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DELEGATION TO INDEPENDENT REGULATORS AND THE RATCHET EFFECT

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Abstract

Dynamic principal-agent settings with asymmetric information but no commitment are well known to create a ratchet effect. Here, the most efficient agents must be provided with extra 'information rent' as an incentive to relinquish their informational advantage over an uninformed principal; this causes welfare to fall. We study this problem in the case of regulatory procurement and show that delegation by the government to an independent regulator whose preferences differ from the government's can overcome this inefficiency, and we provide 'conservative' conditions under which this happens. Our solution reflects several aspects of many modern regulatory settings: government commitment to a particular regulator, the provision of independence to that regulator, and heterogeneity across available regulators. Our results also provide an analogy with the literatures on the benefits of delegation to independent principals in other settings, such as monetary policy, financial regulation and trade and hence contribute to this broader research agenda.

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Contents

1 Introduction

The merits of delegation to an independent regulatory authority in areas as diverse as monetary policy and public utilities have been widely observed over the past three decades. In a long run dynamic relationship with asymmetric information, where commitment to a long run contract is not possible and early contracts reveal information about the regulated firm, subsequent contracts are likely to include a set of tougher performance standards. That is, the problem of the 'ratchet effect' is inclined to emerge. As a result, efficient firms are unwilling to reveal this characteristic and the regulator must induce them to do so by offering an increase in information rent. This can prove harmful to the economy depending, for example, on the weight placed on rent savings into the future (Brown *et al.* (1994)) and on the degree of coordination costs faced by the regulator.[1] The ratchet effect is an instance of a time inconsistency problem.

The time inconsistency problem in extensive form games has been raised by different strands of the literature, such as the theory of the firm (where ex ante decisions with incomplete contracts figure prominently), or macroeconomic policy (see Levine *et al.* (2005) for a summary). There are many examples of time inconsistency problems in monetary policy or fiscal policy, starting with Rogoff (1985). Indeed, recently, time inconsistency problems have been arguably at the core of the regulatory weaknesses that were behind of the 2008 world financial crisis.[2] Kahn and Santos (2005) addresses some of the issues involved for bank regulation.

A number of measures have been suggested in the literature to limit the ratchet effect; measures including contractible investment, low-powered incentive contracts offered by the regulator in the face of unverifiable quality and term limits on regulators preventing gains from the information revealed by early contracts. In this paper, we examine a different solution to the problem of the ratchet effect and we add to the literature on independent regulation, by considering the extent to which the choice of regulator matters. In particular, we are interested to know whether delegation to an independent industry regulator whose preferences differ from those of the government can partially substitute

[1]As an example of the economic costs of the ratchet effect, Litwack (1993) argues that, when combined with coordination costs, the ratchet effect may have damaged Soviet productivity significantly.

[2]A Special Session at the 2011 Royal Economic Society conference was devoted to the theme of "Financial Regulation".

for full intertemporal commitment and, therefore, raise welfare by mitigating the ratchet effect. This solution combines several features of the modern regulatory environment: government commitment to a particular regulator, the provision of independence to that regulator, and heterogeneity across the types of regulators available. Taking commitment first, it is apparent that the process of appointing regulators involves a degree of commitment by the government. Regulators are appointed for a specific (say, five year) period and these terms are contractually agreed. This means that a variety of regulatory decisions upon which governments may be unable to commit over time are handled by the same regulator, whose style and preferences can be expected to maintain across such decisions.

It is also the case that regulators typically enjoy independence from government, and wide powers of discretion, as is clear from the indices of regulatory independence compiled by, for example, Gilardi (2002), Johannsen (2003), Edwards and Waverman (2006) and Trillas and Montoya (2011). It is also clear that independence has been a long-standing feature of numerous regulatory environments. For example, in the British context, Armstrong *et al.* (1994), p 360), describe discretion and independence as a "notable feature of the new regulatory institutions" introduced in the 1980s and 1990s. In common with much of the above literature, they believe that this has generated short-term gains by freeing the industries involved from (some) political interference (see also Carsberg (1995)— a view shared by Stelzer (1996), in the American context.) At the same time, a variety of regulatory preferences is clearly on offer to a government/planner when deciding to whom such independence should be granted and these preferences are clearly discernible *ex ante*.[3] Bearing these points in mind, Baron (Baron, 1998) and Spulber and Besanko

[3]One mechanism for achieving this might be the regulator's public track-record. For example, Tom Winsor's 'pro-consumer' record before being appointed UK rail regulator in 1999 was apparent from his work as chief legal advisor to an earlier UK rail regulator. This is clear from Gribben (1999): "John Prescott, deputy prime minister, yesterday named a "hawkish" lawyer [Tom Winsor] to toughen up rail regulation and make life more difficult for Railtrack and the train operating companies." As further evidence that Winsor's 'type' was apparent *ex ante*, Railtrack shares fell 35 pence following, apparently credible, announcements he made on 27 May (before taking up his post) about the forthcoming rail price review. This happened despite Railtrack's record profits having just been announced Osborne (1999). Stelzer suggests that, by relying on regulation by committee, the US system removes some of this "personality effect". However, it need not prevent regulatory decisions from reflecting particular preferences, as the use of delegation to monetary policy committees attests.

(1992) also consider models with a choice amongst regulators whose types are observable *ex ante*. Like us, they model this 'type' as the amount of weight given to industry profits in the regulator's objective function. However, their interest is in the effects of the political process on the choice of regulator. Baron's analysis of static incentive regulation with asymmetric information shows that a majority voting equilibrium may sacrifice efficiency for equity by selecting a regulator who places high weight on consumer surplus. This occurs when legislators respond to their constituents' preferences and the regulated firm has private information about its costs. However, in the static (non-commitment) framework, there is no incentive for legislators to choose a regulator whose type differs from the median. Spulber and Besanko show that such divergence can happen by introducing the question of policy commitment. They compare the choice of regulator in circumstances where she can/cannot commit to an environmental pollution standard. In a complete information context, commitment is modelled as a Stackelberg game where the regulator has a first-mover advantage when choosing the pollution standard and industry output level; non-commitment produces a Cournot-Nash equilibrium as the Stackelberg equilibrium 'unravels'. Unlike the commitment case, non-commitment involves delegation to a regulator whose preferences may not coincide with the legislature's. The reason, as with central bank delegation, is that the effects of being unable to commit to policy may be offset by a (more feasible) commitment to a related variable—the regulator's type. Given this result, Spulber and Besanko's main focus is on how political interactions (between legislature and executive) may explain observed instances of delegation.

We draw on the idea of delegation in both these papers to consider incentive regulation in a dynamic, non-commitment, principal-agent context. Our focus is more normative, however: we take for granted the presence of political mechanisms to identify, and delegate to, regulators and focus instead on the effects of such delegation. Specifically, we consider the simplest regulatory problem studied in Laffont and Tirole (1993).[4] The regulator wishes to realize a number of projects yielding a fixed gross surplus. There are two types of firms—low and high efficiency types—but the regulator does not know which type she is dealing with. This is a classic principal-agent asymmetric information problem. The regulator designs an incentive scheme consisting of two cost-reimbursement contracts

[4]Evans *et al.* (2011) demonstrate that the results are robust to wider settings; see Section 2.

linking payments to the firms with observable costs. In two-period contracts the best outcome can be achieved if some commitment mechanism is in place that prevents the regulator from re-optimizing after one period, on the basis of revealed information about the firm (Baron and Besanko (1984)). We assume such a mechanism is not in place, but the government can delegate the choice of incentive scheme to an independent regulator who holds office at least for the duration of the two-period contract. We examine whether, and in what circumstances, a careful choice of regulator type can provide a better outcome than leaving regulation in the hands of a representative regulator with the same preferences as the government. By explicitly modelling this dynamic environment, we find that an important influence here is the way the regulator's type can affect the resulting equilibrium: more pro-industry regulators induce greater separation, which, in turn, allows cost-reducing efforts to approach first-best levels. Given the complexity of this regulatory game, we do not consider mechanisms for choosing the regulator (though see Evans *et al.* (2011)). However, as our earlier discussion indicates, the nature of our results would be robust to such extensions.

The rest of the paper is organized as follows. Section 2 describes the model and sets out the complete information solution. Section 3 solves for a two-period, two-type delegation equilibrium under asymmetric information, in which the regulator's preferences differ from those of the appointing government. Section 4 presents the welfare analysis using simulations and Section 5 concludes the paper and indicates how our paper may contribute to the wider research agenda on regulatory independence.

2 The Model

The Set-up

We begin by setting out the basic elements of the delegation game. There are two periods. Costs are observed by the regulator and given by

$$C_t = \beta - e_t;\ t = 1, 2 \tag{1}$$

where e is effort, and β is an efficiency parameter. Neither effort nor efficiency are observed so the regulator faces both an adverse selection and moral hazard problem. The efficiency parameter β takes two values, $\underline{\beta}$ and $\overline{\beta}$, which the regulator believes with probabilities υ_t

and $1 - \upsilon_t$ respectively at the beginning of period t.

Single-period payoffs for the firm and regulator are

$$U_t = r_t - \psi(e_t)\,;\ \psi',\, \psi'' > 0 \text{ for } e_t > 0,\ \psi(e_t) = 0 \text{ otherwise} \tag{2}$$

$$\begin{aligned} W_t &= S - (C_t + r_t) + \alpha U_t - \phi(C_t + r_t)\,;\ \phi',\, \phi'' > 0 \\ &= S - (\beta - e_t + \psi(e_t) + U_t) + \alpha U_t - \phi(\beta - e_t + \psi(e_t) + U_t) \\ &= W(U_t, e_t; \beta, \alpha) \end{aligned} \tag{3}$$

In (2), $\psi(e_t)$ is the disutility of effort. In (3), S is the gross fixed surplus of the project, r_t is a cost-contingent reward paid by the regulator to the firm in addition to the cost C_t and $\phi(.)$ is the disutility from tax distortions arising from the tax burden $C_t + r_t$. In equation (3) $S-(C_t+r_t)-\phi(C_t+r_t)$ is the consumer surplus and the weight α is the weight placed on the firm's profit by the regulator. A utilitarian regulator would have $\alpha = 1$, but in this paper we examine the effect of delegating to a regulator chosen to have different preferences. Suppose that the government has preferences defined by $\alpha = \alpha_s \leq 1$ where $\alpha_s < 1$ would apply to a more egalitarian government. Then a choice $\alpha > \alpha_s$ signifies a 'pro-industry' (pro-rent) regulator type whilst $\alpha < \alpha_s$ signifies an 'anti-industry' regulator type.

Our treatment of tax distortions is an important distinctive feature of our set-up. Suppose the public sector consists of services provided by n projects of the type considered here, each costing T to the taxpayer. Then the total disutility from tax distortions is a function of nT, $f(nT)$ say. Most taxes involve deadweight losses which the public finance literature suggests to be quadratic in the tax rate (see, for example, Stiglitz (1988)). The cost per project, $\phi = f(nT)/n$, should therefore also be quadratic. Assuming a general quadratic form we then write

$$\phi(T) = \lambda T + \mu T^2 \tag{4}$$

This general formulation of the set-up encompasses LT as a special case by putting $\alpha = 1$ and $\mu = 0$.[5]

[5] As noted in the Introduction, Evans *et al.* (2011) presents a model with a number of our current assumptions relaxed. In particular, in the context of the same two period game with asymmetric information about β and e_t it allows for price regulation (not transfers), moral hazard over investment as well as effort, and it endogenises the choice of regulator (α) in a Grossman and Helpman (2001)-style lobbying game. In

Complete Information Contracts

In each period t, the regulator designs contracts $(\underline{r}_t, \underline{C}_t)$, and $(\overline{r}_t, \overline{C}_t)$ for low and high cost types respectively, corresponding to levels of effort $\underline{e}_t = \underline{\beta} - \underline{C}_t$ and $\overline{e}_t = \overline{\beta} - \overline{C}_t$, and rents $\underline{U}_t = \underline{r}_t - \psi(\underline{e}_t)$ and $\overline{U}_t = \overline{r}_t - \psi(\overline{e}_t)$ respectively. In a multi-period contract with complete information there is no learning and therefore no source of dynamics. The multi-period problem then reduces to repetitions of the static single-period one. We therefore drop the time subscript in what immediately follows.

The regulator's problem can be regarded as choosing any two from four variables: transfers, costs, rents and levels of effort for the two contracts, although the actual choice variable is the transfer conditional on costs. Throughout this paper we find it convenient to formulate the problem in terms of choosing rent and effort. Under complete information, the regulator's problem in each period is then:

For each type of firm β, choose U and e to maximize $W(U, e; \beta, \alpha)$ where the social welfare is given by equation (3), subject to the individual rationality constraint $U \geq 0$.

With general functional forms for $\psi(.)$ and $\phi(.)$, the solution to this program is given by $e = e^*$ and $U = \max(0, U^*)$ where e^* and U^* are solutions to

$$\psi'(e^*) = 1 \tag{5}$$

and

$$\phi'(\beta - e^* + \psi(e^*) + U^*) = \alpha - 1 \tag{6}$$

Equation (5) equates the marginal disutility of effort with its marginal social product. Equation (6), which is only relevant if the rationality constraint does not bind, equates the marginal disutility from taxes with the marginal utility of rent.

For the rest of this paper we choose functional forms given by equation (4) and

$$\psi(e) = \frac{1}{2}[\max(e, 0)]^2 \tag{7}$$

this setting, the benefits of independence can be magnified (because of their effects on investment as well as effort), though the range of equilibria is much larger and, as such, the current setting helps to single out the role of independence.

which sets the disutility from negative effort at zero. Then equations (5) and (6) give

$$e^* = 1 \tag{8}$$

$$U^* = U^*(\alpha,\beta) = \frac{\alpha - 1 - \lambda - \mu(2\beta - 1)}{2\mu} \tag{9}$$

The social welfare function now takes the form

$$\begin{aligned} W(U_t, e_t; \beta, \alpha) &= S - (1+\lambda)(\beta - e_t + e_t^2/2) - (1+\lambda-\alpha)U_t \\ &\quad -\mu(\beta - e_t + e_t^2/2 + U_t)^2 \end{aligned} \tag{10}$$

The *first-best* is then achieved under complete information with a representative regulator of type α_s. Then $U = \max(0, U^*) = 0$ for both types and the ex ante expected intertemporal social welfare over two periods is given by

$$\Omega^{FB} = (1+\delta)[v_1 W(0, e^*; \underline{\beta}, \alpha_s) + (1 - v_1)W(0, e^*; \overline{\beta}, \alpha_s)] \tag{11}$$

Now suppose that the government delegates to a regulator of type $\alpha \geq \alpha_s$. Then for $\alpha < \underline{\alpha}$ where $\underline{\alpha} = 1 + \lambda + \mu(2\underline{\beta} - 1)$, the rents for both types of firm are still zero, but for $\alpha \in [\underline{\alpha}, \overline{\alpha}]$ where $\overline{\alpha} = \underline{\alpha} + 2\mu(\overline{\beta} - \underline{\beta})$, the efficient type alone receives *positive* rent up to a maximum difference of $\underline{U} - \overline{U} = \Delta\beta$, where $\Delta\beta = \overline{\beta} - \underline{\beta}$. In this range the regulator will allow rents only for the efficient firm because the lower costs are sufficient partly to offset the cost of financing the rent. As long as $\mu > 0$, this rent is determinate. For $\alpha > \overline{\alpha}$ the regulator is sufficiently pro-rent to allow both types of firm to receive positive rent with $\underline{U} - \overline{U} = \Delta\beta$. Thus, the role of higher α regulators is apparent in the sense that, even with complete information, they allow the regulated firm to earn rents; unlike the baseline model in LT.[6] Figure 1 illustrates these results which are summarized as

Proposition 1

For sufficiently pro-industry regulators, under complete information efficient firms receive more rent up to a maximum differential of magnitude $\underline{U} - \overline{U} = \Delta\beta$.

FIGURE 1 HERE

[6] We have seen that LT's baseline model sets $\alpha = 1$ and $\mu = 0$. This means that $\alpha < \underline{\alpha}$, which also induces the 'no rent' outcome in our model.

3 Two-Period Contracts under Asymmetric Information

This section sets out and solves a two-period, two-type delegation game with the basic structure described in Section 2. Asymmetric information in the form of both an adverse selection and moral hazard problem introduces dynamics through the process of learning about the firm's type. The regulator's optimization problem and the firms' individual rationality constraints are now intertemporal and we assume that these are expressed in terms of a common discount factor given by δ. The ratchet effect can be avoided if the regulator can commit to a two-period contract, but we rule out this possibility. The government however is committed to a particular regulator. The sequence of events for the delegation game is given by:

1. The government has preferences as for the regulator but with rent carrying a weight α_s (reflecting social welfare) and delegates to a regulator of type $\alpha \neq \alpha_s$ for the two periods. In the absence of delegation, the regulator is 'representative' and adopts a weight $\alpha = \alpha_s$.
2. The firm knows her type β; the regulator has the prior v_1.
3. The regulator offers the first-period contract which the firm accepts/rejects.
4. First-period effort e_1 is applied, the cost C_1 is realized and observed by the regulator.
5. The regulator updates her prior v_1 to v_2.
6. The regulator offers a second-period contract which the firm accepts/rejects.

The appropriate equilibrium concept for this game is a Perfect Bayesian Equilibrium (PBE) which imposes three requirements: first, at each information set the player with the move must have a belief regarding which node has been reached. Second, given their beliefs at each information set the current move and subsequent strategies must be optimal given the beliefs and subsequent strategies of the other players. Third, beliefs are determined by Bayes' Rule and the players' equilibrium strategies. We solve for this equilibrium by backward induction beginning with the second period contract.

The Second-Period Contract

The regulator designs contracts $(\underline{r}_2, \underline{C}_2)$, and $(\overline{r}_2, \overline{C}_2)$ for low and high cost types respectively, given the (updated) probability v_2 that the firm is efficient. This corresponds to efforts $\underline{e}_2 = \underline{\beta} - \underline{C}_2$ and $\overline{e}_2 = \overline{\beta} - \overline{C}_2$. Suppose that the efficient (low cost) type mimics the inefficient type by producing at the observable high cost $\overline{C}_2$. It can do this by exerting effort $\overline{e}_2 - \Delta\beta = \underset{\sim}{e}_2$, say,[7] where we recall that $\Delta\beta = \overline{\beta} - \underline{\beta}$ is the efficiency gap between the two types. (Note that mimicking effort by the efficient firm can be negative). Similarly the inefficient type can mimic the efficient type by exerting effort $\underline{e}_2 + \Delta\beta = \tilde{\overline{e}}_2$. The *incentive compatibility constraints* for each type of firm to prefer the contract designed for itself are then

$$\overline{IC}_2 : \overline{r}_2 - \psi(\overline{e}_2) \geq \underline{r}_2 - \psi(\tilde{\overline{e}}_2) \tag{12}$$

$$\underline{IC}_2 : \underline{r}_2 - \psi(\underline{e}_2) \ \geq \ \overline{r}_2 - \psi(\underset{\sim}{e}_2) \tag{13}$$

The *individual rationality constraints* are:

$$\overline{IR}_2 : \overline{r}_2 - \psi(\overline{e}_2) \geq 0 \tag{14}$$

$$\underline{IR}_2 : \underline{r}_2 - \psi(\underline{e}_2) \geq 0 \tag{15}$$

Note that $\underline{IC}_2 + \overline{IR}_2 \Rightarrow \underline{IR}_2$ so we can ignore the latter. As in LT we also ignore $\overline{IC}_2$ for now and we can confirm later that the solution in fact does satisfy this constraint.

As for the complete information case, it is convenient to formulate the problem in terms of the choice of rent and effort levels bearing in mind that contracts are designed as transfers, contingent on observed costs. Then the relevant constraints can be expressed in the form:

$$\underline{IC}_2 : \ \underline{U}_2 \geq \overline{U}_2 + \psi(\overline{e}_2) - \psi(\underset{\sim}{e}_2) = \overline{U}_2 + \Phi(\overline{e}_2) \tag{16}$$

$$\overline{IR}_2 : \ \overline{U}_2 \geq 0 \tag{17}$$

where we have denoted *informational rents* by $\Phi(\overline{e}_2) = \psi(\overline{e}_2) - \psi(\underset{\sim}{e}_2)$. The regulator's problem, to be carried out at each information set characterized by the state variable υ_2, is now:

Choose $(\overline{U}_2, \overline{e}_2)$ and $(\underline{U}_2, \underline{e}_2)$ to maximize the expected welfare

$$E[W_2(\upsilon_2)] = \Omega_1 = \upsilon_2 W(\underline{U}_2, \underline{e}_2; \underline{\beta}, \alpha) + (1 - \upsilon_2) W(\overline{U}_2, \overline{e}_2; \overline{\beta}, \alpha) \tag{18}$$

subject to $\underline{IC}_2$ and $\overline{IR}_2$.

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[7] Throughout the paper we adopt the following notation: $\underset{\sim}{x}$ is some outcome for the efficient firm who mimics the inefficient firm and $\tilde{\overline{x}}$ is the corresponding outcome for the inefficient firm who mimics the efficient firm.

If $\alpha \leq \underline{\alpha}$ then the regulator's welfare is decreasing in rent and the constraints $\underline{IC}_2$ and $\overline{IR}_2$ must bind. But a sufficiently pro-rent regulator will always be willing to offer the unconstrained optimal rents $\max[0, (\alpha - \underline{\alpha})/(2\mu)]$ and $\max[0, (\alpha - \overline{\alpha})/(2\mu)]$ for the efficient and inefficient firms respectively and the constraints may cease to bind. We return to this point later in this section when we characterize completely one possible equilibrium.

If the regulator reserves the option to forego the project in the event that the firm reveals itself as inefficient, then it may offer only one contract designed for the efficient type. This will imply rent $\max[0, U^*(\alpha, \underline{\beta})]$ and effort e^*, and yield an expected welfare

$$\Omega_2 = \upsilon_2 W(U^*(\alpha, \underline{\beta}), e^*; \underline{\beta}, \alpha) \tag{19}$$

The expected welfare in the final period is then $\max(\Omega_1, \Omega_2)$.

The First-Period Contract

In the first period, in general we must consider equilibria in which the efficient firm may mimic the inefficient and vice versa. Suppose that the efficient firm chooses the low cost contract with probability x and the high cost contract with probability $1 - x$. Similarly suppose that the inefficient firm chooses the high cost contract with probability y and the low cost contract with probability $1-y$. Then we have three possible types of equilibrium:

Type I: $\underline{IC}_1$ and $\overline{IR}_1$ bind and the efficient firm may mimic the inefficient firm with probability x.

Type II: $\overline{IC}_1$ and $\overline{IR}_1$ bind and the inefficient firm may mimic the efficient firm with probability y.

Type III: $\underline{IC}_1$, $\overline{IC}_1$ and $\overline{IR}_1$ bind and both firms may mimic the other.

LT show that type II cannot be optimal for the regulator for the case where $\alpha = 1$ and $\mu = 0$. In our simulations we can confirm that this still holds for our more general case where $\alpha \neq 1$ and $\mu > 0$. In view of these results we concentrate on equilibria of types I and III.

FIGURE 2 HERE

Consider first a type III equilibrium. The extensive form of the game is shown in

Figure 2.[8] At information set A (B) a low (high) cost contract has been chosen by the firm in period one. Given the mixed strategies, the probabilities of arriving at A and B are:

$$\Pr(A) = \upsilon_1 x + (1 - \upsilon_1)(1 - y) \tag{20}$$

and

$$\Pr(B) = \upsilon_1(1 - x) + (1 - \upsilon_1)y \tag{21}$$

respectively. Then by Bayes' Rule we have

$$\begin{aligned} \upsilon_2(A) &= \Pr(\text{firm is efficient} \mid \text{low cost contract has been accepted}) \\ &= \frac{\upsilon_1 x}{\Pr(A)} \end{aligned} \tag{22}$$

and

$$\begin{aligned} \upsilon_2(B) &= \Pr(\text{firm is efficient} \mid \text{high cost contract has been accepted}) \\ &= \frac{\upsilon_1(1-x)}{\Pr(B)} \end{aligned} \tag{23}$$

Let the rent obtained by the efficient firm when it mimics the inefficient firm be given by

$$\underline{\tilde{U}}_1 = \overline{U}_1 + \psi(\overline{e}_1) - \psi(\underline{\tilde{e}}_1) \tag{24}$$

where we recall that $\underline{\tilde{e}}_1 = \overline{e}_1 - \Delta\beta$. Similarly let the rent obtained by the inefficient firm when it mimics the efficient firm be given by

$$\tilde{\overline{U}}_1 = \underline{U}_1 + \psi(\underline{e}_1) - \psi(\tilde{\overline{e}}_1) \tag{25}$$

where $\tilde{\overline{e}}_1 = \underline{e}_1 + \Delta\beta$. Then the first-period incentive compatibility and individual rationality constraints are given by:

$$\underline{IC}_1 : \underline{U}_1 + \delta\underline{U}_2(\upsilon_2(A)) \geq \underline{\tilde{U}}_1 + \delta\underline{U}_2(\upsilon_2(B)) \tag{26}$$

$$\overline{IC}_1 : \overline{U}_1 + \delta\overline{U}_2(\upsilon_2(B)) \geq \tilde{\overline{U}}_1 + \delta\overline{U}_2(\upsilon_2(A)) \tag{27}$$

$$\underline{IR}_1 : \underline{U}_1 + \delta\underline{U}_2(\upsilon_2(A)) \geq 0 \tag{28}$$

[8]In accordance with our general notation, $\underline{W}_1 = W(\underline{U}_1, \underline{e}_1; \underline{\beta}, \alpha)$ is the first-period social welfare resulting from the efficient firm choosing the contract designed for itself and $\underline{\tilde{W}}_1 = W(\underline{\tilde{U}}_1, \underline{\tilde{e}}_1; \underline{\beta}, \alpha)$ is the corresponding welfare when it mimics the inefficient firm. $\overline{W}_1 = W(\overline{U}_1, \overline{e}_1; \overline{\beta}, \alpha)$ and $\tilde{\overline{W}}_1 = W(\tilde{\overline{U}}_1, \tilde{\overline{e}}_1; \overline{\beta}, \alpha)$ are similarly defined.

$$\overline{IR}_1 : \overline{U}_1 + \delta\overline{U}_2(\upsilon_2(B)) \geq 0 \tag{29}$$

It is clear that $\underline{IC}_1 + \overline{IR}_1 \Rightarrow \underline{IR}_1$ so that, as for the second-period contract, we can ignore the latter.

The optimization problem for the regulator of type α is now:

Choose $(\overline{U}_1, \overline{e}_1)$ and $(\underline{U}_1, \underline{e}_1)$ to maximize

$$\begin{aligned} E(W_1 + \delta W_2) \quad = \quad & \upsilon_1[xW(\underline{U}_1, \underline{e}_1; \underline{\beta}, \alpha) + (1-x)W(\tilde{\underline{U}}_1, \tilde{\underline{e}}_1; \underline{\beta}, \alpha)] \\ & +(1-\upsilon_1)[yW(\overline{U}_1, \overline{e}_1; \overline{\beta}, \alpha) + (1-y)W(\tilde{\overline{U}}_1, \underline{e}_1 + \Delta\beta; \overline{\beta}, \alpha)] \\ & +\delta E(W_2) \end{aligned} \tag{30}$$

where

$$E(W_2) = \Pr(A)E(W_2 \mid A) + \Pr(B)E(W_2 \mid B) \tag{31}$$

subject to $\underline{IC}_1$, $\overline{IC}_1$ and $\overline{IR}_1$.

This completes the formulation of a type III equilibrium. The computation of a type I equilibrium now follows by dropping the constraint $\overline{IC}_1$, putting $y = 1$ and noting that information set A now becomes a singleton in figure 2, ie, $\upsilon_2(A) = 1$.

Solution for a Type I Separating Equilibrium

This sub-section completely characterizes a type I separating equilibrium (ie with $x = 1$) and produces some analytical results. Of course equilibria are endogenously determined by the incentive scheme which the regulator chooses to maximize its welfare function. However it is instructive to focus on the simplest equilibrium and we examine later by simulations the parameter values for which it is relevant. In fact for all parameter values examined we find in Section 4 below that all type I equilibria are separating, though for some parameter values the regulator may design contracts that result in type III equilibria.

In a type I separating equilibrium $\upsilon_2(A) = 1$ and $\upsilon_2(B) = 0$ and the second-period problem for the regulator is the complete information program set out in Section 2. To recap, for our chosen functional forms we have:

$$\underline{e}_2 = \overline{e}_2 = e^* = 1 \tag{32}$$

$$\underline{U}_2 = \max[0, (\alpha - \underline{\alpha})/(2\mu)] \tag{33}$$

$$\overline{U}_2 = \max[0, (\alpha - \overline{\alpha})/(2\mu)] \tag{34}$$

In the first period, the IC and IR constraints are now

$$\underline{IC}_1 : \underline{U}_1 + \delta \underline{U}_2(1) \geq \tilde{\underline{U}}_1 + \delta \underline{U}_2(0) \tag{35}$$

$$\overline{IR}_1 : \overline{U}_1 + \delta \overline{U}_2(0) \geq 0 \tag{36}$$

In equations (35) and (36), $\underline{U}_2(1)$ and $\overline{U}_2(0)$ are the second-period rents the efficient and inefficient firms respectively receive when they reveal their types; ie $\underline{U}_2(1) = \underline{U}_2$ given by equation (33) and $\overline{U}_2(0) = \overline{U}_2$ given by equation (34). $\underline{U}_2(0)$ is the second-period rent the efficient firm receives when it mimics the inefficient type in the first period (although this never happens in a separating equilibrium); ie $\underline{U}_2(0) = \overline{U}_2 + \psi(\overline{e}_2) - \psi(\tilde{\underline{e}}_2) = \overline{U}_2 + \Phi(\overline{e}_2)$. Similarly from (24) $\tilde{\underline{U}}_1 = \overline{U}_1 + \Phi(\overline{e}_1)$. We can therefore write constraint $\underline{IC}_1$ as

$$\underline{IC}_1 : \underline{U}_1 \geq \overline{U}_1 + \Phi(\overline{e}_1) + \delta(\Phi(e^*) + \overline{U}_2 - \underline{U}_2) \tag{37}$$

The second discounted term in (37) is the familiar *ratchet rent*.

We also know that $\underline{U}_1 \geq (\alpha - \underline{\alpha})/(2\mu)$, the unconstrained optimal rent. It follows that for α sufficiently high, $\underline{IC}_1$ does not bind and then

$$\underline{U}_1 = (\alpha - \underline{\alpha})/(2\mu) \tag{38}$$

For $\alpha > \overline{\alpha}$, $\overline{IR}_1$ does not bind either and then

$$\overline{U}_1 = (\alpha - \overline{\alpha})/(2\mu) \tag{39}$$

The solution of a type I separating equilibrium is completed by choosing $(\overline{U}_1, \overline{e}_1)$ and $(\underline{U}_1, \underline{e}_1)$ to maximize $\upsilon_1 W(\underline{U}_1, \underline{e}_1; \underline{\beta}, \alpha) + (1 - \upsilon_1) W(\overline{U}_1, \overline{e}_1; \overline{\beta}, \alpha)$ subject to $\underline{IC}_1$ and $\overline{IR}_1$. The solution to this program is:

$$\underline{e}_1 = e^* = 1 \tag{40}$$

$$\overline{U}_1 = \max\left[0, (\alpha - \overline{\alpha})/(2\mu)\right] \tag{41}$$

$$\underline{U}_1 = \max[\overline{U}_1 + \Phi(\overline{e}_1) + \delta(\Phi(e^*) + \overline{U}_2 - \underline{U}_2), (\alpha - \underline{\alpha})/(2\mu)] \tag{42}$$

$$\upsilon_1 \Phi'(\overline{e}_1)(\alpha - \underline{\alpha} - 2\mu \underline{U}_1) + (1 - \upsilon_1)(1 - \overline{e}_1)[1 + \lambda + 2\mu(\overline{\beta} - \overline{e}_1 + \psi(\overline{e}_1) + \overline{U}_1)] = 0 \tag{43}$$

if $\underline{IC}_1$ binds, otherwise $\overline{e}_1 = e^* = 1$. From (42), the first term in (43) is negative. It follows from (43) that $\overline{e}_1 < 1$; ie, *the first-period effort of the inefficient firm is always below the first-best* until α reaches a point where $\underline{IC}_1$ ceases to bind.

The equilibrium is illustrated in Figure 3. This shows iso-transfer curves for the two types of firm in rent-effort space. As described earlier, the complete information equilibrium would involve $\underline{e}_1 = \overline{e}_1 = 1$, with the level of rent depending on the regulator's preferences. (In the figure, $\alpha < \underline{\alpha}$ is assumed, so that $\underline{U}_1 = \overline{U}_1 = 0$; the complete information equilibrium is at point A.) Incomplete information allows the efficient firm to mimic the inefficient one by putting in less effort ($\tilde{\underline{e}}_1$). Absent any dynamic considerations, the regulator counters this by reducing $\overline{e}_1$ and $\overline{r}_1$, which in turn lowers $\tilde{\underline{e}}_1$ and $\underline{r}_1$ and, therefore, $\tilde{\underline{U}}_1$: the equilibrium would be at B and D (given $\alpha < \underline{\alpha}$). However, in type I equilibrium, the efficient firm surrenders in period 1 its chance to mimic again in period 2. Accordingly, the regulator must make an additional transfer to buy off this future "information rent". This *ratchet effect* moves the equilibrium to B and E and the ratchet rent is DE.[9]

FIGURE 3 HERE

Now consider the effects of raising α, the extent to which the regulator is pro-industry. For social welfare, as we have just seen, the key variables are $\overline{e}_1$, the ratchet rent and $\underline{U}_1$. We consider these in turn.

Solving (43) we can calculate the effect of delegation on the effort of the inefficient firm in the first period, $\overline{e}_1 = \overline{e}_1(\alpha)$. Differentiation of (43) and some algebraic manipulation then leads to the following proposition (which also summarizes the discussion after (43)). Proofs of this and the subsequent proposition are given in Appendix B.

[9]We can also use figure 3 to illustrate the circumstances in which a type III equilibrium emerges. Recall that this involves the $\overline{\beta}$ firm mimicking the $\underline{\beta}$ firm by providing effort $\tilde{\overline{e}}_1 = \underline{e}_1 + \Delta\beta$. Clearly, when $\tilde{\overline{e}}_1$ is to the right of point F we have a type I equilibrium, while $\tilde{\overline{e}}_1$ to the left of point F yields a type III equilibrium. Hence, the larger is the extra rent due to the ratchet effect, the greater the prospects of a type III equilibrium.

Proposition 2

Consider any α below the value for which $\underline{IC}_1$ ceases to bind. Then in a type I separating equilibrium the first-period effort of the inefficient firm, $\overline{e}_1(\alpha)$, is below the social optimum and increases with α.

The intuition behind Proposition 2 is that given $\underline{IC}_1$, the more pro-industry, pro-rent regulator will make a choice of $\overline{e}_1$ that gives the efficient firm more first-period information rent $\Phi(\overline{e}_1)$ even though the overall rent $\underline{U}_1$ may fall, as we shall see. High information rent for the efficient firm implies high effort by the inefficient firm.

Now consider the ratchet rent $\delta(\Phi(e^*) + \overline{U}_2 - \underline{U}_2)$, the last term in (37). Suppose that a representative regulator has a weight on the firm's profit $\alpha_s < \underline{\alpha}$; for instance in the set-up of LT, $\alpha = 1 < \underline{\alpha}$. Then $\overline{U}_2 = \underline{U}_2 = 0$ and the ratchet rent is $\delta\Phi(e^*)$. By contrast if the regulator is sufficiently pro-industry, we know from proposition 1 that $\overline{U}_2 - \underline{U}_2$ can be as low as $-\Delta\beta$ with the ratchet rent falling to $\delta(\Phi(e^*) - \Delta\beta)$. This shows that in a type I separating equilibrium, *the ratchet rent is reduced by delegation to a sufficiently pro-industry regulator.*

Finally consider the total first-period rent $\underline{U}_1$. Consider the range of regulator types $\alpha < \underline{\alpha}$ where we recall that $\underline{\alpha} = 1+\lambda+\mu(2\beta-1)$ and $\overline{\alpha} = \underline{\alpha}+2\mu(\overline{\beta}-\underline{\beta})$. Then $\underline{U}_2 = \overline{U}_2 = 0$, the ratchet rent is unaffected by α, and from (37) $\frac{d\underline{U}_1}{d\alpha} = \Phi'(\overline{e}_1)\frac{d\overline{e}_1}{d\alpha} > 0$, from Proposition 2. Hence $\underline{U}_1(\alpha)$ *increases with* α. Next consider the range of regulator types $\alpha \in [\underline{\alpha}, \overline{\alpha}]$. Then from (33), $\frac{d\underline{U}_1}{d\alpha} = \frac{1}{2\mu}$. Suppose we narrow the range in $\alpha \in [\underline{\alpha}, \overline{\alpha}]$ to that for which $\underline{IC}_1$ binds. Then differentiating (36) with the equality, we have

$$\frac{d\underline{U}_1}{d\alpha} = \Phi'(\overline{e}_1)\frac{d\overline{e}_1}{d\alpha} - \frac{\delta}{2\mu} \tag{44}$$

From Proposition 2, the first term in (44) is positive. Furthermore in the proof of Proposition 2 in Appendix B this first term is shown to increase with the discount rate δ. However it is also shown in Appendix B that the second term dominates as δ increases. Hence there is a lower bound $\underline{\delta}$ such that if $\delta > \underline{\delta}$ and $\underline{IC}_1$ binds then $\underline{U}_1(\alpha)$ *decreases with* α. Appendix B derives the following conservative lower bound $\underline{\delta}$:

$$\underline{\delta} = \max\left[\frac{2\mu v_1(\Delta\beta)^2}{(1-v_1)(1+\lambda)}, \frac{2\mu v_1}{(1-v_1)(1+\lambda)}\right] \tag{45}$$

For α sufficiently large $\underline{IC}_1$ ceases to bind and $\underline{U}_1 = (\alpha - \underline{\alpha})/(2\mu)$. Then $\underline{U}_1(\alpha)$ starts to *increase with* α. These results are summarized in the proposition:

Proposition 3

Consider a type I separating equilibrium and delegation to a pro-industry regulator of type $\alpha > \alpha_s$. Then if $\alpha < \underline{\alpha}$, the ratchet rent is unaffected and the total first-period rent to the efficient firm, $\underline{U}_1(\alpha)$, increases with α. For $\alpha \in [\underline{\alpha}, \overline{\alpha}]$, in the range for which $\underline{IC}_1$ binds, the ratchet rent decreases and providing that the discount factor is sufficiently high, $\underline{U}_1(\alpha)$, decreases with α. As α rises above this range, $\underline{IC}_1$ ceases to bind, and $\underline{U}_1(\alpha)$ once more increases with α

FIGURE 4 HERE

Figure 4 illustrates the effects of increasing α within $[\underline{\alpha}, \overline{\alpha}]$ for $\delta > \underline{\delta}$ with $\underline{IC}_1$ binding. From Proposition 2, $\overline{e}_1$ increases to $\overline{e}_1{}'$, the iso-transfer curve shifts outwards and the equilibrium for the inefficient firm in the first period shifts from B to B'. In the absence of the second period, the information rent would increase by DD', the first term in (44). However the ratchet rent decreases from DE to $D'E'$, the difference being the second term in (44). Since $\delta > \underline{\delta}$ the second of these effects dominates, the iso-transfer curve for the efficient firm shifts inwards and the overall first-period rent for the efficient firm $\underline{U}_1$ falls.

Taken together Propositions 2 and 3 show that providing the discount factor is sufficiently high, there exists a range $\alpha \in [\underline{\alpha}, \overline{\alpha}]$ for which the first-period effort of the inefficient firm rises from a level below its social optimum and the total first-period rent of the efficient firm falls. Thus the first-period social welfare calculated using the true weight α_s must rise in this interval. However in the interval $\alpha < \underline{\alpha}$ delegation does not provide any incentive for the efficient firm to reveal itself and social welfare will fall.

In this section we have established that delegation to a sufficiently pro-industry regulator can raise first period social welfare. However it also implies a commitment to raising the efficient firm's rent in the second period and therefore a welfare loss for that period. If the former effect outweighs the latter then delegation to a pro-industry regulator of some type within $\alpha \in [\underline{\alpha}, \overline{\alpha}]$ will raise intertemporal social welfare. We demonstrate this possibility in the next section using simulations.

4 Welfare Analysis

This section studies the total intertemporal welfare effects of delegation to a pro-industry regulator. The degree to which the regulator is pro-industry is captured by the parameter α in her single-period welfare function, equation (3). Consider the range of regulator types $\alpha \in [\underline{\alpha}, \overline{\alpha}]$ where we recall that $\underline{\alpha} = 1+\lambda+\mu(2\underline{\beta}-1)$ and $\overline{\alpha} = \underline{\alpha}+2\mu(\overline{\beta}-\underline{\beta})$. From Section 2 we have seen that for α within this range, under complete information only the efficient firm receives rent given by $\underline{U}^* = (\alpha-\underline{\alpha})/(2\mu)$. In a type I separating equilibrium it follows that in the second period we have $\underline{U}_2 = \underline{U}^*$ and $\overline{U}_2 = 0$. As we have also seen, effort is at its efficient levels for both types of firm. In the first period $\underline{e}_1 = e^* = 1$, $\overline{U}_1 = 0$, $\overline{e}_1$ is given by equation (43) and from (42) we then have that

$$\underline{U}_1 = \max[\Phi(\overline{e}_1) + \delta(\Phi(e^*) - \underline{U}^*), (\alpha - \underline{\alpha})/(2\mu)] \tag{46}$$

The intertemporal expected social welfare under delegation is calculated from the welfare function of the government (with weight $\alpha = \alpha_s \leq 1 < \underline{\alpha}$) and is given by

$$\begin{aligned}\Omega(\alpha) &= \upsilon_1 W(\underline{U}_1(\alpha), e^*; \underline{\beta}, \alpha_s) + (1-\upsilon_1)W(0, \overline{e}_1(\alpha); \overline{\beta}, \alpha_s) \\ &\quad +\delta[\upsilon_1 W(\underline{U}^*, e^*; \underline{\beta}, \alpha_s) + (1-\upsilon_1)W(0, e^*; \overline{\beta}, \alpha_s)]\end{aligned} \tag{47}$$

Without delegation the regulator has the same preferences as the government and assigns the true weight α_s to rent when designing the incentive scheme. Then the intertemporal welfare becomes

$$\begin{aligned}\Omega(\alpha_s) &= \upsilon_1 W(\underline{U}_1(\alpha_s), e^*; \underline{\beta}, \alpha_s) + (1-\upsilon_1)W(0, \overline{e}_1(\alpha_s); \overline{\beta}, \alpha_s) \\ &\quad +\delta[\upsilon_1 W(0, e^*; \underline{\beta}, \alpha_s) + (1-\upsilon_1)W(0, e^*; \overline{\beta}, \alpha_s)]\end{aligned} \tag{48}$$

Delegation to a pro-rent regulator of type α is then welfare-enhancing iff $\Omega(\alpha) > \Omega(\alpha_s)$; ie, iff

$$\begin{aligned}&\upsilon_1[W(\underline{U}_1(\alpha), e^*; \underline{\beta}, \alpha_s) - W(\underline{U}_1(\alpha_s), e^*; \underline{\beta}, \alpha_s)] \\ &\quad +(1-\upsilon_1)[W(0, \overline{e}_1(\alpha); \overline{\beta}, \alpha_s) - W(0, \overline{e}_1(\alpha_s); \overline{\beta}, \alpha_s)] \\ &\quad > \delta\upsilon_1[W(0, e^*; \underline{\beta}, \alpha_s) - W(\underline{U}^*, e^*; \underline{\beta}, \alpha_s)]\end{aligned} \tag{49}$$

The left-hand-side of this inequality is the potential first-period welfare gain from delegation discussed after Propositions 2 and 3; the right-hand side is the second-period welfare loss from delegation discounted at the rate δ. This arises because delegation implies a commitment to positive rent for the efficient firm after revelation which reduces welfare calculated using $\alpha_s \leq 1$.

Simulations

We have carried out a large number of simulations for combinations of parameters α_s, $\underline{\beta}$, $\overline{\beta}$, μ, λ, υ_1 and δ and here we report an interesting selection. Our objectives in these simulations are twofold: first to demonstrate the *possibility* that a lowering of the ratchet effect and an increase in the first-period effort of the inefficient firm, through delegating to a pro-industry regulator, can lead to first-period welfare gains sufficient to outweigh the discounted second-period welfare loss; second, to investigate the combinations of parameter values that might enhance this effect.

FIGURES 5a and 5b HERE

First consider a baseline selection of parameter values: $\alpha_s = 1$, $\underline{\beta} = 1$, $\overline{\beta} = 1.5$, $\mu = 0.25$, $\lambda = 0$, $\delta = 0.95$ and $\upsilon_1 = 0.5$. For these parameter values (45) gives $\underline{\delta} = 0.5$. Thus $\delta > \underline{\delta}$ and Proposition 3 applies. S is assumed to be sufficiently large to prevent the regulator offering only one contract to the efficient firm on the basis of its priors. Figure 5a plots the first-period rent of the efficient firm, $\underline{U}_1$, and the first-period effort of both types of firm $\underline{e}_1$ and $\overline{e}_1$ against the regulator type α. Figure 5b plots the intertemporal welfare gain from delegation calculated as the absolute gain $[\Omega(\alpha) - \Omega(\alpha_s)]$ expressed as a percentage of the welfare gap between the first-best (realized under complete information and with the weight on rent $\alpha = \alpha_s$) and the welfare without delegation $\Omega(\alpha_s)$. Thus the welfare gain is given by

$$G = \frac{(\Omega(\alpha) - \Omega(\alpha_s))}{(\Omega^{FB} - \Omega(\alpha_s))} \times 100 \tag{50}$$

where Ω^{FB} is given by (11), $\Omega(\alpha_s))$ by (48) and $\Omega(\alpha))$ by (47).[10]

For the baseline parameter values we find that $\underline{\alpha} = 1.25$ and $\overline{\alpha} = 1.5$. Then for $\alpha < \underline{\alpha}$ the optimal incentive scheme induces a separating type III equilibrium in which incentive

[10] The comparison of $\Omega(\alpha)$ with the first-best welfare outcome Ω^{FB} actually underestimates the value of delegation as a commitment mechanism because optimal contracts with commitment and incomplete information are still second-best.

compatibility constraints bind for both types of firm and $x = y = 1$.[11] For $\alpha > \underline{\alpha}$ we obtain the important result that *delegation induces an equilibrium change: a switch from type III to type I where constraint* $\overline{IC}_1$ *no longer binds.* It turns out that the optimal contract is now a separating type I with $x = 1$ and Propositions 2 and 3 apply.

The constraint $\underline{IC}_1$ ceases to bind at a value $\alpha = \hat{\alpha}$ given by

$$\overline{U}_1 + \Phi(\overline{e}_1) + \delta(\Phi(\overline{e}_2) + \overline{U}_2 - \underline{U}_2) = (\hat{\alpha} - \underline{\alpha})/(2\mu) \tag{51}$$

and $\underline{U}_1$ is then given by (42). This switch occurs at $\hat{\alpha} = 1.45$. For $\alpha \in [\underline{\alpha}, \hat{\alpha}]$, $\underline{U}_1$ falls and for $\alpha > \hat{\alpha}$, $\underline{U}_1$ starts to rise again, all as predicted by Proposition 3. In the type I equilibrium, $\overline{e}_1$ rises as predicted by Proposition 2. This provides the potential for welfare gains from delegation. Figure 5b shows that potential is realized for this particular combination of parameter values. As the weight α increases from $\alpha = \alpha_s = 1$, delegation leads to a slight welfare loss until α reaches the interval $\alpha \in [\underline{\alpha}, \hat{\alpha}]$ when $\underline{U}_1$ starts to fall sharply and the first-period effort of both types approach the first-best. These changes are sufficient to ensure that the first-period welfare gain outweighs the second-period loss. The welfare gap is closed by around 15% in these first baseline simulations. Beyond $\alpha = \hat{\alpha}$, the regulator becomes *too* pro-industry and intertemporal social welfare drops sharply.

FIGURES 6a and 6b HERE

The trajectories for first-period effort in the region where a type III equilibrium exists require further explanation. Constraints $\underline{IC}$ and $\overline{IC}$ given by (26) and (27) respectively imply the following relationship between the first-period effort of the two types of firm:

$$\underline{e}_1 = \overline{e}_1 - \Delta\beta + \delta/(\Delta\beta)[\underline{U}_2(\nu_2(B)) - \underline{U}_2(\nu_2(A))] \tag{52}$$

(see A.17 in the Appendix). For baseline parameters we obtain a type III separating equilibrium ($x = y = 1$). Hence $v_2(A) = 1$ and $v_2(B) = 0$. For $\alpha < \underline{\alpha}$ we then have that $\underline{U}_2(v_2(B)) = \underline{U}_2(0) = \Phi(e^*)$ and $\underline{U}_2(v_2(A)) = \underline{U}_2(1) = 0$. Thus (52) becomes

$$\underline{e}_1 = \overline{e}_1 - \Delta\beta + \delta/(\Delta\beta)[\Phi(e^*)] \tag{53}$$

[11]The calculations of type III equilibria and of type I semi-separating follow the same lines as the separating equilibrium set out in Section 3. Full details of these computations which generalize those of LT, Appendix 9.9, to the case where $\alpha \neq 1$ and $\mu > 0$ can be obtained from the authors.

For baseline parameters this gives $\underline{e}_1 > \overline{e}_1$ and the difference is constant throughout this equilibrium.

Now consider variations about these baseline values. The baseline value for the discount factor $\delta = 0.95$ is plausible for a time-period of one year. Suppose that we interpret the single period as a regulatory review period within which the regulator cannot change the contract. If this is increased from one to five years then the discount factor in the model decreases to $\delta = 0.95^5 = 0.77$ which is still greater than $\underline{\delta}$. Figure 6a and 6b show this case. For this lower discount factor the optimal contract induces only a type I equilibrium which again turns out to be separating. This is as expected from the analysis of LT, chapter 9. Now delegation only induces a better type I equilibrium rather than a switch between type III and type I. As predicted by Propositions 2 and 3, $\overline{e}_1(\alpha)$ increases throughout the range of α; $\underline{U}_1$ first increases for $\alpha < \underline{\alpha}$, decreases in the range $[\underline{\alpha}, \hat{\alpha}]$ and increases for $\alpha > \hat{\alpha}$. The corresponding welfare gain from delegation is now smaller at around 10%.

FIGURES 7a, 7b and 7c HERE

Next we examine the effect of increasing the discount factor δ. Figures 7a to 7c show results for $\delta = 2$. High values of $\delta > 1$ are a simple way of modelling a short-term followed by a long-term contract without abandoning the two-period set-up of this paper and of LT. For low values of α, the regulator now designs contracts that induce a *pooling* type III equilibrium in which the inefficient firm mimics the efficient firm with a probability $1 - y$ close to unity and the efficient firm mimics the inefficient firm with a probability $1 - x$ close to 0. The actual values of x and y are shown in Figure 7b. Now delegation to an increasingly pro-industry regulator has the effect of *gradually inducing separation* until, at a value of α well within the interval $\alpha \in [\underline{\alpha}, \overline{\alpha}]$, a switch to type I occurs. Because delegation plays the additional role of inducing separation, the welfare improvement is now rather higher, closing the welfare gap by over 20%.

The trajectories for the first-period effort in the type III equilibrium are now rather different from those in Figure 5a. Because for α close to unity the type III equilibrium is close to a pooling type we have that $v_2(A) \approx v_2(B)$ and hence from (52) we now have for low α that $\underline{e}_1 < \overline{e}_1$. However as α increases this encourages the regulator to induce separation and we then revert to $\underline{e}_1 > \overline{e}_1$ as before.

FIGURE 8 HERE

Finally Figure 8 returns to baseline values and recalculates the welfare assuming that the social welfare of the government is measured using $\alpha_s = 0.4, 0.8, 1.2$ instead of the utilitarian $\alpha_s = 1$. Lower values of α_s would apply to egalitarian governments who would wish to redistribute rent, whilst the higher value would apply to a government with opposite preferences. Results indicate that very egalitarian governments would obtain no benefit from delegation whilst a government that is itself pro-industry with $\alpha_s = 1.2$ would see its measure of welfare rising by almost 40%.

5 Conclusions

This paper has examined whether delegation to an industry regulator whose preferences differ from those of the government can act as a partial substitute for full intertemporal commitment by mitigating the ratchet effect. We have found that this indeed is the case: by delegating to an independent regulator who is more pro-industry than itself, the government can reduce the first-period rent of the efficient firm and raise first-period welfare sufficiently to offset the second-period costs from higher rents. We also find a second benefit from such delegation: in some circumstances, a sufficiently pro-industry regulator is able to induce a separating equilibrium, which allows firms' cost-reducing efforts to converge towards their first-best levels, thus again raising intertemporal welfare. A strong example of this arises when the discount factor is high. Here, the regulator's willingness to allow future rent removes the inefficient firm's incentives to mimic its efficient counterpart and, hence, encourages earlier separation. Both of these results provide new justifications for the widespread use of independent regulators in a variety of countries.

The ability to alleviate time inconsistency problems is not the only advantage of regulatory independence. It also compensates for the policy uncertainty that results from changing political majorities[12], may help to recruit scarce experts in complex industries[13] and can serve to de-politicise decision-making in static as well as dynamic situations.[14] Many of these benefits are described in Trillas (2010), Levine *et al.* (2005) and Evans *et al.* (2008). At the same time, there are clearly costs to independence. Our model has identified the welfare effects of delegation to excessively pro-industry regulators, while Bernstein (1955) provides an early insightful discussion of several others. One of these is that independence does not necessarily fix, so much as relocate, the commitment problem, which becomes one of the government finding it difficult to commit to preserving the independence of regulators (see Trillas and Montoya (2011) and Hauge *et al.* (2010)). In similar vein, Posen (1993) argues that regulatory independence is just a consequence of a preference for commitment, but not its real cause. Besides, independent regulators may find it more difficult than ministries to coordinate with the rest of government, which is costly when there are gains from cooperation due to policy externalities. In addition, *politicised* regulators may sometimes be useful in order to drive change and overcome inertia or resistance to change, for example in liberalization processes. Despite these counter-arguments, empirical evidence shows in general that regulatory independence has positive effects on network expansion and efficiency, as summarized in Trillas (2010), Edwards and Waverman (2006) and Cambini and Rondi (2010). The literature on the selection method of regulators also shows both theoretically and empirically that appointed regulators fare better in terms of facilitating investment than elected regulators Besley and Coate (2003), a result the authors interpret as suggesting benefits from avoiding regulatory over-reliance on particular stakeholders (perhaps the equivalent of our intermediate ranges for α).

We believe that our model can be amended to further the above research agenda in a number of ways. For example, questions of the appropriate level of independence are closely related to ones of regulatory capture that have been studied elsewhere in the regula-

[12] See Faure-Grimaud and Martimort (2003)

[13] However, expert commissions are not free from behavioral biases, as pointed out by Landier and Thesmar (2010), pages 171-195.

[14] The recent IEAE report into Japan's nuclear crisis at Fukushima identified a lack of independent regulation as the reason why the hazard posed by tsunamis to nuclear plants had been underestimated; see IAEA (2011), Lesson 16. Similar arguments in favour of de-politicising such sensitive regulation are behind the British Health and Safety Executive's proposals to create an independent Office of Nuclear Regulation.

tion literature. Typically, capture is regarded as inefficient to the extent that it wastefully uses resources and may distort regulatory decisions. However, our model suggests that a fine line may exist between the benefits of pro-industry regulators and effects of capture itself. Consideration of this issue would require us to treat explicitly the capture process (and to endogenize the wasteful expenditures it involves), in a manner similar to Boyer and Laffont (1999) recent treatment of lobbying for environmental regulation. Such a focus on the political economy aspects of regulation should also be extended to endogenising the choice of regulator (Baron (1988), Spulber and Besanko (1992); more generally, see Laffont (2000). It would be interesting, for example, to examine Baron's political equilibrium for circumstances when majority voting favours pro-industry, as opposed to pro-consumer, regulation.

In a related paper, we have taken some steps in this direction, and demonstrated benefits to regulatory independence in related settings. These have included ones where the regulator's 'type' is endogenised in a lobbying game, and where both investment and price regulation feature as part of the regulatory set-up (see Evans *et al.* (2011)). Similarly, Levine *et al.* (2005) uses a complete information model to show that delegation can help correct underinvestment problems. The current paper deliberately focuses on a simple regulatory environment in order to emphasize the role of delegation but it is interesting that benefits remain (often in enhanced fashion) in these related settings. Future research may also generalize the model we have used. Thus, an infinite time horizon would capture more explicitly the importance of future considerations (currently captured by the discount rate alone). Additional issues could also be addressed by considering the role of delegation in regulating product quality, an area where dynamics without commitment can generate inefficiencies.

Our paper suggests that the choice of regulator matters when a government is delegating regulatory authority, and when the costs and benefits of regulatory independence are being assessed. The above suggestions set out an interesting agenda for research to enhance our understanding of the potentially important role played by this choice. More generally, the achievement of adequate levels of ex ante decisons such as managerial effort or investment depends on a number of policy and institutional instruments taken often by a variety of jurisdictions. Acemoglu (2010) for example argues that more efficient instruments may trigger more costly rent seeking unless there are sufficient checks and balances. Sinn (2004) analyzes how in a context of increasingly integrated markets states compete for mobile factors combining instruments such as taxation or investment in local infrastructures. The implications of this debate on instruments and jurisdictions for the regulation of network industries are preliminary explored by Trillas (2008).

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A Details of Equilibria

This Appendix sets out the details of the equilibria used in the paper. It is essentially a generalization of LT, section A9.9, to allow for delegation to a pro-industry regulator with the weight on rent $\alpha > 1$, and for quadratic tax distortions. The general procedure for computing the equilibria is as follows. First we look for a type I equilibrium. Assume that the efficient firm chooses the low-cost contract with probability x which is given, for the moment. Then solve for given x resulting in a pair of contracts and a social welfare function that are functions of x. The regulator then chooses a pair of contracts that maximizes the social welfare with respect to x, which is then endogenously determined by the efficient firm. Having computed the type I equilibrium we then check that the $\overline{IC}_1$ constraint holds and is not binding. If this is not the case then we make $\overline{IC}_1$ bind and proceed to calculate the type III equilibrium. For both types I and III, the second-period solution for a given probability ν_2 is given by:

Second-Period Solution

The problem is to choose $(\overline{U}_2, \overline{e}_2)$ and $(\underline{U}_2, \underline{e}_2)$ to maximize

$$E[W_2(\upsilon_2)] = \upsilon_2 W(\underline{U}_2, \underline{e}_2; \underline{\beta}, \alpha) + (1 - \upsilon_2) W(\overline{U}_2, \overline{e}_2; \overline{\beta}, \alpha) \tag{A.1}$$

subject to

$$\underline{IC}_2 \;:\; \underline{U}_2 \geq \overline{U}_2 + \psi(\overline{e}_2) - \psi(\underline{\tilde{e}}_2) = \overline{U}_2 + \Phi(\overline{e}_2) \tag{A.2}$$

$$\overline{IR}_2 \;:\; \overline{U}_2 \geq 0 \tag{A.3}$$

where informational rents are given by $\Phi(\overline{e}_2) = \psi(\overline{e}_2) - \psi(\underline{\tilde{e}}_2)$ and $\underline{\tilde{e}}_2 = \overline{e}_2 - \Delta\beta$. The social welfare function takes the form

$$\begin{aligned} W(U_t, e_t; \beta, \alpha) &= S - (1+\lambda)(\beta - e_t + \psi(e_t)) - (1 + \lambda - \alpha) U_t \\ &\quad - \mu(\beta - e_t + \psi(e_t) + U_t)^2 \end{aligned} \tag{A.4}$$

If the value function in (A.1) is less than $\upsilon_2 W(\max[0, U^*(\alpha, \underline{\beta})], e^*; \underline{\beta}, \alpha)]$ where $U^*(\alpha, \underline{\beta}) = (\alpha - \underline{\alpha})/(2\mu)$ then only one contract is offered designed for the efficient type and the inefficient firm closes.

For sufficiently low α the $\underline{IC}_2$ and $\overline{IR}_2$ constraints will bind, but as α increases first the $\underline{IC}_2$ and then the $\overline{IR}_2$ constraints cease to bind. Then the regulator will offer contracts demanding optimal effort with unconstrained optimal rents

$U^*(\alpha, \underline{\beta}) = (\alpha - \underline{\alpha})/(2\mu)$ and $U^*(\alpha, \overline{\beta}) = (\alpha - \overline{\alpha})/(2\mu)$ for the efficient and inefficient firm respectively. Thus we have:

$$\begin{aligned} \overline{U}_2 &= \max\left[(\alpha - \overline{\alpha})/(2\mu), 0\right] \\ \underline{U}_2 &= \max\left[(\alpha - \underline{\alpha})/(2\mu), \overline{U}_2 + \Phi(\overline{e}_2)\right] \end{aligned} \tag{A.5}$$

Now express $\underline{U}_2$ consistent with (A.5) as $\underline{U}_2 = \underline{U}_2(\overline{e}_2)$. The problem now is to choose $\underline{e}_2, \overline{e}_2$ to maximize

$$\upsilon_2 W(\underline{U}_2(\overline{e}_2), \underline{e}_2; \underline{\beta}, \alpha) + (1 - \upsilon_2) W(\overline{U}_2, \overline{e}_2; \overline{\beta}, \alpha) \tag{A.6}$$

The first order conditions then give:

$$\underline{e}_2 = e^* \tag{A.7}$$

$$\upsilon_2(\alpha - \underline{\alpha} - 2\mu \underline{U}_2)\frac{d\underline{U}_2}{d\overline{e}_2} + (1 - \upsilon_2)(1 - \psi'(\overline{e}_2)[1 + \lambda + 2\mu(\overline{\beta} - \overline{e}_2 + \psi(\overline{e}_2) + \overline{U}_2] = 0 \tag{A.8}$$

where $\frac{d\underline{U}_2}{d\overline{e}_2} = \Phi'(\overline{e}_2)$ if $(\alpha - \underline{\alpha})/(2\mu) < \overline{U}_2 + \Phi(\overline{e}_2)$, and $\frac{d\underline{U}_2}{d\overline{e}_2} = 0$, otherwise. For the rest of the solution and for our simulations we choose $\psi(e) = 1/2[\max(0, e)]^2$. Then $e^* = 1$, $\Phi'(\overline{e}_2) = \overline{e}_2$ if $\overline{e}_2 \leq \Delta\beta$ and $\Phi'(\overline{e}_2) = \Delta\beta$ otherwise. Given υ_2, equations (A.8) and (A.5) give solutions $\overline{e}_2 = \overline{e}_2(\upsilon_2)$ and $\overline{U}_2 = \overline{U}_2(\upsilon_2)$ and the social welfare at nodes A and B:

$$E(W_2 \mid A) = \upsilon_2(A) W(\underline{U}_2(\upsilon_2(A)), e^*, \underline{\beta}, \alpha) + (1 - \upsilon_2(A)) W(\overline{U}_2, \overline{e}_2(\upsilon_2(A)), \overline{\beta}, \alpha) \tag{A.9}$$

with an analogous result for $E(W_2 \mid B)$. This completes the second-period optimization problem.

First-Period Solution:Type III

It is convenient to set out the type III equilibrium procedure first. Given x and y, the optimization problem for the regulator of type α is to choose $(\overline{U}_1, \overline{e}_1)$ and $(\underline{U}_1, \underline{e}_1)$ to maximize

$$\begin{aligned} E(W_1 + \delta W_2) \quad = \quad & \upsilon_1[x W(\underline{U}_1, \underline{e}_1; \underline{\beta}, \alpha)] + (1 - x) W(\tilde{\underline{U}}_1, \tilde{\underline{e}}_1; \underline{\beta}, \alpha)] \\ & + (1 - \upsilon_1)[y W(\overline{U}_1, \overline{e}_1; \overline{\beta}, \alpha)] + (1 - y) W(\tilde{\overline{U}}_1, \underline{e}_1 + \Delta\beta; \overline{\beta}, \alpha)] \\ & + \delta E(W_2) \end{aligned} \tag{A.10}$$

where

$$E(W_2) = \Pr(A) E(W_2 \mid A) + \Pr(B) E(W_2 \mid B) \tag{A.11}$$

subject to $\underline{IC}_1$, $\overline{IC}_1$ and $\overline{IR}_1$ given by:

$$\underline{IC}_1 : \underline{U}_1 + \delta \underline{U}_2(\upsilon_2(A)) = \tilde{\underline{U}}_1 + \delta \underline{U}_2(\upsilon_2(B)) \tag{A.12}$$

$$\overline{IC}_1 : \overline{U}_1 + \delta \overline{U}_2(\upsilon_2(B)) = \tilde{\overline{U}}_1 + \delta \overline{U}_2(\upsilon_2(A)) \tag{A.13}$$

$$\overline{IR}_1 : \overline{U}_1 + \delta \overline{U}_2(\upsilon_2(B)) = 0 \tag{A.14}$$

where

$$\tilde{\underline{U}}_1 = \overline{U}_1 + \psi(\overline{e}_1) - \psi(\tilde{\underline{e}}_1), \tag{A.15}$$

$$\tilde{\overline{U}}_1 = \underline{U}_1 + \psi(\underline{e}_1) - \psi(\tilde{\overline{e}}_1) \tag{A.16}$$

where $\tilde{\underline{e}}_1 = \overline{e}_1 - \Delta\beta$ and $\tilde{\overline{e}}_1 = \underline{e}_1 + \Delta\beta$ are mimicking levels of first-period effort.

For type III equilibria both IC constraints must be binding. This will not be the case for high values of α for which only type I equilibria are possible. (We confirm this in the simulations). For the rest of the solution we assume that $\alpha < \overline{\alpha}$. Then $\overline{U}_2 = 0$ and the $\overline{IR}_1$ constraint becomes $\overline{U}_1 \geq 0$ which must bind for contracts to be optimal.

Constraints $\underline{IC}_1$ and $\overline{IC}_1$ above imply the following relationship between the first-period effort of the two types of firm:

$$\underline{e}_1 = \overline{e}_1 - \Delta\beta + \delta/(\Delta\beta)[\underline{U}_2(\nu_2(B)) - \underline{U}_2(\nu_2(A))] \tag{A.17}$$

From (A.15) and (A.16) $\tilde{\underline{U}}_1 = \tilde{\underline{U}}_1(\overline{e}_1)$ and $\tilde{\overline{U}}_1 = \tilde{\overline{U}}_1(\overline{e}_1, \underline{e}_1)$. Hence using (A.17), the maximization of (A.10) reduces to a maximization with respect to $\overline{e}_1$ for which the first-order condition is:

$$\begin{aligned}
& \upsilon_1 x \quad \left[\frac{\partial W}{\partial \underline{U}_1}\frac{d\underline{U}_1}{d\overline{e}_1} + \frac{\partial W}{\partial \underline{e}_1}\frac{d\underline{e}_1}{d\overline{e}_1}\right] \\
+ \quad & \upsilon_1(1-x)\left[\frac{\partial W}{\partial \tilde{\underline{U}}_1}\frac{d\tilde{\underline{U}}_1}{d\overline{e}_1} + \frac{\partial W}{\partial \tilde{\underline{e}}_1}\frac{d\tilde{\underline{e}}_1}{d\overline{e}_1}\right] \\
+ \quad & (1-\upsilon_1)y\frac{\partial W}{\partial \overline{e}_1} + (1-\upsilon_1)(1-y)\frac{\partial W}{\partial \tilde{\overline{U}}_1}\left[\frac{\partial \tilde{\overline{U}}_1}{\partial \overline{e}_1} + \frac{\partial \tilde{\overline{U}}_1}{\partial \underline{e}_1}\frac{d\underline{e}_1}{d\overline{e}_1}\right] = 0
\end{aligned} \tag{A.18}$$

The solution to the first-period problem, given x and y is then completed by noting that

$$\frac{d\underline{U}_1}{d\overline{e}_1} = \frac{d\tilde{\underline{U}}_1}{d\overline{e}_1} = \frac{\partial \tilde{\overline{U}}_1}{\partial \overline{e}_1} = \Phi'(\overline{e}_1) \tag{A.19}$$

where

$$\begin{aligned}
\Phi'(\overline{e}_1) \quad &= \quad \overline{e}_1 \qquad \text{if} \qquad \overline{e}_1 \leq \Delta\beta \\
&= \quad \Delta\beta \qquad \text{if} \qquad \overline{e}_1 \geq \Delta\beta
\end{aligned} \tag{A.20}$$

$$\frac{\partial \tilde{\overline{U}}_1}{\partial \underline{e}_1} = -\Delta\beta; \qquad \frac{d\underline{e}_1}{d\overline{e}_1} = 1 \tag{A.21}$$

$$\frac{\partial W}{\partial e_t} = (1 - e_t)[1 + \lambda + 2\mu(\beta - e_t + e_t^2/2 + U_t)] \tag{A.22}$$

$$\frac{\partial W}{\partial U_t} = -(1 + \lambda - \alpha) - 2\mu(\beta - e_t + e_t^2/2 + U_t) \tag{A.23}$$

The intertemporal welfare loss (A.10) can now be calculated using the solutions above for $(\overline{U}_t, \overline{e}_t), (\underline{U}_t, \underline{e}_t), t = 1, 2$ and the Bayesian rules:

$$\upsilon_2(A) = \frac{\upsilon_1 x}{\Pr(A)} = \frac{\upsilon_1 x}{\upsilon_1 x + (1 - \upsilon_1)(1 - y)} \tag{A.24}$$

$$\upsilon_2(B) = \frac{\upsilon_1(1 - x)}{\Pr(B)} = \frac{\upsilon_1(1 - x)}{\upsilon_1(1 - x) + (1 - \upsilon_1)y} \tag{A.25}$$

The type III equilibrium is finally obtained by maximizing the intertemporal welfare with respect to x and y using a standard numerical maximization procedure.[15] **First-Period Solution:Type I**

Given x, the optimization problem for the regulator of type α is to choose $(\overline{U}_1, \overline{e}_1)$ and $(\underline{U}_1, \underline{e}_1)$ to maximize

$$\begin{aligned} E(W_1 + \delta W_2) \quad = \quad & \upsilon_1[xW(\underline{U}_1, \underline{e}_1; \underline{\beta}, \alpha)] + (1 - x)W(\tilde{\underline{U}}_1, \tilde{\underline{e}}_1; \underline{\beta}, \alpha)] \\ & +(1 - \upsilon_1)[W(\overline{U}_1, \overline{e}_1; \overline{\beta}, \alpha)] + \Delta\beta; \overline{\beta}, \alpha)] \\ & +\delta E(W_2) \end{aligned} \tag{A.26}$$

where

$$E(W_2) = \Pr(A)E(W_2 \mid A) + \Pr(B)E(W_2 \mid B) \tag{A.27}$$

subject to $\underline{IC}_1$, and $\overline{IR}_1$ given by:

$$\underline{IC}_1 \quad : \underline{U}_1 + \delta\underline{U}_2(\upsilon_2(A)) = \tilde{\underline{U}}_1 + \delta\underline{U}_2(\upsilon_2(B)) \tag{A.28}$$

$$\overline{IR}_1 \quad : \overline{U}_1 = 0 \tag{A.29}$$

where

$$\tilde{\underline{U}}_1 = \overline{U}_1 + \psi(\overline{e}_1) - \psi(\tilde{\overline{e}}_1), \tag{A.30}$$

The rest of the solution follows almost as before putting $y = 1$ so that $\Pr(A) = \upsilon_1 x$, $\Pr(B) = \upsilon_1(1 - x)$ and $\upsilon_2(A) = 1$. The only other change arises from the fact that in

[15] All the numerical calculations were performed using MATLAB.

the first period the constraint $\overline{IC}_1$ may cease to bind for high α. Then in a separating equilibrium with $x = 1$ (A.19) is replaced with

$$\begin{aligned} \frac{d\underline{U}_1}{d\overline{e}_1} = \frac{d\tilde{\underline{U}}_1}{d\overline{e}_1} &= \Phi'(\overline{e}_1) \qquad \text{if} \qquad (\alpha - \underline{\alpha})/(2\mu) < \tilde{\underline{U}}_1 + \delta(\underline{U}_2(\upsilon_2(B)) - \underline{U}_2(1)) \\ &= 0 \qquad \text{otherwise} \end{aligned} \tag{A.31}$$

The type I equilibrium is finally obtained by maximizing the intertemporal welfare with respect to x using a standard numerical maximization procedure.

B Proof of Propositions 2 and 3

Proposition 2

Differentiating (43) with respect to α and using (44) we obtain

$$\overline{e}_1'(\alpha) = \Theta_1/\Theta_2 \tag{B.1}$$

where

$$\begin{aligned} \Theta_1 &= (1+\delta)\nu_1\Phi'(\overline{e}_1) \\ \Theta_2 &= (1-\nu_1)(1+\lambda+2\mu[(1-\overline{e}_1)^2+\overline{C}_1+\overline{r}_1]) - \nu_1\Phi''(\overline{e}_1)(\alpha-\underline{\alpha}-2\mu\underline{U}_1) \\ &+ 2\mu(\Phi'(\overline{e}_1))^2 \end{aligned}$$

We can now show that all the terms defining Θ_1 and Θ_2 are positive hence proving proposition 2. Θ_1 is positive because $\Phi'(\overline{e}_1) > 0$. The first term in Θ_2 is positive because total transfers to the inefficient firm, $\overline{C}_1 + \overline{r}_1$, are positive. Since $\Phi'(\overline{e}_1) > 0$ and $\Phi''(\overline{e}_1) \geq 0$ the second and third terms are non-negative if $\underline{U}_1 \geq (\alpha - \underline{\alpha})/2\mu$, which always holds because $(\alpha - \underline{\alpha})/(2\mu)$ is the unconstrained optimal rent for the efficient firm.

Proposition 3

For α in the range $[\underline{\alpha}, \overline{\alpha}]$ for which $\underline{IC}$ binds we have from (44) and (B.1) that

$$\frac{d\underline{U}_1}{d\alpha} < \frac{(1+\delta)\nu_1(\Phi(\overline{e}_1))^2}{(1-\nu_1)(1+\lambda)+2\mu\nu_1(\Phi(\overline{e}_1))^2} - \frac{\delta}{2\mu} < 0 \tag{B.2}$$

if $(1-\nu_1)(1+\lambda)\delta > 2\mu\nu_1(\Phi(\overline{e}_1))^2$. For the case where $\overline{e}_1 > \Delta\beta$, the first-period mimicking effort of the efficient firm is positive and $\Phi'(\overline{e}_1) = \Delta\beta$. For the case where $\overline{e}_1 < \Delta\beta$, the first-period mimicking effort of the efficient firm is negative and then $\Phi'(\overline{e}_1) = \overline{e}_1 \leq 1$. It follows that a *conservative* lower bound for which if $\delta > \underline{\delta}$ then $\frac{dU_1}{d\alpha} < 0$ is given by

$$\underline{\delta} = \max \left[\frac{2\mu\nu_1(\Delta\beta)^2}{(1-\nu_1)(1+\lambda)}, \frac{2\mu\nu_1}{(1-\nu_1)(1+\lambda)} \right] \tag{B.3}$$

Hence the proposition is proved and, in addition, we have found an explicit lower bound for δ.

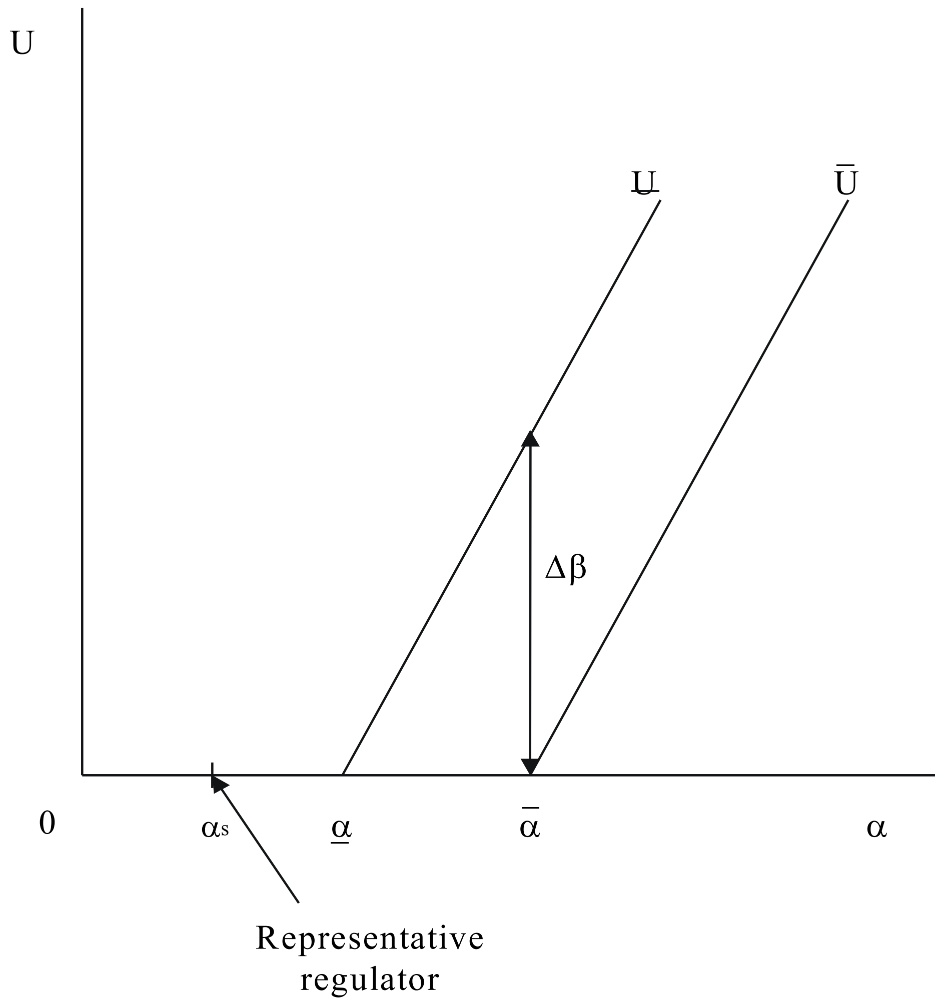

Figure 1. Delegation and rents under complete information

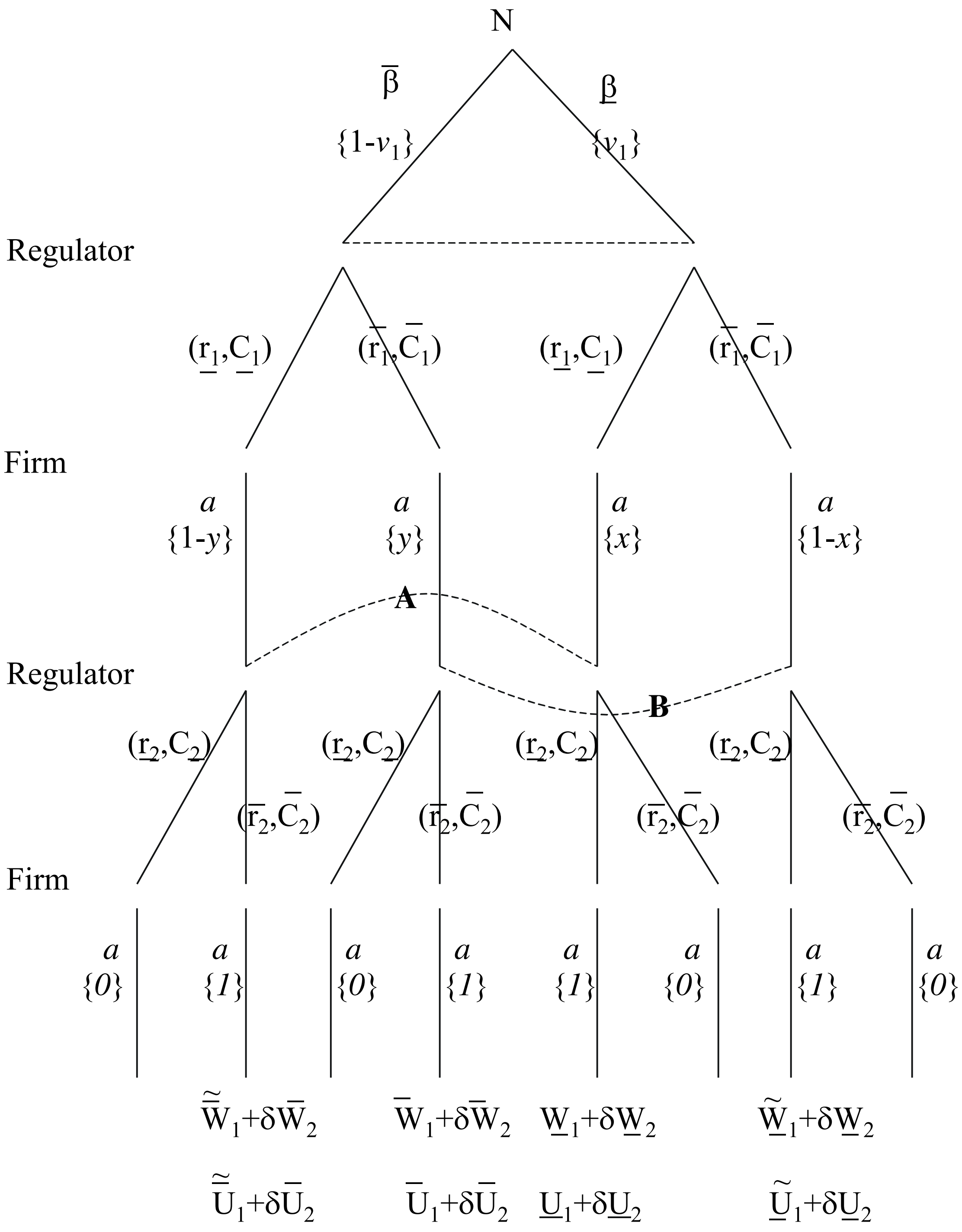

Figure 2. Type III equilibrium.

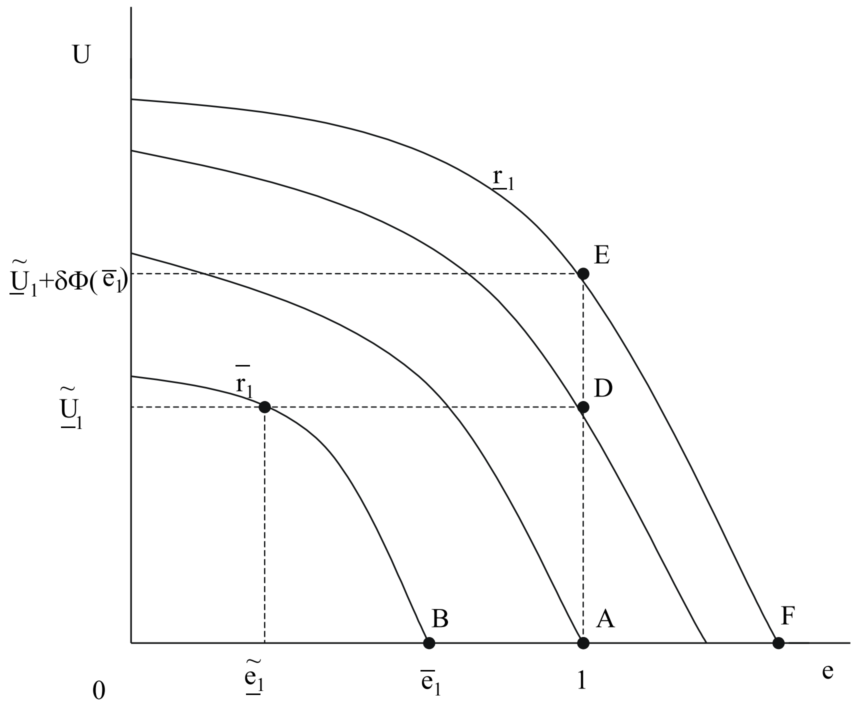

Figure 3. Incomplete information equilibrium

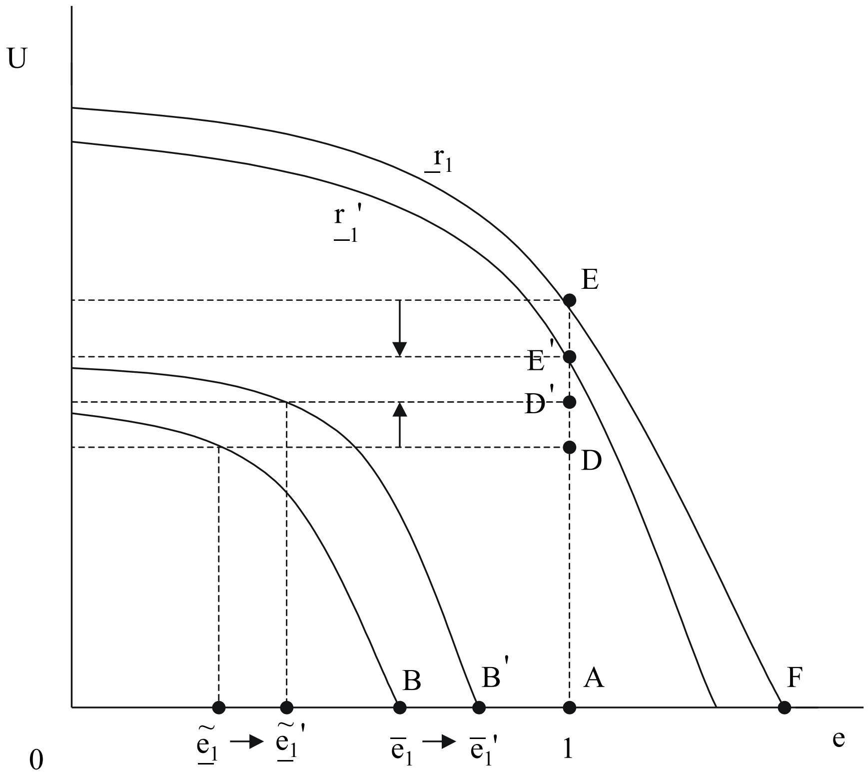

Figure 4. The effects of a more pro-industry regulator

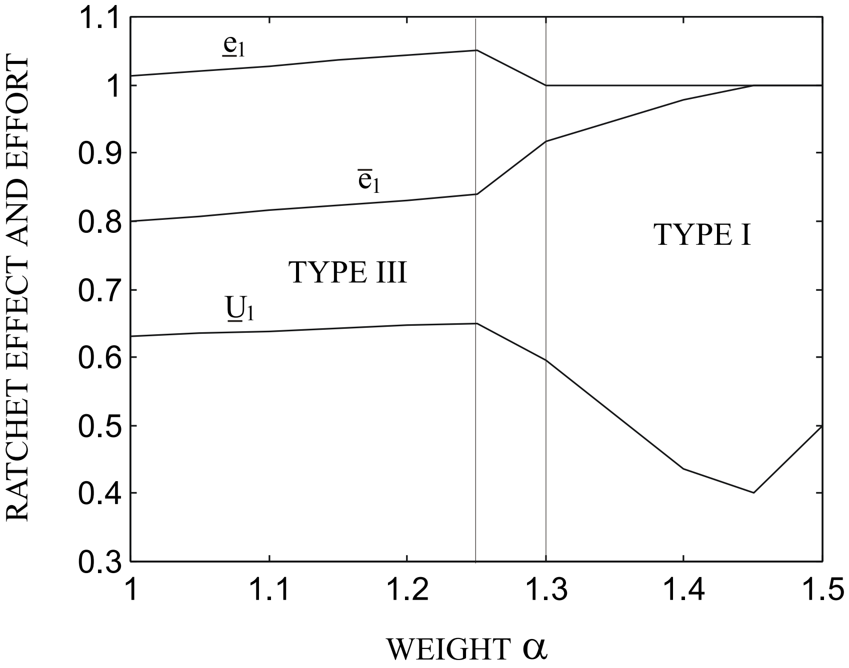

Figure 5a. First-Period Effort of both Firms and Rent of Efficient Firm. Baseline Values

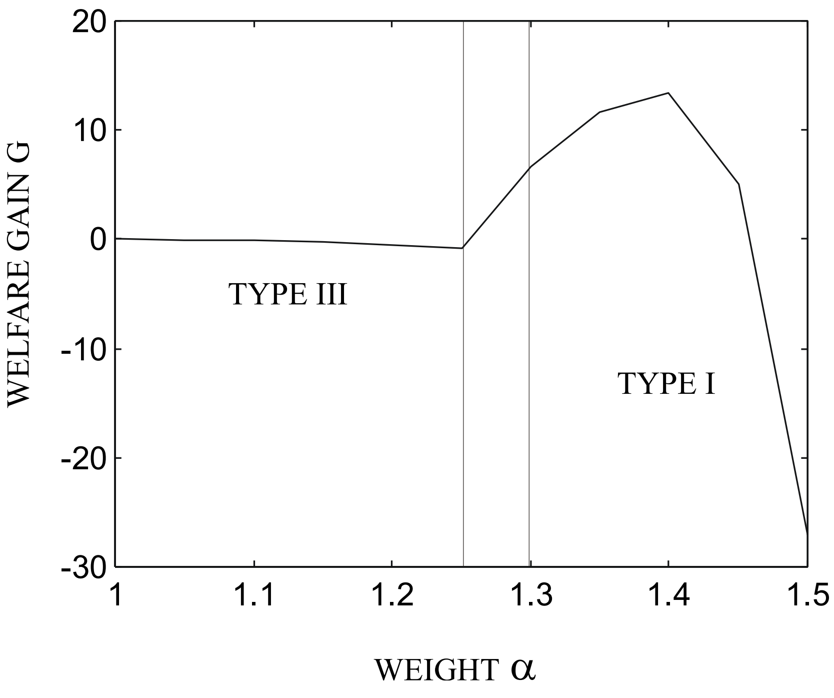

Figure 5b. Intertemporal Welfare Gain. Baseline Values

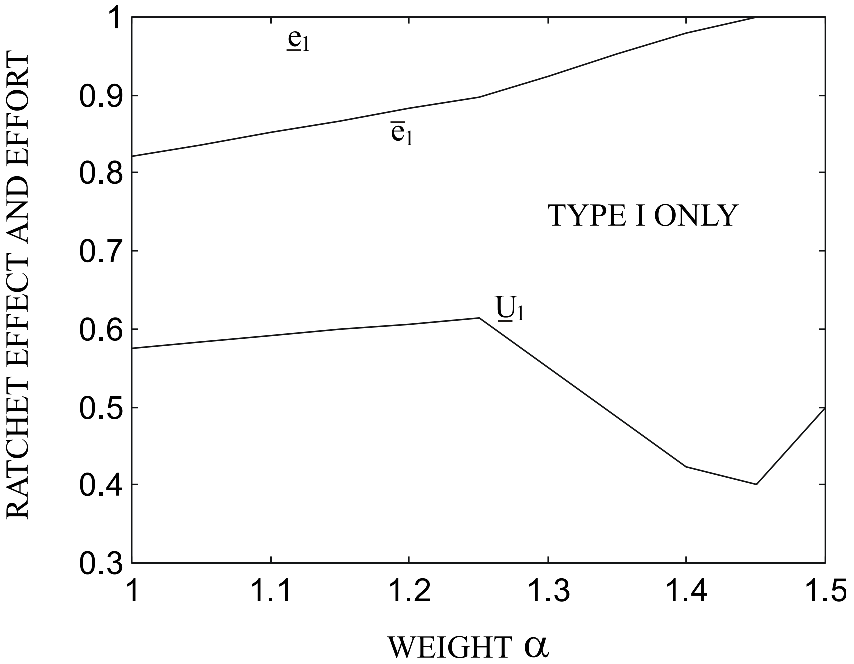

Figure 6a. First-Period Effort of both Firms and Rent of efficient Firm. $\delta=0.95^5$

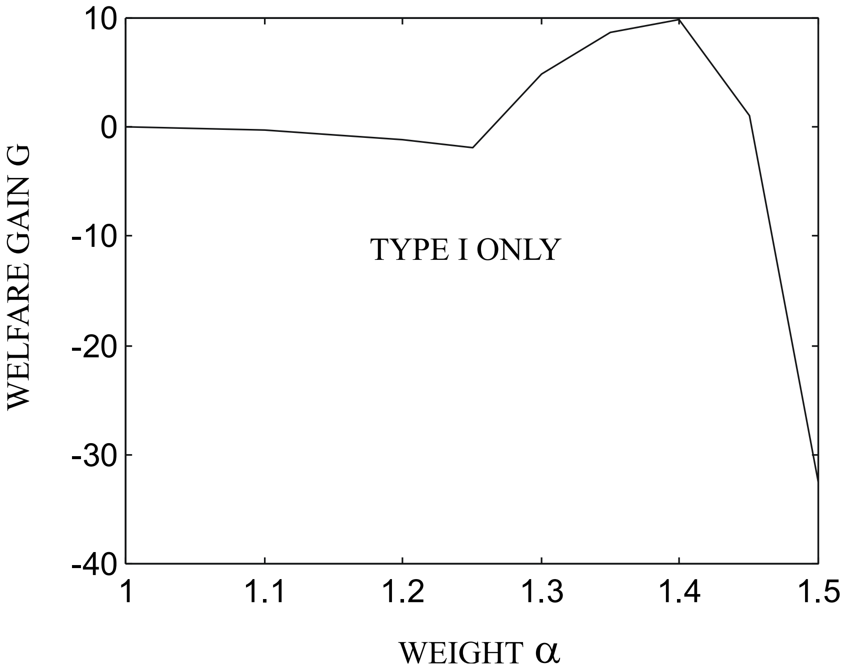

Figure 6b. Intertemporal Welfare Gain. $\delta=0.95^5$

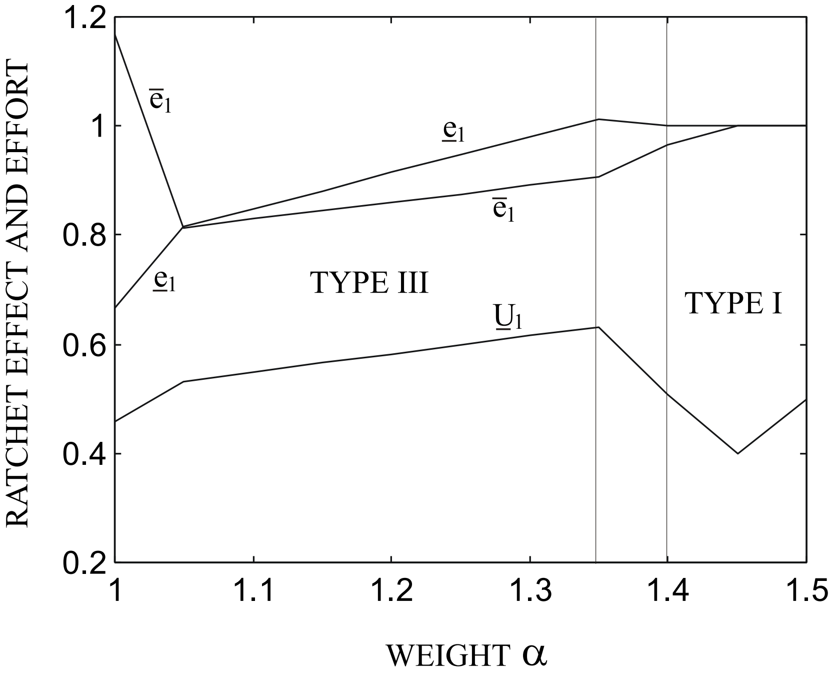

Figure 7a. First-Period Effort of both Firms and Rent of Efficient Firm. δ=2

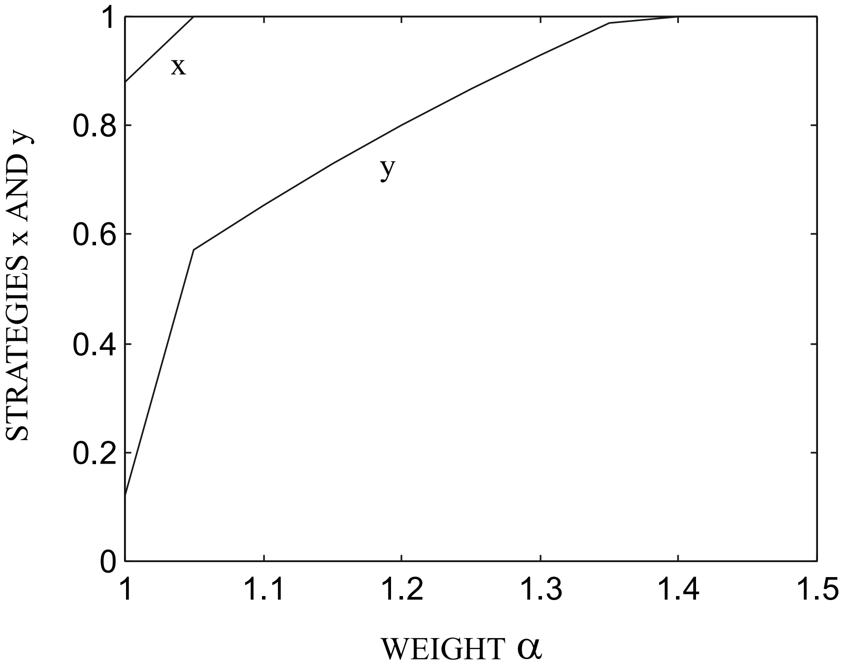

Figure 7b. Mixed Strategies

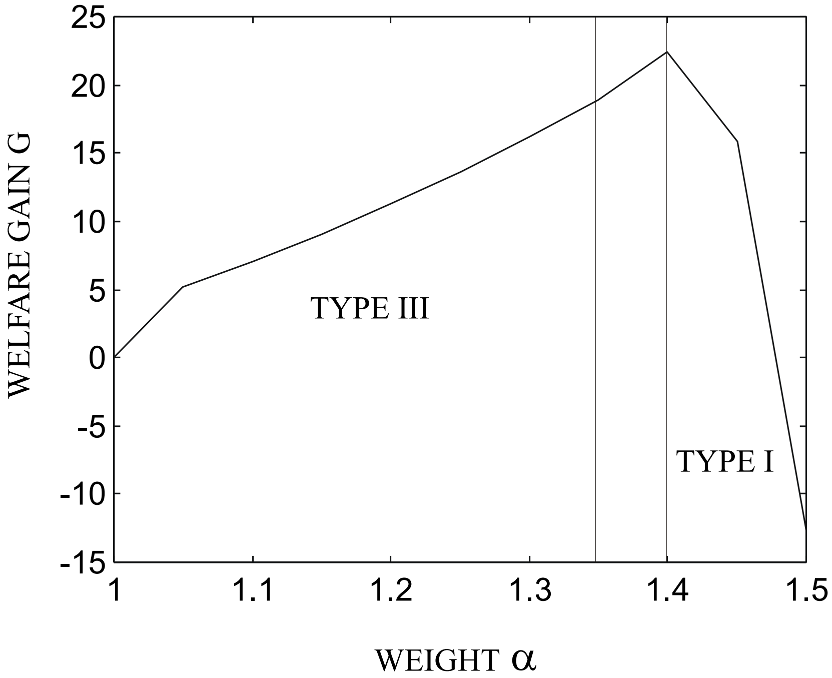

Figure 7c. Intertemporal Welfare Gain. δ=2

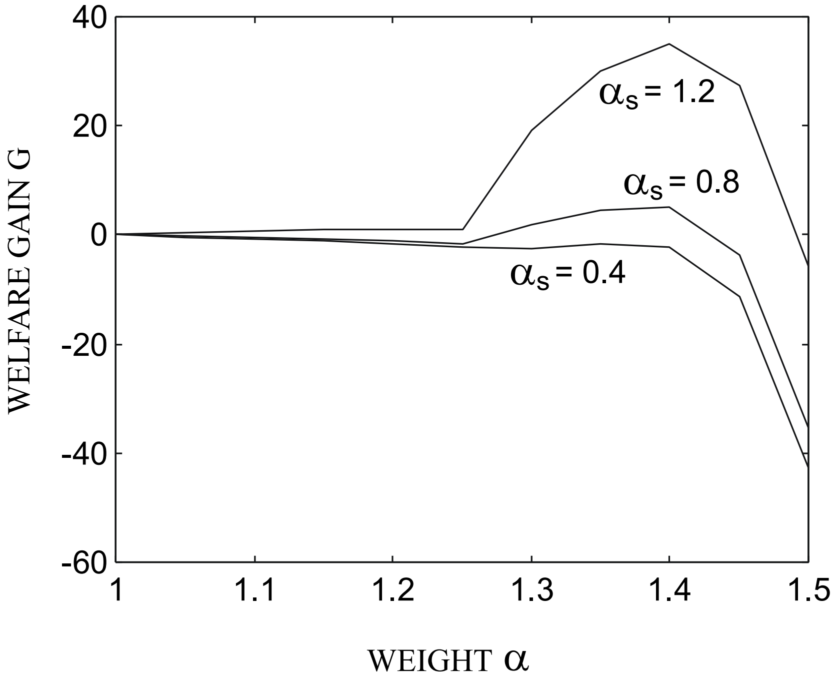

Figure 8. Intertemporal Welfare Gain. Baseline values with α_s=0.4, 0.8, 1.2