Dynamic Yardstick Mechanisms[1]

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ABSTRACT

This paper shows that the inability of principals to commit to long term contracts is irrelevant when dealing with several agents whose private information is correlated. This sharply contrasts with the dynamics of contracting without such correlation. The paper also explores what limitations on yardstick mechanisms can justify the use of long term contracts. We found that the inability of a principal to commit not to renegotiate long-term contracts is without consequence even if there is a bound on transfers that an agent can be asked to pay. In contrast, short-term contracting fails to implement the commitment solution with constraints on transfers. Second, absent current yardstick, the possibility of using correlated mechanisms in the future allows the principal to implement the first-best with a renegotiation-proof long-term contract whereas this cannot be achieved with short-term contracting.

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1 Introduction

Twenty years ago, most regulated firms were operating as monopolies. It has been recognized both in academic circles (Baron and Myerson 1982, and Laffont and Tirole 1986) and among practitioners, that regulating those firms is a task made particularly difficult by the existence of private information. Since regulators are viewed to be at an informational disadvantage with respect to firms, regulatory schemes must be designed to elicit hidden information. This task appears even more daunting in a dynamic context. Repeatedly eliciting private information from regulated firms introduces additional difficulties when regulators cannot fully commit to future regulation (Laffont and Tirole 1988, 1990). In contrast, when regulatory commitment is absolute, the dynamic incentive problem becomes essentially static (see Baron and Besanko, 1984). The impossibility to fully commit to future regulatory schemes seems the right assumption to make both on empirical grounds (for instance in the U.K., regulatory contracts, although unusually long, typically do not last for more than 5 to 7 years) and from a theoretical point of view. For instance, it seems difficult to ban Pareto improving renegotiation.

Nowadays, the picture of regulated industries has drastically changed. Almost all regulated firms evolve in a competitive framework or under the threat of possible entry by competitors. It has already been argued that such an evolution makes the task of regulators easier (e.g. Shleifer 1985, and Armstrong, Cowan and Vickers 1994): competitors are likely to have some information (maybe private) about the incumbent's private information and regulators should find a way to extract this additional information in order to be less at an informational disadvantage than absent competition.[1] This paper presents a novel argument: not only can competition make the task of regulators less difficult but it can also make regulators better at performing it.

If our motivation comes from industrial regulation, our point is derived in the classical set up of mechanism design. It is well known that in a repeated contracting framework, principals may suffer from the so-called ratchet effect: if an agent at a given period reveals that he is rather a "good" type (whether this means higher productivity for a worker, greater cost efficiency for a regulated firm, higher willingness to buy for a buyer) the principal has an incentive to take advantage of this information in her future dealings with that agent. Anticipating this effect, the agent is more reluctant initially to reveal this positive information since by not doing so, he can enjoy extra rents in the present as well as in the future. It is also known that in a *static* framework principals can better screen agents' private information if information across agents is correlated. Along the lines of Crémer and McLean (1985, 1988) or McAfee and Reny (1990), one can design transfers for an agent reporting negative news about himself that depend on other agents' reports in such a way that they just satisfy the participation constraint of a true bad type while simultaneously penalizing a good type who would wrongly pretend to be a bad type.[4] This is possible because a good type agent and a bad one face different conditional distributions for the types of the other agents, if one assumes that agents' costs are interdependent.

We first extend this result to a dynamic setting by showing that principals can implement first best outcomes at every period. Second, we show that this is possible with a sequence of short term contracts. Commitment is not an issue because even if the lack of it *does prevent* the principal from simply offering the repetition of the optimal static correlated mechanism, the principal can design initial transfers that still induce full revelation in the first period, without giving up rents. Thus, neither the extent to

[1] Relative performance, or yardstick, mechanisms are now used in regulation over a wide range of markets. Examples are Medicare's reimbursement policy of hospitals (Dranove 1987), the regulation of electricity supply (Kumbhakar and Hjalmarsson 1998), of the water industry (Cowan 1997) and of telecommunications (FCC 1997).

[4] The discussion implicitly considers the case of a binary type distribution but the reasoning applies in general.

which private information can be screened nor the efficiency of the contracting solution depend on the assumption of perfect commitment. Similarly, the difference between spot contracting and long-term contracting with renegotiation disappears.[5] The ratchet effect is washed out by the use of correlated mechanisms. This result is shown to hold true for any time horizon, any discount factor and any degree of correlation.

We then investigate what limitations are likely to make long term contracting worthwhile when agents' information is correlated. We first show that long-term contracts allow the principal to implement repeated correlated mechanisms even if she is unable to commit not to renegotiate those long-term contracts. This has the additional benefit of reducing the variability of per-period transfers, making it easier to ensure that those are within some admissible bounds. We also show that long term contracting allows the principal to extract all rents using the sole *threat* of future use of correlated mechanisms. This threat remains powerful even without commitment not to renegotiate. These last results will not hold if only short term contracting is possible. Notice that in any case, the principal's inability to commit not to renegotiate is of no consequence.

Some limitations of mechanisms making use of relative performance (sometimes referred to as yardstick mechanisms) have been analyzed by Dalen (1998) and Sobel (1999) in a setting where regulated firms can invest into cost reductions. These papers show that an ex-ante regulatory scheme using yardstick mechanisms can achieve the full-information outcome only if the regulator can commit to such a scheme before investments are undertaken. In contrast, if she cannot commit to a scheme the regulator will expropriate all of a firm's rent by using a correlated mechanism which in turn dilutes investment incentives. Our analysis concentrates on a dynamic interaction instead where contracting takes place repeatedly. Although correlated mechanisms might be inefficient in solving hold-up type problems as in this literature, we show they perform well when dealing with the ratchet effect.

We first present a simple model of contracting. Section 3 shows that the first best outcome can be implemented by a sequence of short term contracts. Section 4 presents two extensions. First, we consider limits on negative transfers. Second, we analyze optimal contracting with a single agent but under the possibility that in the future agents with correlated information may enter. A final section contains conclusions about the implications of our results for the interplay of deregulation and competition and discusses directions for further research.

2 The Model

Consider a screening model as follows:

∘ Agents: two agents $i = \{1, 2\}$ have to produce a quantity q^i of a consumption good. The cost of production for each agent is $\theta^i q$. Hence, the total cost of producing $q = (q^1, q^2)$ units is $\theta^1 q^1 + \theta^2 q^2$. This production generates a surplus of $R(q^1, q^2)$ directly accrued to the principal. Agents are paid a transfer t^i from the principal.

∘ Information: for both agents, assume θ^i takes value in $\{\theta_1, \theta_2\}$, with $\Delta\theta \equiv \theta_2 - \theta_1 > 0$. We assume that the exact realization of θ^i is private information to agent i. It is common knowledge that these random variables are drawn from a discrete probability distribution $(p_{nk})_{n,k=1,2}$, where p_{nk} is

[5] Rey and Salanie (1996) characterize conditions under which either spot contracting or short term (two-period) contracting can implemement the long-term renegotiation-proof optimum in a setting with only one agent. They show that the conditions needed for the former are considerably more stringent.

the probability that agent i's cost is equal to θ_n and agent j's cost is equal to θ_k.[6] We denote by $\rho \equiv p_{11}p_{22} - p_{12}p_{21}$ the correlation coefficient and we make the convention that $\rho > 0$, i.e. types are positively correlated.

∘ Contracts: the principal offers contracts to agents which specify a monetary transfer t^i to each agent, and a quantity to be produced q^i. We focus on direct mechanisms, where each agent is asked to make a report about its type.[7] We denote by $q^{i\tau}_{nk} \equiv q^{i\tau}(\theta_n, \theta_k)$ and $t^{i\tau}_{nk} \equiv t^{i\tau}(\theta_n, \theta_k)$, the production implemented and the transfer to agent i at time τ, when agent i reports θ_n and agent j reports θ_k.

∘ Timing: there is an initial period 0, in which agents' costs are realized, and $T-1$ periods of production, indexed by τ. We denote by δ the common factor used to discount payoffs that accrue later in time. The sequence of events unfolds as follows:

i) Period 0
   - agents receive private information about their costs.

ii) Periods $1 \leq \tau \leq T-1$
   - each period the principal makes a contract offer which, unless specified otherwise, is valid for period τ only.
   - agents simultaneously accept or reject this contract. If one rejects, no production takes place for this period and no transfers are paid.
   - agents make reports to the principal, production and transfers take place.

We will also write $u^{i\tau}_{nk} \equiv t^{i\tau}_{nk} - \theta_n q^{i\tau}_{nk}$ to denote the equilibrium utility level agent i receives in period τ. The intertemporal expected utilities of the different players are:

- for agent i of type θ_n :

$$EU^i_n \equiv \sum_{\tau=1}^{T} \sum_{k=1}^{2} \delta^{\tau-1} \frac{p_{nk}}{p_{n1}+p_{n2}} u^{i\tau}_{nk}$$

- for the principal:

$$EW \equiv \sum_{\tau=1}^{T} \sum_{n,k=1}^{2} \delta^{\tau-1} p_{nk} \left(R(q^{1\tau}_{nk}, q^{2\tau}_{kn}) - \left(\theta_n q^{1\tau}_{nk} + \theta_k q^{2\tau}_{kn}\right) - \left(u^{1\tau}_{nk} + u^{2\tau}_{kn}\right)\right)$$

  Absent asymmetric information, the principal would set $u^{i\tau}_{nk} = 0$ and would choose first best quantities $q^{i\tau}_{nk} \equiv q^{i*}_{nk}$, for all $1 \leq \tau \leq T-1$, so that marginal benefit of production equals marginal (social) cost:

$$\frac{\partial R(q^{1*}_{nk}, q^{2*}_{kn})}{\partial q^1} = \theta_n \tag{1}$$

$$\frac{\partial R(q^{1*}_{nk}, q^{2*}_{kn})}{\partial q^2} = \theta_k. \tag{2}$$

[6] This formulation implies that agents are symmetric, i.e. $p_{nk} = p_{kn}$. There would be no qualitative change in the results if we assumed agents to be asymmetric.

[7] Without commitment, the Revelation Principle cannot be used to ensure that restricting attention to direct mechanisms is without loss of generality. However, we are going to characterize contracts that implement the first best so that there is no need to consider more general mechanisms.

3 The Optimal Sequence of Short Term Contracts

We start by observing that the problem is not trivial when parties can only write short term contracts: it is *not* the case that the first best can be implemented at every period by just repeating the optimal static correlated mechanism. If agents and principals cannot commit to long term contracts, the repetition of the optimal static contract is not implementable because the beliefs of the parties change over time: as long as some information is revealed, agents' information about other agents is modified and so are the conditions for participation and incentive compatibility. However, we now construct an equilibrium where the principal can circumvent her lack of commitment and still implement the first best outcome in all periods, with full separation of types.

Suppose that indeed the principal can achieve full separation in the first period and assume that she has received a report of (θ_n, θ_k). Then, starting with any period $\tau > 1$, the principal faces no more incentive constraints. Still, the subsequent short term contracts have to be individually rational, i.e.: $u_{nk}^{i\tau} \geq 0$.

The optimal short term contract entails setting

$$q_{nk}^{i\tau} \equiv q_{nk}^{i*} \text{ and } t_{nk}^{i\tau} = \theta_n q_{nk}^{i*}, \tag{3}$$

resulting in zero rent at every period $\tau > 1$ for an agent who has reported truthfully in the first period. Although sufficient for efficiency, it is worth noting that the condition on transfers is not necessary, as will become clear later.

Coming back to the first period, an agent i with type θ_1 will truthfully reveal his type iff:

$$\begin{aligned} p_{11}u_{11}^{i1} + p_{12}u_{12}^{i1} \quad \geq \quad & p_{11}\left(t_{21}^{i1} - \theta_1 q_{21}^{i1}\right) + p_{12}\left(t_{22}^{i1} - \theta_1 q_{22}^{i1}\right) \\ & + (\delta + \delta^2 + ... + \delta^{T-1})\Delta\theta(p_{11}q_{21}^{i*} + p_{12}q_{22}^{i*}), \end{aligned} \tag{4}$$

as pretending in the first period that his costs are high results in the agent saving $t_{2k}^{i\tau} - \theta_1 q_{2k}^{i*} = \Delta\theta q_{2k}^{i*}$ forever. An agent i with type θ_2 will reveal his cost iff:

$$p_{21}u_{21}^{i1} + p_{22}u_{22}^{i1} \geq p_{21}\left(t_{11}^{i1} - \theta_2 q_{11}^{i1}\right) + p_{22}\left(t_{12}^{i1} - \theta_2 q_{12}^{i1}\right) \tag{5}$$

This second incentive constraint uses the fact that a θ_2 agent who understates his first period cost can refuse to produce in any subsequent period (the "take the money and run" strategy as identified by Laffont and Tirole 1988, 1993). Remark that if we assume a slightly stronger commitment power by agents, namely, that they can be asked to commit to produce for several periods, an additional negative term $-\frac{1-\delta^T}{1-\delta}\Delta\theta(p_{21}q_{11}^{i*} + p_{22}q_{12}^{i*})$ will appear on the right-hand-side of (5): by pretending to be a low cost agent, the high cost agent commits himself to produce a high quantity and receives a low compensation for all consecutive periods. Since this makes it easier to satisfy the incentive constraint, showing that the first-best can be achieved under spot contracting automatically proves the same result for renegotiation-proof long-term contracts.[8]

[8] Incentive constraints are constructed with 'passive' beliefs by the principal following a "take the money and run" strategy. After an agent's claim in period $\tau = 1$ that he is of type θ_1 and his subsequent refusal to produce for some periods $\tau > 1$, the principal should continue to believe that the agent is indeed of type θ_1 and thus should offer the efficient allocation (defined in (3)) for this type. We claim that these beliefs are the only ones consistent with equilibrium behavior in the continuation game starting from period 2. This is because any more favorable offer by the principal after an observed shut-down would also attract the low cost type. Since this type earns zero rent in the equilibrium of the continuation game, this agent does not suffer from a shut-down but would benefit from convincing the principal that he is actually a deviating high cost type. In order to prevent such an imitation by the low cost type, the principal has to maintain unchanged beliefs off the equilibrium path. In our game, passive beliefs satisfy the intuitive criterion and sequential rationality.

Given that in a separating equilibrium agents obtain no rents in future periods, such a contract will be individually rational for agent i in period 1 iff:

$$p_{n1}u_{n1}^{i1} + p_{n2}u_{n2}^{i1} \geq 0 \qquad n = 1, 2 \tag{6}$$

Setting the first period quantities to their first best levels, the principal leaves no rents to θ_1 agents and ensures their acceptance of the contract by choosing (for instance):

$$u_{11}^{i1} = u_{12}^{i1} = 0. \tag{7}$$

Then, making (4) binding and ensuring that for a high cost agent it is the case that $p_{21}u_{21}^{i1} + p_{22}u_{22}^{i1} = 0$, we have:

$$u_{21}^{i1} = \frac{-p_{22}}{\rho}\frac{1-\delta^T}{1-\delta}\Delta\theta(p_{11}q_{21}^{i*} + p_{12}q_{22}^{i*}), \quad u_{22}^{i1} = \frac{p_{21}}{\rho}\frac{1-\delta^T}{1-\delta}\Delta\theta(p_{11}q_{21}^{i*} + p_{12}q_{22}^{i*}). \tag{8}$$

This utility profile satisfies the previous dynamic incentive constraints. We can now state our main result:

Theorem 1: *There is a sequence of short term contracts that implements the first best in any period, for any value of δ and any $\rho \neq 0$. Hence, the principal's ability to commit is irrelevant.*

Proof: The previous utility profiles leave no rent at any period to the agents. Then maximization of the expected welfare per period is obtained by choosing first best quantities.

It should be clear to the reader that although derived with a binary cost distribution, the result is more general: whenever the principal can extract all rents in a static framework, her commitment ability is irrelevant in a dynamic setting.[9]

It is indeed true that the lack of commitment of the principal subjects her to some "ratcheting": she cannot refrain from using in subsequent periods what she has learned in the first. It is also true that this effect creates an extra incentive for agents to misreport their types in the first period. But the correlated mechanism is powerful enough to make sure that regardless of the size of the extra rents that an agent can secure in future periods, the principal can recoup them in the first one. This is achieved by increasing the loss an agent would make in the first period, if he was to hide his type, given that the other agent does not and that types are correlated. As the time horizon increases, future gains of initially misreporting an efficient type increase. However the principal can still recoup them, but the risk to which the agent is exposed (here $u_{22}^{i1} - u_{21}^{i1}$) has to increase to maintain incentive compatibility. Notice however that after this first period, the mechanism provides full insurance for all remaining periods. As already indicated in the introduction, we see the main application of our analysis to be dealing with the regulation of large privatized former public utility companies. In that respect concerns about risk aversion may be less relevant. We investigate the robustness of our result to the introduction of a lower bound on transfers in the following section.

Focusing on our main application, regulation of former utilities, the optimal mechanism above has a simple interpretation: regulated firms obtain cost reimbursement (the so called "cost-plus-regulation", that is $t = \theta q$) except possibly in the first period when high costs are reported. Such a firm is put to

[9] We refer the reader to Crémer and McLean (1985, 1988) for such conditions. Only in the two type case considered here is non independence sufficient. Otherwise, first best implementation requires the conditional distribution matrix to have full rank.

the test: if another firm claims that its costs are low, a penalty is imposed. If the other firm also reports high cost, costs are reimbursed and firms receive an extra payoff. This extra transfer is calculated to cover a high production cost in expectation, where the expectation is taken conditionally on the firm telling the truth, i.e. conditional on high cost. But it is also chosen in such a way that a deviating low cost firm receives an expected payoff of 0. This is possible since the conditional distribution when a firm has a low cost differs from the one when its cost is high.

Notice that the optimal contract just described is consistent with the observation that this sort of yardstick contracts are rarely used in practice, while cost-plus-regulation seems pervasive. The model can provide some justification for this fact as here yardstick mechanisms are used only initially, when a firm claims high cost. After that we should only observe cost-plus-regulation. It is enough to put the firm to the yardstick test once.

The analysis so far was conducted assuming that an agent's cost was determined once and for all at the beginning of the game. This simplifying assumption may not be realistic, especially when one considers a long time horizon. To conclude this section, we relax this assumption of perfect intertemporal correlation and show that Theorem 1 still holds for imperfect intertemporal correlation.

To this end, we focus on a simple two period model. The extension to a more general model with T periods is straightforward but involves even more cumbersome notation. We consider the following specific intertemporal correlation structure. First nature draws θ^i at the beginning of period 1. With probability $\varepsilon \leq 1$, agents' costs in $t = 2$ are the same as in period 1. With probability $1 - \varepsilon$, agents' costs are drawn again from the same initial distribution.

Define by ${}_{nk}\nu$ the conditional probability distribution over second period costs, given that first period costs are (θ_n, θ_k), i.e. agents 1 and 2 have first period costs θ_n and θ_k respectively. For example, ${}_{12}\nu_{12} = \varepsilon + (1 - \varepsilon)p_{12}$ is the probability that given that first period costs are (θ_1, θ_2), second period costs are also (θ_1, θ_2). Some observations are due to clarify the implications of this structure:

- This formalization contains two special cases. If $\varepsilon = 1$, the model is identical to the previous one: costs are perfectly correlated over time and Theorem 1 applies. If $\varepsilon = 0$, the time periods are independent. Obviously there is no ratcheting as information is not long lived. The principal has to solve a sequence of static problems. Therefore she can implement the first best at every period, regardless of her commitment abilities. The analysis below is thus concerned with $\varepsilon \in]0, 1[$.
- Probability distributions ${}_{12}\nu$ and ${}_{21}\nu$ treat agent's 1 and 2 asymmetrically (e.g. ${}_{12}\nu_{12} \neq {}_{12}\nu_{21}$), which implies that second period spot contracts will differ for each agent.
- Although first period costs are positively correlated, second period costs can be uncorrelated or negatively correlated. Define by ${}_{nk}\rho$ the second period cost correlation coefficient. Then ${}_{nn}\rho = (1 - \varepsilon)^2\rho + \varepsilon(1 - \varepsilon)p_{kk}$ and thus ${}_{nn}\rho > 0$, $n = 1, 2$. Intuitively, if first period costs are identical across agents it is more likely that costs are the same in the second period as well. In contrast, ${}_{nk}\rho = (1 - \varepsilon)^2\rho - \varepsilon(1 - \varepsilon)p_{kn}$, $n \neq k$, and this expression is either positive or negative for sufficiently small, respectively large values of ε. Intuitively, if first period costs differ and ε is very large it is more likely that second period costs will also differ which implies ${}_{nk}\rho < 0$. For one value of ε, namely $\varepsilon = \rho/(\rho + p_{nk})$, second period costs are uncorrelated, i.e. ${}_{nk}\rho = 0$. For a discussion of this case see the footnote following Corollary 1.

We have:

Corollary 1: *For all $\varepsilon \neq \rho/(\rho + p_{nk})$ there is a sequence of short term contracts that always implements the first best in both periods. Hence, the principal's ability to commit is irrelevant.*[10]

Proof: see appendix.

Somehow, whenever $\varepsilon < 1$, there is less scope for the ratchet effect to play an important role, and so it is not very surprising that our result can be extended to any value of ε. However it considerably enhances the relevance of our finding.

4 The Value of Long Term Contracting

We now explore the possibility that long term contracting may achieve more than a sequence of short term contracts in environments where the usefulness of correlated mechanisms is limited. We study two such limitations: the first one introduces lower bounds on transfers that can be imposed on agents, the second is concerned with situations where although the principal is dealing with a single agent initially, there is the possibility of contracting with other agents in the future. We show that even with such constraints, the impossibility of principals to commit not to renegotiate contracts does not matter.

4.1 Lower Bound on Transfers and Principal's Commitment

Considering the previous sequence of short term contracts, a high cost agent is subject to some risk as the first period transfers he receives along the equilibrium path are:

$$t_{21}^{i1} = \theta_2(p_{11}q_{21}^{i*} + p_{12}q_{22}^{i*}) - \frac{p_{22}}{\rho}\frac{1-\delta^T}{1-\delta}\Delta\theta(p_{11}q_{21}^{i*} + p_{12}q_{22}^{i*}), \tag{9}$$

$$t_{22}^{i1} = \theta_2(p_{11}q_{21}^{i*} + p_{12}q_{22}^{i*}) + \frac{p_{21}}{\rho}\frac{1-\delta^T}{1-\delta}\Delta\theta(p_{11}q_{21}^{i*} + p_{12}q_{22}^{i*}) \tag{10}$$

Consider now the possibility of a lower bound on transfers. For instance, agents may be protected by some form of limited liability so that we need $t_{nk}^{i\tau} \geq K$ with $K \leq \max\{\theta_1 q_{11}^{i*}, \theta_1 q_{12}^{i*}, \theta_2 q_{21}^{i*}, \theta_2 q_{22}^{i*}\}$: the constraint on transfers would not prevent the first best outcome to be implemented, absent informational issues.[11] We now explore whether this constraint affects our results on the importance of a principal's commitment.

The previous contract is feasible only if:

$$K \leq \theta_2(p_{11}q_{21}^{i*} + p_{12}q_{22}^{i*}) - \frac{p_{22}}{\rho}\frac{1-\delta^T}{1-\delta}\Delta\theta(p_{11}q_{21}^{i*} + p_{12}q_{22}^{i*}),$$

[10] For $\varepsilon = \rho/(\rho+p_{nk})$ second period costs are uncorrelated and the principal cannot make use of correlated mechanisms in this period. She will thus only implement the second best in the second period and the agent will be left with some rents in equilibrium. Nevertheless, the principal will implement the first best in the first period with appropriately selected correlated mechanisms that take into account the agents' second period rents. Hence also in this case, the principal's commitment power is irrelevant.

[11] Demougin and Garvie (1991) provide a detailed analysis of the static case.

which is equivalent to

$$\frac{\frac{1-\delta^T}{1-\delta}\Delta\theta(p_{11}q_{21}^{i*}+p_{12}q_{22}^{i*})}{\theta_2(p_{11}q_{21}^{i*}+p_{12}q_{22}^{i*})-K}\leq\frac{\rho}{p_{22}}. \tag{11}$$

Thus, for the previous contract to work we need ρ not too small. Observe that implementing the first best under this new constraint may be more difficult in a dynamic setting than in a static one: the condition is more stringent the higher the number of periods (the left hand side of (11) increases with T, $T=1$ corresponding to the static condition). However this reasoning is incomplete as it does not distinguish between the different commitment possibilities.

To see why, let us consider first the case where the principal could fully commit to future contracts. The repeated interactions give the possibility for the principal to spread penalties over time. For instance, the principal can at each period offer the same production levels and the same utility profiles as before except for:

$$u_{21}^{i\tau}=\frac{-p_{22}}{\rho}\Delta\theta(p_{11}q_{21}^{i*}+p_{12}q_{22}^{i*}),\quad u_{22}^{i\tau}=\frac{p_{21}}{\rho}\Delta\theta(p_{11}q_{21}^{i*}+p_{12}q_{22}^{i*})\qquad\forall\tau,$$

The difference with the previous sequence of contracts is that now a high cost agent is subject to a transfer scheme that results in either a negative or a positive utility *in every period,* depending on the report of the other agent. This contract gives the same expected welfare to the principal as the one of Theorem 1. It also satisfies all the previous constraints. Agents are guaranteed a non negative utility in expectation. Incentive constraints are also satisfied as a low cost agent deviating in $\tau=1$ would expect:

$$\begin{aligned}&p_{11}\left(\Delta\theta q_{21}^{i*}-\frac{p_{22}}{\rho}\Delta\theta(p_{11}q_{21}^{i*}+p_{12}q_{22}^{i*})\right)\left(1+\delta+\delta^2+...+\delta^{T-1}\right)\\&+p_{12}\left(\Delta\theta q_{22}^{i*}+\frac{p_{21}}{\rho}\Delta\theta(p_{11}q_{21}^{i*}+p_{12}q_{22}^{i*})\right)\left(1+\delta+\delta^2+...+\delta^{T-1}\right),\end{aligned}$$

which is equal to the right hand side of (4). Similarly a high cost agent has no incentive to deviate.

To implement the long term contract the principal must be able to prevent the "take the money and run strategy" by imposing penalties to an agent who first reports low cost and then stops to produce. Also, the long term contract should prevent an agent who reported high cost while the other one reported low cost to exit the market. Therefore, with full commitment, the first best can be implemented in our dynamic setting whenever:

$$\frac{\Delta\theta(p_{11}q_{21}^{i*}+p_{12}q_{22}^{i*})}{\theta_2(p_{11}q_{21}^{i*}+p_{12}q_{22}^{i*})-K}\leq\frac{\rho}{p_{22}}, \tag{12}$$

which is identical to the static condition.

This contract where a high cost agent is subject to a correlated mechanism at every date is renegotiation-proof. If the agent reveals low cost, the principal is happy to repay his cost at every period. If the agent initially reports high cost, the principal repays less than those if the other agent reports low cost, while he repays more if both agents claim high cost. Importantly, the principal does so in every period. Then, in the first case, the principal does not want to renegotiate. The agent would like to leave, but the long term contract can have a clause that forbids exit. In the second case, the principal would like to repay less but the agent refuses to renegotiate.

This optimal renegotiation-proof long term contract cannot be implemented by a sequence of short term contracts. If both agents report high cost in the first period, in future periods, the principal would not offer a payment that leaves agents with positive rents and so $u_{22}^{i\tau} > 0$ is not implementable for $\tau > 1$. Similarly, if agents announce different costs, the high cost agent prefers to leave the market, since he cannot be forced to receive a negative utility in consecutive periods. In other words, $u_{21}^{i\tau} < 0$ is not implementable for $\tau > 1$.

The principal's inability to write long term contracts could be circumvented by asking her to pay a high reimbursement in the first period if both agents report high cost as detailed in (10). Such a scheme would be feasible in the absence of any restriction on the *positive* transfers from the principal to the agent.[12] In all ensuing periods both high cost agents are simply reimbursed their costs. In contrast, the agent's lack of commitment remains a binding constraint due to the lower bound on transfers. In fact, only the sequence of short term contracts of Theorem 1 is subgame perfect so the condition for their implementability when transfers are constrained remains (12).

Putting these observations together gives the following result:

Proposition 1 *Suppose that there exists a lower bound K on the transfers that agents can be asked to receive. Then, whenever the principal can implement the first best with full commitment, she can do so with long term contracts even if she cannot commit not to renegotiate. For some correlation values and with a sufficiently long time horizon a sequence of short term contracts fails to achieve the same outcome.*

Proof: It has already been argued that a long term contract with renegotiation implements the first best whenever full commitment does too. Comparing (11) and (12), whenever (11) is satisfied so is (12) but the converse is not true.

Constraining the correlated mechanisms to satisfy some constraint on transfers does not necessarily make the principal's ability to commit relevant. First it remains true that some form of lack of commitment is always without consequence: whenever the principal can implement the first best with full commitment, she can do so with long term contracting and renegotiation. Her inability to commit not to renegotiate is thus immaterial. Indeed, long term contracting allows the principal to impose smaller punishments per period, but for a longer period of time (and similarly, she can offer smaller rewards per period, but for a longer period of time, so that Proposition 1 would remain valid if instead we had considered an upper bound on transfers). This is not undone by renegotiation possibilities. Second, there is a welfare loss if the principal cannot write long term contracts at all, but only for intermediate values of correlation. For these values, the principal would like to submit the agent who reports high cost to a sequence of yardstick contracts. The impossibility to do so comes from the agent's lack of commitment: a low cost agent who deviates in the first period could "take the money and run" as he would refuse the yardstick contracts being offered in consecutive periods which would give him a negative expected utility.

[12] Notice that the case where there exist some *upper* bounds on the transfers could correspond to situations where for instance political constraints prevent regulators to leave too large rents to firms. In that respect, such constraints may also impede on the implementation of the optimal correlated mechanisms. However, Proposition 1 holds with an upper bound on transfers, that is, the principal's inability not to renegotiate long term contracts is immaterial in the same way as it is with a lower bound on transfers.

4.2 The Threat of Future Correlated mechanism

Consider again our main application to industrial regulation. Although many regulated agents have come to share their core markets with newcomers, most of the time the entry process is not over: there remains scope for further entry. Therefore, it is worth investigating the case where instead of being subject to current competition, regulated firms operate under the threat of future entry. We show that in such a situation, a sequence of short term contracts fails to implement the first best, while again there is no loss in having the principal unable to commit not to renegotiate.

To make this point, we suppose that initially there is only one agent, an "incumbent" I. We consider the potential entry of one new agent (E) in the future: there is at least a date τ' where agent E enters with probability π.[13] If entry takes place, we assume that E's cost is correlated with the incumbent's. The set up is as in section 2 except that consumer surplus is written as $R(q^I)$ if only the incumbent is in the market and as $R(q^I, q^E)$ after entry. In a first step, we neglect to study the asymmetric information problem between the entrant and the principal, that is, we do not analyze the optimal contract that allows the principal to elicit E's cost. A discussion of this problem can be found after the next proposition, where we also study the incentives to enter. In this section, we assume no constraints on feasible transfers.

With full commitment, one can construct a long term contract that leaves no rents to the incumbent. Consider for instance the following contract: the principal offers to repay the cost that the incumbent claims to incur to produce q^I unless entry takes place. If E enters, an incumbent who has reported high cost is submitted to a correlated mechanism, calculated so that it imposes expected penalties to a deviating low cost incumbent high enough to exceed all future rents. We then show:

Proposition 2 *It is enough that there is at least one period in the future where an entrant with correlated cost may enter to implement the first best with a long term contract. This contract is renegotiation-proof so that the inability of the principal to commit not to renegotiate is irrelevant. Short term contracting cannot achieve this result.*

Proof: see appendix.

There is more than one way to implement the first best with a renegotiation-proof long-term contract as one could submit the high cost incumbent to yardstick contracts for several periods of time (and spread penalties over time as previously). But the contract above is quite simple: the principal offers to reimburse costs forever unless the incumbent demands a high reimbursement. Then, if entry takes place, the incumbent is put to the test: he receives a transfer that depends on the entrant's cost report. This is renegotiation-proof as it implements the first best along the equilibrium path. For such a contract to work the principal must be able to prevent the take-the-money-and-run strategy. Otherwise, a deviating low cost incumbent could report high cost and exit the market upon entry of E to avoid being put to the test. The long term contract has to stipulate penalties for such a behaviour, and those are obviously renegotiation-proof.

In fact, there is even a mechanism which is immune to the threat of the take-the-money-and-run strategy: in the first period the principal asks the incumbent to report a cost level. If the incumbent reports low cost, he gets it reimbursed at every period. If the incumbent reports high cost, he has to

[13] Still with exogenous entry, having either entry for sure or multiple entry would not invalidate our results.

pay a fee F initially and then the incumbent has his variable cost reimbursed at the high cost level, i.e. at $\theta_2 q$. If entry takes place and if the new entrant has high cost, the principal repays F plus some premium to the incumbent. One can always find F and a premium so that a high cost agent breaks even on average while a low cost agent does not if he deviates by pretending his costs are high. This contract is implemented even if the principal cannot commit not to renegotiate and the agent cannot commit not to quit the market at some time in the future.

Consider now a sequence of short term contracts. The first contract described (with future penalties) cannot be implemented with short term contracts because if the principal cannot specify future penalties to ban exit, an agent can leave the market whenever his expected payoff per period is negative. A low cost agent would then prefer to report high cost and take advantage of the higher reimbursement as long as entry does not occur, and then possibly leave upon entry. Similarly, the second contract described which makes use of an initial fee is not implementable absent long term contracting because we need the principal to repay a high cost agent following a future entry of a high cost competitor.

In summary, with future competition it is the *simultaneous* inability of both parties to write long term contracts that prevents implementation of the first-best with a sequence of short-term contracts, in contrast to the above subsection where we studied the implication of lower bounds on transfers and where only the agent's lack of commitment mattered.

Notice that here we abstract from discussing the incentive problems for the entrant. If the entrant itself has some private information about his cost, the principal cannot use the *incumbent's* announcement to costlessly extract the entrant's information since the incumbent's costs are known along the equilibrium path. Moreover we have taken so far the probability of entry as exogenous. We now study more precisely a new agent's entry decision and the principal's incentives to promote entry.

To better highlight the implications of these changes, we make a number of simplifying assumptions. First we suppose that $T = 2$.[14] In $\tau = 1$, only the incumbent can produce (and $R(q^I)$ is the principal's revenue from this production), while in $\tau = 2$, either the entrant entered and there are two agents producing in that period (with $R(q^I, q^E)$ the principal's revenue function) or the situation is the same as in $\tau = 1$. We suppose that entry is desirable per se, that is, in $\tau = 2$ there always exists q^E so that: $R(q^I, q^E) - \theta^I q^I - \theta^E q^E \geq R(q^I) - \theta^I q^I$ for all θ^i, q^I.

Next, we suppose that the entrant has to pay a fixed cost of entry F. If he chooses to do so, then the entrant's marginal cost of production, θ^E, is realized and we take $\theta^E \in \{\theta_1, \theta_2\}$ as for the incumbent and denote as in the rest of the text by p_{nk} the probability that the entrant has cost θ_k while the incumbent has θ_n. Assume that the entrant only learns the value of his marginal cost upon entry.

Our previous proposition tells us that if entry takes place with positive probability, the first best is implemented in $\tau = 1$ and the incumbent truthfully reveals his type at that period. Therefore, the entrant when deciding whether or not to enter knows the incumbent's cost. This information is of some importance because the extent to which his private information matters depends on what the incumbent has revealed: indeed, the incumbent's report about his own cost is a signal about the entrant's private information. To see why this matters, remark that if the entrant enters, the best *short term* contract that the principal will offer him solves:

$$\max_{q^E_{n1}, q^E_{n2}} p_{1/n}\left[R(q^{I*}_{n1}, q^E_{n1}) - \theta_1 q^E_{n1} - \Delta\theta q^E_{n2}\right] + p_{2/n}\left[R(q^{I*}_{n2}, q^E_{n2}) - \theta_2 q^E_{n2}\right], \qquad n = 1, 2,$$

[14] The more general case makes notations cumbersome without adding much insight.

where $p_{k/n} = \Pr(\theta^E = \theta_k/\theta^I = \theta_n)$. As usual, if the entrant turns out to be a low cost type, then his production level is first best, i.e., satisfies $\partial R(q^{I*}_{n1}, q^E_{n1})/\partial q^E = \theta_1$, while in the case where his costs are high, there is a distortion, proportional to the likelihood ratio $\frac{p_{1/n}}{p_{2/n}}$. This ratio clearly depends on θ^I, that is on the information that the incumbent has revealed about his own cost. We made this point clear focusing on short term second period contracts (which do not implement the first best as we know from our previous analysis) but the argument remains valid in the case of long term contracts with renegotiation.

This discussion also makes clear that the entrant can expect a minimum rent of

$$U^E = p_{1/n}\Delta\theta q^E_{n2}$$

Therefore, whenever $F \leq \min\{p_{1/1}\Delta\theta q^E_{12}, p_{1/2}\Delta\theta q^E_{22}\}$, where q^E_{n2}, $n = 1, 2$, are taken to be the solutions to the previous programmes, there will always be entry: when the principal implements the optimal contract for the entrant after entry, the entrant is guaranteed some informational rents high enough to make it worthwhile for him to pay the fixed cost. Consider now higher values of F. Unless the principal promises higher levels of rents to the entrant, entry may not take place. Notice that the advantage of entry from the principal's perspective is that she can extract all the rents from the incumbent as in Proposition 2. Therefore, she may find it optimal to include in the long term contract offered in $\tau = 1$ a covenant that states that the entrant will be offered rents in the second period $U^{E\prime} \geq \max\{U^E, F\}$. This contract is renegotiation-proof: once the entrant has entered the principal would like to renegotiate if $F > U^E$, as she can extract the entrant's information about his marginal cost for less, but not the entrant. The trade-off faced by the principal regarding the decision to include this covenant is as follows: on the negative side, she has to offer larger rents to the entrant in $\tau = 2$, on the positive side, in addition to the increase in her revenue in $\tau = 2$ due to the production of two firms $(R(q^I, q^E) - R(q^I))$, there is the added benefit of extracting the incumbent's information and implementing the first best in $\tau = 1, 2$. Consequently, we show:

Proposition 3 *Suppose that there exists a fixed cost F of entry. For $F \leq \min\{p_{1/1}\Delta\theta q^E_{12}, p_{1/2}\Delta\theta q^E_{22}\}$ or if $p_{1/1}\Delta\theta q^E_{12} \leq F \leq p_{1/2}\Delta\theta q^E_{22}$, there is no need for the principal to actively promote entry and the incumbent keeps no rent. Otherwise, there exists for any finite F a threshold $\delta_0(F) > 0$ so that for all $\delta \leq \delta_0$ the principal promotes entry by offering a long term contract stipulating rents for the entrant high enough to repay F, while the incumbent keeps no rent.*

Proof: see appendix.

Proposition 3 shows that our previous findings do not rely on the assumption of an exogenous entry process. If the principal values sufficiently the first period (δ low), actively promoting entry is her favored policy because it generates a first period gain and this more than compensates any possible second period loss. Proposition 3 also points towards a new possibility: if $p_{1/1}\Delta\theta q^E_{12} \leq F \leq p_{1/2}\Delta\theta q^E_{22}$ the incumbent who has low cost realizes that absent a pro-entry policy, entry will not take place if he reveals his cost truthfully. Does this prevent the principal from extracting the incumbent's rents? It does not because if the incumbent were to lie and announce high cost, entry would take place and the incumbent would be put to the yardstick test. Therefore, the incumbent may not benefit from his private knowledge even though he faces neither present nor future competition. Entry does not actually take place in equilibrium, but the mere threat of entry deters the incumbent from exaggerating his cost.

More generally, we could have studied the implication of the entry process in a model with more than 2 periods. The insight of Proposition 3 will not be invalidated but moreover new effects will appear. Indeed, suppose that there is now a third period during which a second entrant may enter. Once he has entered, the second entrant is now in the same situation as our incumbent previously: all his rents can be extracted and the first best production levels for this entrant can be implemented. Of course, some rents have to be given up to induce him to pay the fixed cost F. As long as it is Pareto efficient, the principal can induce entry by leaving a rent to the second period entrant just equal to F. If there were T periods and N potential entrants, the principal could induce entry of $N-1$ entrant with this sequential process and always implement the first best. In fact there is even a way to extract the rents of the final entrant by having a process of simultaneous entry: if they all enter at once and are subject to a yardstick mechanism, entrants obtain no rents from their private knowledge of their costs. Of course, for entry to take place the principal will have to commit to reimburse N times F. But reimbursing entry costs and implementing correlated mechanisms achieves the first best outcome. This argument could be taken as supportive of the view that instead of being substitute, regulation and competition could complement each other.

4.3 Conclusion

This paper has shown that the dynamics of contracting when agents' private information is correlated strongly differs from the uncorrelated case. Most importantly, we have shown that mechanism design in correlated environments offers conclusions that depart from those obtained under independence in more than one aspect. The fact that correlated mechanisms implement first best outcomes has often been viewed as troublesome for contract theory because it introduces a discontinuity between the case of uncorrelated and correlated information. In the former situation, the principal can only implement a second best allocation that can be very inefficient relative to the outcome under full information, whereas in the latter the first best obtains, no matter how weak correlation is.[15] This paper shows that a situation in which agents' private information is correlated starkly departs from the situation of uncorrelated information in another respect: in a correlated world, the inability of a principal to commit to long term contracts does not matter. Our findings may thus have implications for the literature on the Coase conjecture (as in Hart and Tirole 1988), a manifestation of the lack of commitment of a durable goods monopolist, which could turn out to be not so severe if consumers have correlated valuations. They may also matter for the theory of organizations. For instance, Olsen (1996) makes the point that integration of several units in one firm may be suboptimal if aggregation increases the scope for ratcheting. This conclusion could be reversed if subdivisions have correlated private information. Another range of applications regards the structure of supervision. Typically, a supervisor in charge of overseeing an agent observes a signal correlated with the agent's private information. The dynamics of supervision could be free of ratcheting as the commitment of the principal would not be an issue.

Our findings also have several implications for what we regard as our main application, industrial regulation. First, it makes regulator's inability not to renegotiate existing contracts irrelevant. Second, it provides an explanation for the relatively excessive use (from the viewpoint of incentive theory) of cost-plus-regulation and the minor role played by yardstick mechanisms in practice: we show in a dynamic setting that cost-plus-contracts are chosen in every period but one. Third, it suggests

[15] To our knowledge, only two approaches have attempted to bridge the gap between the two settings. Using the fact that with very small correlation, truth telling requires submitting agents to highly risky bets, Robert (1991) and Kosmopoulou and Williams (1998) show that the usefulness of correlated mechanisms vanishes when correlation goes to zero if agents are risk averse and/or if a bound on the magnitude of transfers is imposed (see also Demougin and Garvie 1991). Laffont and Martimort (2000) and Faure-Grimaud, Laffont and Martimort (2003) have shown that correlation can help agents to collude which may prevent the principal from making use of correlated mechanisms.

that regulation becomes more efficient with competition not only because informational asymmetries are reduced but also because principals' shortcomings can be circumvented. This paper can provide arguments to challenge the view that the development of competition should necessarily reduce the role of regulators. If indeed more competition reduces the need for regulation, it is shown here that it can also increase its marginal benefits. The overall effect in practical issues is to be determined.

Some further extensions may be considered. At a theoretical level, the recent papers by McLean and Postlewaite (2002, 2004) show that the amount of rent left to agents with correlated private information can be made arbitrarily small if an agent's 'informational size' is vanishing. Their setting differs from ours as they analyze a situation in which an agent receives a private signal correlated with the true state of nature (for example the cost state in our principal setting) that affects all agents' utilities simultaneously. Intuitively, an agent is "informationally small" if his signal adds little to the information contained in the aggregate of the other agents' signals. Agents might become informationally small as the number of agents increases, holding fixed the accuracy of each agent's signal. In our framework this could mean that implementing first best regulation can be achieved with relatively little variance in transfers even for small degree of correlation, as the number of competitors increases.

Appendix

Proof of Corollary 1:

We want to show that the first-best quantities q_{nk}^{1*}, q_{kn}^{2*} are implementable in both periods. In line with the preceding section, denote by t_{nk}^i the *first* period transfer to agent i when agent i reports θ_n and agent j reports θ_k and call $u_{nk}^i \equiv t_{nk}^i - \theta_n q_{nk}^{i*}$ agent i's *first* period utility when both agents truthfully announce their types θ_n and θ_k. We have dropped the time parameter to simplify the notation. Then, denote by ${}_{nk}h_{n'k'}^i$ the *second* period transfer to agent i when agent 1 reports θ_n in the first and $\theta_{n'}$ in the second period, while agent 2 reports θ_k in the first and $\theta_{k'}$ in the second period. Similarly, call ${}_{nk}w_{n'k'}^i \equiv {}_{nk}h_{n'k'}^i - \theta_{n'} q_{n'k'}^{i*}$ agent i's *second* period utility when both agents announce their costs truthfully in both periods. We need this specification because a) first-period announcements affect the principal's beliefs about second period costs and therefore affect his contract offers and b) agents are not symmetric in the second period.

In what follows we will solve for the optimal contract for agent 1 only, assuming that agent 2 reports his types truthfully in both periods. A similar analysis applies for agent 2, given that 1 reports truthfully.

We start in the second period. Assume that in the first period agents announced truthfully their types (θ_n, θ_k).

Then, it is straightforward to check that in the second period the principal will elicit agent 1's cost truthfully, implement the first-best quantities and leave no rent to agent 1 by setting

$$\begin{aligned}
{}_{nk}w_{11}^1 &= 0 & {}_{nk}w_{12}^1 &= 0 \\
{}_{nk}w_{21}^1 &= -\frac{{}_{nk}\nu_{22}}{{}_{nk}\rho}\Delta\theta({}_{nk}\nu_{11}q_{21}^{1*} + {}_{nk}\nu_{12}q_{22}^{1*}), & {}_{nk}w_{22}^1 &= -\frac{{}_{nk}\nu_{21}}{{}_{nk}\nu_{22}}\,{}_{nk}w_{21}^1.
\end{aligned}$$

Turning to period 1, with the second period contract in place call r_n^1 the second period rent that agent 1 with first- period type θ_n claiming to be θ_m can expect to make in the second period. Then,

$$r_n^1 = \sum_k \frac{p_{nk}}{p_{n1} + p_{n2}}(\,{}_{nk}r_1^1 + \,{}_{nk}r_2^1),$$

where

$$\begin{aligned}
{}_{nk}r_1^1 &= \max\{0,\ {}_{nk}\nu_{11}\ {}_{mk}w_{21}^1 + \ {}_{nk}\nu_{12}\ {}_{mk}w_{22}^1 + \Delta\theta(\ {}_{nk}\nu_{11}q_{21}^{1*} + \ {}_{nk}\nu_{12}\ q_{22}^{1*})\} \\
{}_{nk}r_2^1 &= \max\{0,\ {}_{nk}\nu_{21}\ {}_{mk}w_{21}^1 + \ {}_{nk}\nu_{22}\ {}_{mk}w_{22}^1, \\
&\qquad {}_{nk}\nu_{21}\ {}_{mk}w_{11}^1 + \ {}_{nk}\nu_{22}\ {}_{mk}w_{12}^1 - \Delta\theta(\ {}_{nk}\nu_{21}q_{11}^{1*} + \ {}_{nk}\nu_{22}\ q_{12}^{1*})\}.
\end{aligned}$$

Then, the following optimal first period contract to agent 1 ensures truthful revelation of first period costs, implements first-best quantities and leaves no rent to agent 1.

$$\begin{aligned}
u_{11}^1 &= \frac{p_{12}}{\rho}(\delta r_2^1 - \Delta\theta(p_{21}q_{11}^{1*} + p_{22}q_{12}^{1*})), \quad u_{12}^1 = -\frac{p_{11}}{p_{12}}u_{11}^1 \\
u_{21}^1 &= \frac{-p_{22}}{\rho}(\delta r_1^1 + \Delta\theta(p_{11}q_{21}^{1*} + p_{12}q_{22}^{1*})), \quad u_{22}^1 = -\frac{p_{21}}{p_{22}}u_{21}^1.
\end{aligned}$$

Remark, that in the first period also a θ_2 agent's incentive constraint might be binding. He could announce low cost and suffer a negative utility in the first period in order to obtain a positive rent

r_2^1 in the second period. In order to make such a deviation non profitable, the utility level given in equilibrium to a θ_2 agent must depend on the other agent's types as well.

Proof of Proposition 2:

Consider a cost plus contract for the incumbent I at every period but possibly at date τ' if E enters. The quantities that I is asked to produce in every period are the first-best levels. These are q_n^{I*} if I has cost θ_n and is alone in the market, i.e. the consumer surplus is $R(q^I)$, and q_{nk}^{I*}, if I has cost θ_n, E has cost θ_k and the market is shared, i.e. the consumer surplus is $R(q^I, q^E)$. Following entry at date τ', a high cost incumbent's transfer payments are $\{t_{2k}^{I\tau'}\}_{k=1,2}$, depending on the cost announcement of the entrant, whereas a low cost incumbent receives his cost.

To check that such a contract implements the first best, notice that a θ_1 incumbent's incentive constraint is satisfied if we can find transfers $t_{21}^{I\tau'}$ and $t_{22}^{I\tau'}$ such that:

$$\begin{aligned} 0 \quad \geq \quad & \textstyle\sum_{\tau<\tau'} \delta^{\tau} \Delta\theta q_2^{I*} \\ & + \delta^{\tau'} \left[(1-\pi)\, \Delta\theta q_2^{I*} + \pi \left(p_{11} \left(t_{21}^{I\tau'} - \theta_1 q_{21}^{I*} \right) + p_{12} \left(t_{22}^{I\tau'} - \theta_1 q_{22}^{I*} \right) \right) \right] \\ & + \textstyle\sum_{\tau>\tau'} \delta^{\tau} \left[(1-\pi)\, \Delta\theta q_2^{I*} + \pi \left(p_{11} \Delta\theta q_{21}^{I*} + p_{12} \Delta\theta q_{22}^{I*} \right) \right] \end{aligned} \tag{13}$$

Indeed, an incumbent agent with low cost obtains zero rent at every period for truthfully reporting his type. Pretending otherwise results in a positive rent of $\Delta\theta q_2^{I*}$ in every period before entry takes place, since the incumbent is a monopolist in the market. Now at date τ', if entry does not take place, the incumbent remains a monopolist and produces that same level forever. If entry does take place, the incumbent is offered a yardstick contract at that date only. In all subsequent periods the incumbent shares the market with the entrant and receives an expected rent of $p_{11}\Delta\theta q_{21}^{I*} + p_{12}\Delta\theta q_{22}^{I*}$. Remark, that we could have also constructed a mechanism which submits the incumbent to yardstick competition for a longer period of time, as in the section on bounded transfers. The incentive constraint of a θ_2 incumbent is trivially satisfied as lying would result in negative rents at every period. So we simply need the two participation constraints to be satisfied, and given the cost plus contract at every period but τ', only the high cost participation remains to be checked. This constraint reduces to:

$$p_{21} \left(t_{21}^{I\tau'} - \theta_2 q_{21}^{I*} \right) + p_{22} \left(t_{22}^{I\tau'} - \theta_2 q_{22}^{I*} \right) \geq 0 \tag{14}$$

Whenever $p_{11}p_{22} - p_{12}p_{21} > 0$, (13) and (14) can both be made binding with appropriate transfers $t_{21}^{I\tau'}$ and $t_{22}^{I\tau'}$, leaving no rents to any type of agent.

This contract is renegotiation-proof: the principal can forbid a possibly deviating low cost agent to exit the market if entry takes place, to avoid being subjected to the yardstick contract. Since along the equilibrium path the first best is implemented there is no scope for renegotiation.

Proof of Proposition 3:

Consider first the possibility that the long term contract does not specify anything for the entrant. If entry takes place, the principal then offers a contract to the entrant in $\tau = 2$. This contract may be dependent on what the incumbent has revealed. The contract needs to satisfy the low cost type's incentive constraint and the high cost type's participation constraint, that is:

$$\begin{aligned} t^E_{n1} - \theta_1 q^E_{n1} &\geq t^E_{n2} - \theta_1 q^E_{n2} \\ t^E_{n2} - \theta_2 q^E_{n2} &\geq 0 \end{aligned}$$

when the incumbent reported θ_n. With these two constraints binding, the optimal contract is the solution of the programme presented in the text. Therefore a low cost entrant gets a rent equal to $\Delta\theta q^E_{n2}$. Therefore, whenever $F \leq p_{1/n}\Delta\theta q^E_{n2}$ entry takes place. Similarly, when the principal abstains from offering a long term contract that contains terms concerning the entrant and when $p_{1/1}\Delta\theta q^E_{12} \leq F \leq p_{1/2}\Delta\theta q^E_{22}$, the optimal short term contract is conducive to entry only if the incumbent announces high cost. There is no need for the principal in that case to offer a different contract because such a potential entry is enough to prevent the incumbent to wrongly pretend that it has high cost. This is compatible with the observation that the incumbent receives no rents and there is no entry.

For other values of F, entry does not take place unless the principal offers something else than the optimal short term contract to the entrant. It is always weakly optimal to offer such a contract at $t = 1$, as then the incumbent knows that the principal actively promotes entry at $t = 2$. In fact, the principal has to choose between two options.

- Either she does not actively promote entry. In that case, the optimal second period contract with no commitment not to renegotiate is derived as for example in Laffont and Martimort (2002), pp 365-369, and we know that there exists a threshold δ'_0 for which the best contract is fully separating in $t = 1$ whenever $\delta \leq \delta'_0$. Moreover this contract implements the usual static second best contract in the first period for the incumbent.

- Or, the principal decides to offer at $\tau = 1$ a contract for a potential entrant at $\tau = 2$ that leaves the entrant with expected rents in that period larger than F. Knowing this offer, the incumbent does not keep any informational rents in $\tau = 1$.

Choosing the second strategy offers a gain in $\tau = 1$ of

$$G_1 = (1 - p_1)\left(R(q^{I*}_2) - \theta_2 q^{I*}_2 - \left(R(q^I_2) - \theta_2 q^I_2\right)\right) + p_1\Delta\theta q^I_2$$

where $p_1 = p_{11} + p_{12}$ is the ex ante probability that the incumbent has low cost and q^I_2 denotes the quantity that a high cost incumbent is asked to produce in the second best. But choosing the second strategy may also involve a relative loss in $\tau = 2$ if F is high enough: it could be that the second period principal's net revenues are lower after entry, as it involves reimbursing F to the entrant, than those obtained when only the incumbent produces in $\tau = 2$ (if not, obviously promoting entry is the best strategy). Denote by $L_2 \leq 0$ this relative loss. Nonetheless, for $\delta \leq \delta''_0 = -\frac{G_1}{L_2}$, this second strategy is best. We have $\delta_0 = \min\{\delta'_0, \delta''_0\}$.

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