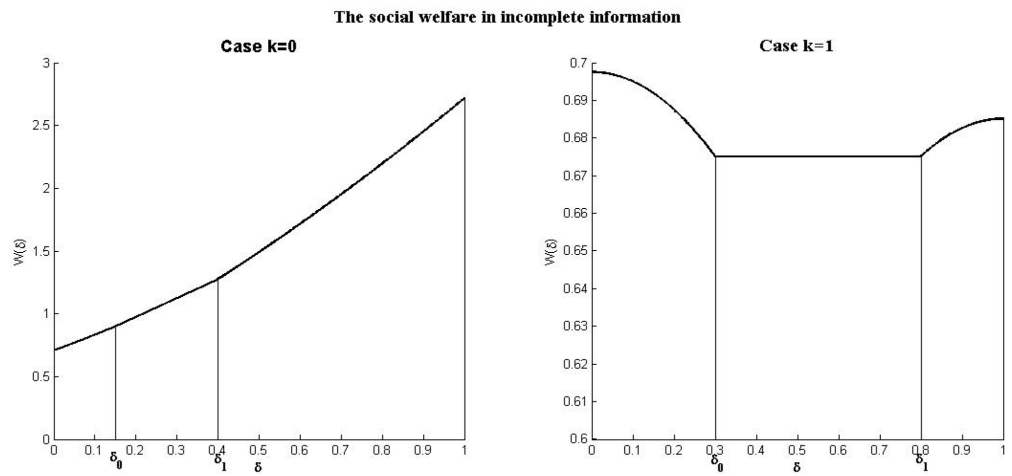

Figure 4: The social welfare with $k = 0$ and $k = 1$ in which $\alpha = 3$, $\lambda = 0.5$, $\beta = 1.2$, $q_{ref} = 1.5$.

later), the expected output is given by:

$$E_\delta\left[q(\delta)\right] = \int_0^{\delta_0} \left[\alpha - (1+\lambda)\beta + (1+2\lambda-k)\delta\right]\ d\delta + \int_{\delta_0}^{\delta_1} q_{ref}\ d\delta + \int_{\delta_1}^{1} \left[\alpha - (1+\lambda)\beta + (1+2\lambda-k)\delta - \lambda\right]\ d\delta. \tag{13}$$

Equating (13) to q_{ref}, we obtain the unique equilibrium value of q_{ref} as

$$q^*_{ref} = \alpha - (1+\lambda)\beta + \frac{1}{2}(1+\lambda-k). \tag{14}$$

Observing that $q^*_{ref} \in [\alpha - (1+\lambda)\beta, \alpha + (1+\lambda)(1-\beta) - k]$, we validate, using Proposition 3, our initial assumption about the reference output taking an intermediate value.

We can now prove that this the only possible equilibrium. Indeed, if we assume that the reference output is large, we have

$$E_\delta\left[q(\delta)\right] = \int_0^{\delta_0} \left[\alpha - (1+\lambda)\beta + (1+2\lambda-k)\delta\right]\ d\delta + \int_{\delta_0}^{1} q_{ref}\ d\delta, \tag{15}$$

and equating (15) to q_{ref}, we obtain as candidate equilibrium value $q_{ref} = \alpha - (1+\lambda)\beta + \frac{1-k}{2} + \lambda$. We immediately observe that this value is lower than $\alpha + (1+\lambda)(1-\beta) - k$, contradicting our assumption that we were in the large reference output case.

Similarly, if we assume that the reference output is small, we have

$$E_\delta\left[q(\delta)\right] = \int_0^{\delta_1} q_{ref} d\delta + \int_{\delta_1}^{1} \left[\alpha - (1+\lambda)\beta + (1+2\lambda-k)\delta - \lambda\right] d\delta, \tag{16}$$

and equating (16) to q_{ref}, we obtain as candidate equilibrium the value $q_{ref} = \alpha+(1+\lambda)(1-\beta) - k$. We immediately observe that this value is larger than $\alpha - (1+\lambda)\beta$, contradicting our assumption that we were in the small reference output case. This is summarized in Proposition 6 below.

Proposition 6 (Endogenous reference output).

The unique endogenous reference output level is given by equation (14). It is such that only the "intermediate reference output case" occurs at equilibrium.

Making the reference output endogenous in this way leads us to reconsider what has been said at the end of the previous section. It is true that, for a given reference output, the firms may not respond to "small" changes in cost when their managers' types are intermediate. However, the (endogenous) reference output itself will adjust in response to changes in cost. Then, it makes sense to distinguish between short-run and long-run output elasticity with respect to changes in cost. In the short-run, the reference output is given, for instance because the contracts have already been signed between the regulators and the managers, and output can be insensitive to changes in costs or taxes for a whole category of firms. However, in the long run, as the old managers leave their jobs, new contracts are passed referring to the new reference output, and output converges to its new equilibrium value. It follows that the long-run output elasticity is going to be larger than the short-run one.

6 Concluding remarks and extensions

In this paper, we analyzed the optimal regulation of a firm when the manager's empire-building preference (manager's utility of output) is private information and the reservation utility is type-dependent. We showed that the optimal output function is such that output is distorted upward when the manager has a low preference for output, downward when he/she has a high preference for output and equals his/her reference output when he/she has an intermediate preference for output and the individual rationality constraint is binding. When the government does not care about the non-monetary part of the manager's utility, the interval over which the output is constant and the participation constraint is binding moves to the right, while, outside this interval, equilibrium output is lower.

These results have implications for cost sensitivity of output. In the short-run, when the reference output can be considered as exogenous, the output of firms whose managers' types are intermediate are not going to respond to small variations in their unit cost of production, while the output of firms whose managers' types are either small or large will respond in the expected direction.[15] The overall sensitivity of output to cost variations depends on the relative numerical importance of these three groups of firms, or, using the terminology of this model, on the length of the interval $[\delta_0, \delta_1]$. In the long-run, the reference output adjusts progressively to its new equilibrium level, and so the output elasticity is larger.

For the sake of simplicity, we assumed throughout this paper that the government can observe the unit cost of production, and we simultaneously ignored the issue of moral hazard. Analyzing a model where both the marginal cost and the manager's utility for output are private information would be fruitful. This will be the subject of future research.

[15]This looks like the result obtained by Sweezy (1939) in the very different framework of "the kinked oligopoly demand curve".

A Appendix: Problem of the firm

A.1 Differentiability of output, transfer, and utility functions

In this section, we prove that if (5) holds, then the output, transfer and value functions are almost everywhere differentiable.

For simplicity of exposition, we will denote by $U(\tilde{\delta}, \delta)$ the utility attained by a manager that announces $\tilde{\delta}$ when his type is δ.

Lemma 1. $\tilde{\delta} < \delta \Rightarrow q(\tilde{\delta}) \leq q(\delta)$.

Proof. If (5) holds, then:

$$\begin{aligned} t(\delta) + \delta \left[q(\delta) - q_{ref}\right] &\geq t(\tilde{\delta}) + \delta \left[q(\tilde{\delta}) - q_{ref}\right], \\ t(\tilde{\delta}) + \tilde{\delta} \left[q(\tilde{\delta}) - q_{ref}\right] &\geq t(\delta) + \tilde{\delta} \left[q(\delta) - q_{ref}\right]. \end{aligned}$$

Adding the two inequalities, we obtain:

$$\left(\delta - \tilde{\delta}\right) \left[q(\delta) - q(\tilde{\delta})\right] \geq 0.$$

Then, $\delta - \tilde{\delta} > 0$ implies that $q(\delta) - q(\tilde{\delta}) \geq 0$. □

Lemma 2. $U(\tilde{\delta}, \delta)$, as a function of $\tilde{\delta}$, is nondecreasing on $[\underline{\delta}, \delta]$ and nonincreasing on $\left[\delta, \overline{\delta}\right]$.

Proof. Let us show monotonicity on $[\underline{\delta}, \delta]$. Assume that $\tilde{\delta} < \delta' < \delta$ and, by way of contradiction, $U(\tilde{\delta}, \delta) > U(\delta', \delta)$, that is:

$$t(\tilde{\delta}) + \delta \left[q(\tilde{\delta}) - q_{ref}\right] > t(\delta') + \delta \left[q(\delta') - q_{ref}\right].$$

On the other hand, we know that a firm of type δ' prefers to announce δ' rather than announce $\tilde{\delta}$:

$$t(\delta') + \delta' \left[q(\delta') - q_{ref}\right] \geq t(\tilde{\delta}) + \delta' \left[q(\tilde{\delta}) - q_{ref}\right].$$

Adding the last two equations, we obtain:

$$(\delta - \delta') \left[q(\tilde{\delta}) - q(\delta')\right] > 0 \;\Rightarrow\; q(\tilde{\delta}) - q(\delta') > 0.$$

Which is in contradiction with Lemma 1.

Monotonicity on $\left[\delta, \bar{\delta}\right]$ can be proved in the same way. □

Lemmas 1 and 2 imply that the functions $q(\delta)$ and $t(\delta) + \delta' \left[q(\delta) - q_{ref}\right]$ are a.e. differentiable. Hence, $t(\delta)$ and $V(\delta) = t(\delta) + \delta \left[q(\delta) - q_{ref}\right]$ are also a.e. differentiable.

A.2 Second incentive compatibility condition

The local second-order condition of the maximization program is:

$$\left.\frac{\partial^2 U(\tilde{\delta}, \delta)}{\partial \tilde{\delta}^2}\right|_{\tilde{\delta}=\delta} \leq 0 \;\Leftrightarrow\; t''(\delta) + \delta q''(\delta) \leq 0. \tag{17}$$

We want to show that (given the first-order condition) it is equivalent to $q'(\delta) \geq 0$.

Notice that, under the first incentive compatibility condition (5), the value function is:

$$V(\delta) = t(\delta) + \delta \left[q(\delta) - q_{ref}\right]. \tag{18}$$

Evaluating the derivative of (18) and equating to (6), we obtain:

$$t'(\delta) + \delta q'(\delta) = 0. \tag{19}$$

The derivative of (19) is:

$$t''(\delta) + q'(\delta) + \delta q''(\delta) = 0. \tag{20}$$

Subtracting (20) from (17), the local second order condition becomes:

$$q'(\delta) \geq 0.$$

□

A.3 The local second order condition implies the global one

Lemma 4. The first and second incentive compatibility conditions, (8) and (6), imply that truth-telling is optimal (the local second order condition implies the global one).

Proof. From the first incentive compatibility condition, (8), we obtain:

$$t'(\delta) + \delta q'(\delta) = 0.$$

Therefore, for $\tilde{\delta} > \delta$:

$$\begin{aligned} t(\tilde{\delta}) + \delta\left[q(\tilde{\delta}) - q_{ref}\right] &= t(\delta) + \int_{\delta}^{\tilde{\delta}} t'(\gamma)d\gamma + \delta\left[q(\delta) + \int_{\delta}^{\tilde{\delta}} q'(\gamma)d\gamma - q_{ref}\right] = \\ &= t(\delta) + \delta\left[q(\delta) - q_{ref}\right] + \int_{\delta}^{\tilde{\delta}} t'(\gamma) + \delta q'(\gamma)d\gamma. \end{aligned}$$

To conclude the proof, observe that since $q'(\gamma) \geq 0$:

$$\int_{\delta}^{\tilde{\delta}} t'(\gamma) + \delta q'(\gamma)d\gamma < \int_{\delta}^{\tilde{\delta}} t'(\gamma) + \gamma q'(\gamma)d\gamma = 0.$$

□

B Appendix: Problem of the government

B.1 Necessary and sufficient conditions

We start by ignoring the second order incentive compatibility condition (8) but we shall check later that the solution of problem (11) is the solution of the general problem (9).

Necessary conditions

The Hamiltonian is:

$$H = \{S[q(\delta)] - (1+\lambda)\beta q(\delta) - \lambda V(\delta) + (1+\lambda-k)\delta[q(\delta)-q_{ref}]\} f(\delta) + \\ +\mu(\delta)[q(\delta)-q_{ref}] + \eta(\delta)\lambda V(\delta), \tag{21}$$

where $\mu(\delta)$ is the co-state variable associated with (6) and $\eta(\delta)$ is the multiplier associated with the participation constraint.

The first-order conditions imply:

$$\mu'(\delta) = \lambda[f(\delta) - \eta(\delta)], \tag{22a}$$

$$V'(\delta) = q(\delta) - q_{ref}, \tag{22b}$$

$$S'[q(\delta)] - (1+\lambda)(\beta-\delta) - k\delta + \frac{\mu(\delta)}{f(\delta)} = 0, \tag{22c}$$

$$\eta(\delta)V(\delta) = 0, \tag{22d}$$

$$\mu(\underline{\delta}) = \mu(\overline{\delta}) = 0, \tag{22e}$$

$$\eta(\delta) \geq 0, \quad V(\delta) \geq 0. \tag{22f}$$

Equation (22a) is the equation of motion of the co-state variable. Equation (22d) is the complementary slackness condition. Equation (22e) gives the transversality conditions.

Integrating equation (22a) we obtain:

$$\mu(\delta) = \lambda[F(\delta) - \zeta(\delta)], \tag{23}$$

and using (22e):

$$\mu(\underline{\delta}) = \lambda \left[F(\underline{\delta}) - \zeta(\underline{\delta})\right] \;\; \Leftrightarrow \;\; 0 = -\lambda\zeta(\underline{\delta}) \Leftrightarrow \zeta(\underline{\delta}) = 0, \tag{24}$$

$$\mu(\overline{\delta}) = \lambda \left[F(\overline{\delta}) - \zeta(\overline{\delta})\right] \;\; \Leftrightarrow \;\; 0 = \lambda \left[1 - \zeta(\overline{\delta})\right] \Leftrightarrow \zeta(\overline{\delta}) = 1. \tag{25}$$

These last two equations imply that:

$$\int_{\underline{\delta}}^{\overline{\delta}} \eta(\delta) d\delta = \int_{\underline{\delta}}^{\overline{\delta}} f(\delta) d\delta = 1, \tag{26}$$

meaning that $\eta(\cdot)$ is a probability distribution on $\left[\underline{\delta}, \overline{\delta}\right]$ and $\zeta(\cdot)$ is the corresponding c.d.f..

Replacing equation (23) into (22c), we find that output is such that:

$$S'\left[q(\delta)\right] - (1+\lambda)(\beta - \delta) - k\delta + \lambda \frac{F(\delta) - \zeta(\delta)}{f(\delta)} = 0.$$

The only difference with respect to the complete information case is the last term. It should be clear that $\zeta(\delta) = 1$ implies downward distortion and $\zeta(\delta) = 0$ implies upward distortion.

Note that if the participation constraint (6) is not binding on some open interval, (δ_a, δ_b), then $\zeta(\cdot)$ is constant on it, since $\zeta'(\delta) = \eta(\delta) = 0$.

Sufficient condition

The second order derivative of the Hamiltonian (21) is: $\frac{\partial^2 H}{\partial q^2} = S''\left[q(\delta)\right] < 0$.

B.2 Solution of the general problem

We now check that the condition which was omitted in the problem (11), $q'(\delta) \geq 0$, is satisfied. Differentiating equation (12) with respect to δ, we obtain:

$$q^{*'}(\delta) = -\frac{1 + \lambda - k + \lambda\left(1 - \frac{\eta(\delta)}{f(\delta)}\right) - \lambda \frac{f'(\delta)\left[F(\delta) - \zeta(\delta)\right]}{f(\delta)^2}}{S''[q(\delta)]}.$$

The assumption of monotone hazard rates is used here. Observe that:

$$\frac{d}{d\delta}\left[\frac{f(\delta)}{F(\delta)}\right] < 0 \;\Leftrightarrow\; \frac{f'(\delta)F(\delta)}{f(\delta)^2} < 1$$

and

$$\frac{d}{d\delta}\left[\frac{f(\delta)}{1-F(\delta)}\right] > 0 \;\Leftrightarrow\; \frac{f'(\delta)\left[F(\delta)-1\right]}{f(\delta)^2} < 1.$$

For $\delta < \delta_0$, we have $\eta(\delta) = 0$ and $\zeta(\delta) = 0$, implying that:

$$q^{*'}(\delta) = -\frac{1+2\lambda-k-\lambda\frac{f'(\delta)F(\delta)}{f(\delta)^2}}{S''[q(\delta)]} > -\frac{1+\lambda-k}{S''[q(\delta)]} > 0.$$

For $\delta > \delta_1$, we have $\eta(\delta) = 0$ and $\zeta(\delta) = 1$, implying that:

$$q^{*'}(\delta) = -\frac{1+2\lambda-k-\lambda\frac{f'(\delta)[F(\delta)-1]}{f(\delta)^2}}{S''[q(\delta)]} > -\frac{1+\lambda-k}{S''[q(\delta)]} > 0.$$

When the participation constraint is binding, $q^*(\delta) = q_{ref}$ and, therefore, $q^{*'}(\delta) = 0$. This implies that (8) is verified. The solution of the unconstrained problem (11) is also the solution of the general problem (9). □

B.3 Characterization of the output function

Proof. In the main text, we have explained why one of these three situations must occur.

In case (i), since $\zeta(\delta) = 1, \forall\delta \in (\underline{\delta}, \overline{\delta}]$, the output, for $\delta > \underline{\delta}$, is given by:

$$S'\left[q(\delta)\right] - (1+\lambda)(\beta-\delta) - k\delta = \lambda\frac{1-F(\delta)}{f(\delta)} > 0.$$

The left term is null in the case of complete information, therefore we have $q(\delta) < q_c^*(\delta)$.

In case (ii), since $\zeta(\delta) = 1, \forall \delta \in (\delta_1, \overline{\delta}]$, the output, for $\delta > \delta_1$, is given by:

$$S'[q(\delta)] - (1+\lambda)(\beta - \delta) - k\delta = \lambda \frac{1 - F(\delta)}{f(\delta)} > 0,$$

which, for the same reason, implies that $q(\delta) < q_c^*(\delta)$.

The first incentive compatibility constraint, $V'(\delta) = q(\delta) - q_{ref}$, and the binding participation constraint, $V(\delta) = 0$, imply that, for $\delta \in (\underline{\delta}, \delta_1)$, we have $q(\delta) = q_{ref}$ and, thus, $t(\delta) = 0$.

The first incentive compatibility constraint is equivalent to $t'(\delta) + \delta q'(\delta) = 0$. Then, the second incentive compatibility constraint implies that, for $\delta > \delta_1$, we have $t(\delta) < 0$.

Cases (iii), (iv) and (v) can be analyzed similarly. □

C Appendix: The linear-quadratic case

Characterizing the optimal output level and the manager's utility over the interval $[\delta_0, \delta_1]$ is straightforward. When $\delta \in [\delta_0, \delta_1]$, the participation constraint is binding: $V(\delta) = 0$. From the first incentive compatibility constraint (6), we have $q(\delta) = q_{ref}$, $\forall\, \delta \in [\delta_0, \delta_1]$.

Below, we determine the precise values of δ_0 and δ_1 and we study the two intervals where the participation constraint is not binding: $\delta \in [0, \delta_0)$ and $\delta \in (\delta_1, 1]$.

C.1 The values of δ_0 and δ_1

From Lemma 4.1, we know that:

$$\zeta(\delta) = \frac{1}{\lambda}\left[\alpha - q(\delta) - (1+\lambda)\,\beta - k\delta\right] + \left(2 + \frac{1}{\lambda}\right)\delta. \tag{27}$$

Since $\zeta(0) = 0$ and $\eta(\delta) = 0$ for all $\delta < \delta_0$, we must have $\zeta(\delta_0) = 0$. Replacing in equation

(27) and using the fact that $q(\delta_0) = q_{ref}$, we obtain:

$$\delta_0 = max\left\{0, \frac{q_{ref} - \alpha + (1+\lambda)\beta}{1 + 2\lambda - k}\right\}. \tag{28}$$

When $q_{ref} > \alpha - (1+\lambda)\beta \equiv q^*(0)$, we obtain $\delta_0 > 0$, whereas, when $q_{ref} \leq \alpha - (1+\lambda)\beta$, bunching occurs at the bottom of the interval, i.e. $\delta_0 = 0$.

Since $\zeta(1) = 1$ and $\eta(\delta) = 0$ for all $\delta > \delta_1$, it must be the case that $\zeta(\delta_1) = 1$. Replacing in equation (27) and using $q(\delta_1) = q_{ref}$, we obtain:

$$\delta_1 = min\left\{\frac{q_{ref} - \alpha + (1+\lambda)\beta + \lambda}{1 + 2\lambda - k}, 1\right\}. \tag{29}$$

When $q_{ref} < \alpha - (1+\lambda)\beta + 1 + \lambda - k \equiv q^*(1)$, we obtain $\delta_1 < 1$; whereas, when $q_{ref} \geq \alpha - (1+\lambda)\beta + 1 + \lambda - k$, bunching occurs at the top of interval, i.e, $\delta_1 = 1$.

C.2 When $0 < \delta < \delta_0$

When $\delta_0 > 0$ and $\delta \in (0, \delta_0)$, the participation constraint is not binding. Therefore, $\zeta(\delta)$ is null on this interval, since $\zeta(0) = 0$ and $\eta(\delta) = 0$. From Lemma 4.1, we obtain:

$$q(\delta) = \alpha - (1+\lambda)\beta + (1 + 2\lambda - k)\delta.$$

Integrating equation (6), we obtain the manager's attainable utility:

$$V(\delta) = \int q(s)ds - \delta q_{ref} + C = \left[\alpha - (1+\lambda)\beta - q_{ref}\right]\delta + (1 + 2\lambda - k)\frac{\delta^2}{2} + C,$$

where C is an integration constant. To determine C, we use the continuity of V at $\delta = \delta_0$. We know that $V(\delta_0) = 0$. Then:

$$C = -\left[\alpha - (1+\lambda)\beta - q_{ref}\right]\delta_0 - (1 + 2\lambda - k)\frac{\delta_0^2}{2}.$$

Substituting the expression for δ_0 given by equation (28), we obtain $C = \frac{\left[\alpha-(1+\lambda)\beta-q_{ref}\right]^2}{2(1+2\lambda-k)}$.

We conclude that, for $\delta \in [0, \delta_0)$, there is upward distortion, $q(\delta) = q_c^*(\delta) + \lambda\delta$, and a positive monetary transfer, $t(\delta) > 0$:

$$q(\delta) = \alpha - (1+\lambda)\beta + (1+2\lambda-k)\delta, \tag{30}$$

$$V(\delta) = \frac{\left[\alpha - (1+\lambda)\beta - q_{ref}\right]^2}{2(1+2\lambda-k)} + \left[\alpha - (1+\lambda)\beta - q_{ref}\right]\delta + (1+2\lambda-k)\frac{\delta^2}{2}, \tag{31}$$

$$t(\delta) = -(1+2\lambda-k)\frac{\delta^2}{2} + \frac{\left[\alpha - (1+\lambda)\beta - q_{ref}\right]^2}{2(1+2\lambda-k)}. \tag{32}$$

C.3 When $\delta_1 < \delta < 1$

When $\delta_1 < 1$ and $\delta \in (\delta_1, 1)$, the participation constraint is not binding. Then, $\zeta(\delta) = 1$ on this interval, since $\eta(\delta) = 0$ and $\zeta(1) = 1$. From Lemma 4.1, output is given by:

$$q(\delta) = \alpha - (1+\lambda)\beta + (1+2\lambda-k)\delta - \lambda.$$

Integrating equation (6), we obtain:

$$V(\delta) = \int q(s)ds - \delta q_{ref} + C = \left[\alpha - (1+\lambda)\beta - \lambda - q_{ref}\right]\delta + (1+2\lambda-k)\frac{\delta^2}{2} + C.$$

To determine the integration constant, C, we use continuity of V at $\delta = \delta_1$. Since $V(\delta_1) = 0$:

$$C = -\left[\alpha - (1+\lambda)\beta - q_{ref} - \lambda\right]\delta_1 - (1+2\lambda-k)\frac{\delta_1^2}{2}.$$

With δ_1 given by equation (29), we find that $C = \frac{\left[\alpha-\beta(1+\lambda)-q_{ref}-\lambda\right]^2}{2(1+2\lambda-k)}$.

We conclude that, for $\delta \in (\delta_1, 1]$, there is downward distortion, $q(\delta) = q_c^*(\delta) - \lambda(1-\delta)$, and a negative monetary transfer, $t(\delta) < 0$:

$$q(\delta) = \alpha - (1+\lambda)\beta + (1+2\lambda-k)\delta - \lambda, \quad (33)$$

$$V(\delta) = \frac{\left[\alpha - \beta(1+\lambda) - \lambda - q_{ref}\right]^2}{2(1+2\lambda-k)} + \left[\alpha - (1+\lambda)\beta - q_{ref} - \lambda\right]\delta + (1+2\lambda-k)\frac{\delta^2}{2}, \quad (34)$$

$$t(\delta) = -(1+2\lambda-k)\frac{\delta^2}{2} + \frac{\left[\alpha - (1+\lambda)\beta - q_{ref} - \lambda\right]^2}{2(1+2\lambda-k)}. \quad (35)$$

□

C.4 The government's participation constraint

The regulator's welfare when the agent's type is δ is:

$$W(\delta) = S\left[q\left(\delta\right)\right] - (1+\lambda)\beta q(\delta) + (1+\lambda-k)\delta\left[q(\delta) - q_{ref}\right] - \lambda V(\delta).$$

Differentiating and accounting for the incentive compatibility condition (6) we obtain:

$$W'(\delta) = \left\{S'\left[q\left(\delta\right)\right] - (1+\lambda)(\beta-\delta) - k\delta\right\}q'(\delta) + (1-k)\left[q(\delta) - q_{ref}\right]. \quad (36)$$

From condition (12), we know that:

$$S'\left[q(\delta)\right] - (1+\lambda)(\beta-\delta) - k\delta = -\lambda\frac{F(\delta) - \zeta(\delta)}{f(\delta)}.$$

Notice that here $F(\delta) = \delta$. Replacing in (36), we obtain:

$$W'(\delta) = (1-k)\left[q(\delta) - q_{ref}\right] - \lambda\left[\delta - \zeta(\delta)\right]q'(\delta).$$

Let us consider the three possible cases:

1. When $\delta \in [\delta_0, \delta_1]$, it easy to check that $W'(\delta) = 0$.

2. When $\delta \in [0, \delta_0)$, we know that $\zeta(\delta) = 0$, $q(\delta) = \alpha - (1+\lambda)\beta + (1+2\lambda-k)\delta$ and $q'(\delta) = 1 + 2\lambda - k$. It follows that

$$W'(\delta) = (1-k)[\alpha - (1+\lambda)\beta + (1+2\lambda-k)\delta - q_{ref}] - \lambda\delta(1+2\lambda-k).$$

When $k = 1$, this simplifies to $W'(\delta) = -2\lambda^2\delta$, which is negative. When $k = 0$, it simplifies to $W'(\delta) = \alpha - (1+\lambda)\beta + (1-\lambda)(1+2\lambda)\delta - q_{ref}$, which is positive under the assumption of the proposition when $\lambda < 1$.

3. When $\delta \in [\delta_1, 1]$, we know that $\zeta(\delta) = 1$, $q(\delta) = \alpha - (1+\lambda)\beta + (1+2\lambda-k)\delta - \lambda$ and $q'(\delta) = 1 + 2\lambda - k$. It follows that

$$W'(\delta) = (1-k)[\alpha - (1+\lambda)\beta + (1+2\lambda-k)\delta - \lambda - q_{ref}] + \lambda(1-\delta)(1+2\lambda-k).$$

This is always positive. When $k = 1$, it simplifies to $W'(\delta) = 2\lambda^2(1-\delta)$. When $k = 0$, it simplifies to $W'(\delta) = (1-\lambda)(1+2\lambda) + 2\lambda^2$, which is positive when $\lambda < 1$.

(i) When $k = 1$, $W(\delta)$ takes its minimum value for $\delta \in [\delta_0, \delta_1]$, where it equals $\alpha q_{ref} - \frac{1}{2}q_{ref}^2 - \beta(1+\lambda)q_{ref}$. In order to guarantee that the participation constraint of the principal is always satisfied, it is enough to assume that $q_{ref} \leq 2\left[\alpha - (1+\lambda)\beta\right]$.

(ii) When $k = 0$, assuming $\lambda < 1$, $W(\delta)$ takes its minimum value for $\delta = 0$. In the case in which the participation of the manager is not binding at $\delta = 0$, we have $q(0) = \alpha - (1+\lambda)\beta$ and $W(0) = \frac{1}{2}\left[\alpha - (1+\lambda)\beta\right]^2 - \lambda V(0)$. As $q_{ref} \leq 2\left[\alpha - (1+\lambda)\beta\right]$, we have $V(0) \leq \frac{1}{2+4\lambda}\left[\alpha - (1+\lambda)\beta\right]^2$. This implies that $W(0)$ is positive. If the participation of the manager is binding at $\delta = 0$, then $W(0) = \alpha q_{ref} - \frac{1}{2}q_{ref}^2 - \beta(1+\lambda)q_{ref} \geq 0$ as before. □

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