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Influencing Bureaucratic Decisions

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Influencing bureaucratic decisions

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Abstract

We consider a setting in which projects involving private benefits and public costs are subject to government approval. The decision about whether to approve a proposed project is made in a decentralised fashion by comparing its costs and benefits to a predetermined standard. Importantly, we introduce the possibility that the party proposing a project can take (costly) actions that affect the government agency's assessment of the project; that is, the bureaucratic decision rule may potentially be subject to opportunistic manipulation. We find that, although opportunistic behaviour does occur at equilibrium and hence decisions will be distorted, specific measures to counter manipulation - including making opportunistic behaviour more costly and adjusting the standard by which projects are evaluated - may not be warranted. Moreover, although the direction in which the evaluation standard should be adjusted depends finely upon the parameters of the model, there is generally a trade off between a higher regulatory capacity (making opportunistic behaviour more difficult) and the extent to which the standard is distorted.

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1 Introduction

4th July 1996, TrioVing, the largest producer of keys and locks in Norway, bought all shares in Møller Undall, the dominant importer and wholesaler of such products. The Norwegian Competition Authority (NCA) investigated the case under the merger control provision in the Norwegian Competition Act, according to which the authority can block or restrict a merger if it finds that the merger has negative effects on competition in conflict with the objective of the Act (viz., an efficient allocation of resources). The NCA found that although the merger was primarily vertical competition in the Norwegian market for keys and locks would be substantially reduced as a consequence of the merger, and *ex ante* this reduction of competition was in conflict with the objective of the Act. However, at the time when the NCA had completed its investigation, the merging companies were already integrated to such an extent that it would be very difficult to restore them to their original state. Since the costs of re-establishing earlier levels of competition were considered to outweigh the positive effects of blocking the merger, the NCA decided that *ex post* it did not have sufficient reason to do so.[1]

This case raises, in our view, a number of interesting issues. These concern the merits of the particular merger project and, more generally, competition policy as such. There are also questions concerning the government's handling of the case and the role played by the private parties involved. It is on the latter issue that we want to concentrate here: while we do not want to suggest that, in this particular case, the companies involved deliberately attempted to influence the decision of the competition authority, it is evident that their actions in effect determined the outcome; had it been the companies' intention to strategically manipulate the investigation, then their efforts certainly met with success. This observation is the starting point for the present analysis, by which we aim to shed light on the following question: given that private agents may have incentives - and opportunity - for strategically influencing bureaucratic decisions, how should policy be designed to take account of such behaviour?

While our analysis is motivated by an example from merger policy the

[1] NCA decleared its intention to investigate the merger in a letter dated 30th July 1996 and its final decision was communicated in a letter of 12th June 1997. The length of the investigation period exceeded the normal limit of 6 months that is mandated in the Competition Act (§3-11), and hence the process of integration between the two companies may have been more extensive than what would be normal in such cases. While not directly opposing the merger, NCA imposed certain restrictions, including the termination of an exclusive dealership agreement between Trio Ving and one of its suppliers.

problem may arise in other contexts as well. For example, it seems a recurrent phenomenon that developers go ahead with projects before planning permission has been granted - or that they alter projects along the way without obtaining the necessary permission. Listing of buildings and sites is sometimes hampered by owners' neglect, or outright sabotage, which reduces the historical value of a property or increases the cost of returning it to its earlier state. Similarly, in order to avoid the introduction of environmental regulation natural habitats may not be protected properly, or even damaged intentionally. In such cases, the enforcement agency may be presented with a fait accompli; once the agency becomes aware of a case, and is able to reach a decision, it may be very difficult, if at all possible, to restore status quo.

An obvious remedy is to restrict the set of actions available to agents before a project is approved. For instance, the EC Merger Regulation requires that a merger shall not be put into effect either before its notification or before the Commission has declared it compatible with the Common Market.[2] Had a similar regulation existed in the Norwegian Competition Act the actions taken by TrioVing and Møller Undall may well have been considered illegal.[3] However, it is hardly possible to eliminate any action that could potentially influence the assessment of a particular project. For example, a company can take unilateral actions - reorganising its structure, closing down a product line, selling off parts of the business or renegotiating contracts with input suppliers or distributors - that while being consistent with preparations for a merger could also be deemed economically rational even if the merger is not allowed to go through. Given the inevitable informational handicap of a goverment authority, and the fact that actions may have been taken a considerable time before the intention to go through with a particular project

[2] Council Regulations (EEC) No 4064/89 of 21st of December 1989 and No 1310/97 of 30th of June 1997 on the control of concentrations between undertakings (The EC Merger Regulation) regulates mergers in the European Community, and in the European Economic Agreement-area. The Regulation requires that '*concentrations with a Community dimension ... shall be notified to the Commission not more than one week after the conclusion of the agreement, or the announcement of the public bid, or the acquisition of a controlling interest'* (article 4-1). Furthermore, *'A concentration ... shall not be put into effect either before its notification or until it has been declared compatible with the common market'* (article 7-1).

[3] Allowing the NCA the opportunity to provisionally block a merger under investigation was discussed when the new merger regulations was introduced. However, at that time it was felt that a time limit on investigations would be sufficient to ensure that a decision could be reached before a merger was too far advanced. Later experience has lead the Norwegian Government to propose a change in the Competition Act to mandate provisional blocking of mergers. The argument given for this change explicitly recognises the opportunity for private parties to affect the outcome of a merger investigation (cf Ot. prop. 97 (1998-99) of 19th September 1999).

is made public, it would in many cases be very difficult to prove that such actions were illegal. Furthermore, a draconien rule, banning private agents from making important decisions, while not only difficult to enforce, would also be very costly as it would seriously undermine the effectiveness with which agents could conduct their normal business. The question, therefore, is how far one would like to extend the regulatory powers of a government authority, taking into account the inevitable costs that such regulations impose (including the costs of delaying the completion of approved projects).

An alternative remedy to counter opportunistic behaviour is to provide government authorities, not only with more regulatory powers, but also with more resources. By increasing the effectiveness with which an authority conducts its investigations the time needed to reach a decision may be reduced (it may also be easier to detect actions that are in breach of regulations restricting private agents behaviour before or during an investigation). In the formal analysis below, we model regulatory powers and regulatory effectiveness (which will both be included in an index of 'regulatory capacity') as measures that increase the costs to private agents of reaching a certain level of influence. We find that it will in general not be optimal to entirely eliminate any scope for opportunistic behaviour; in particular, as long as there are no significant fixed (private) costs associated with strategic manipulation such behaviour will take place at equilibrium. More interesting perhaps, is that it may be optimal not to take any specific regulatory measures at all. While making opportunistic behaviour more costly discourages such behaviour, it also increases waste in the event that manipulation does take place. Under quite reasonable assumptions the cost of increasing regulatory capacity outweigh the gain and hence specific measures to combat strategic manipulation are not warranted.

Given that a government authority's decisions may be subject to manipulation one may ask whether this should have an impact on the decisions themselves. By raising the welfare standard by which the merits of a project are evaluated the government can increase the efforts required to overturn decision in a given case. On the one hand, this may reduce incentives to engage in such activities. On the other hand, in those cases that manipulation does occur more effort will be spent and hence more costs will be wasted. As we shall see, in the most general case it is not clear which of these effects dominate and hence whether it is optimal to raise or lower the welfare standard to counter opportunistic behaviour (however, we are able to shed some light on how characteristics of the environment should influence the choice of standard). What is clear is that an entirely permissive policy is never optimal. Furthermore, while we find that the implications for the choice of welfare standard is ambiguous, we detect a certain trade off between regulatory capacity and the strictness of policy; in particular, the welfare standard should be distorted further away from its first best value the higher is the cost of regulatory capacity.

I a broad sense, our analysis is related to the literature on 'influence cost' (e.g., Milgrom, 1988; Milgrom and Roberts, 1988; and Meyer, Milgrom and Roberts, 1992; see also Gibbons, 1999). A distinction has been made between three categories of such costs. Firstly, resources may be devoted to affecting the distribution of benefits rather than creating value. Secondly, suboptimal decisions may result as a consequence of influence activities. And, thirdly, performance may by degraded due to actions or organisational changes aimed at limiting influence activities. Interestingly, and in contrast with much of the previous literature, in our model all types of influence costs may, and often will be, present at equilibrium: even though resources are spent on limiting influence activities, such (costly) activities do take place and, as a result, bureaucratic decisions become suboptimal.

Our work is perhaps most closely related to that of Besanko and Spulber (1993), although these authors are dealing with the somewhat different problem of how policy should be adjusted to take account of the fact that a government authority may be unable to make credible enforcement commitments. The interaction between a competition authority and firms that may potentially be involved in a merger is modelled as a three-stage game. In the first stage, a welfare standard is chosen so as to maximize expected social welfare when the impact of the standard on firms' merger decisions and the authority's enforcement decisions is taken into account.[4] In the second stage, firms privately observe the profit gain (or, cost savings) that can be realised by the merger and decide whether or not to propose it. In the third stage of the game, the authority decides whether or not to challenge a proposed merger. Besanko and Spulber show that in sequential equilibrium the competition authority will choose a probability of challenge that is lower than the probability that maximises ex ante social welfare, thereby reducing the likelihood of blocking welfare enhancing mergers. In order to counteract the resulting bias towards allowing mergers that have negative effects on welfare the competition authority will put more weight on consumer welfare than on firms profits in it's welfare standard.

We consider a similar game but allow for the possibility that (in the second stage) private parties can take actions that affect the authority's assessment of the overall benefit of their project. We also allow the authority opportunity to introduce measures (in the first stage of the game) that increase agents

[4] See Section 7 of their paper for a discussion of the reasonableness of the assumption that the competition authority can be committed to a certain welfare standard.

cost of opportunistic behaviour. However, in order to simplify the analysis, we disregard the possibility that the authority cannot commit to enforcement (a possible interpretation of our model is that the authority can observe the private profitability of a project, but cannot distinguish between genuine gains and the impact of strategic investments); in other words, we abstract from the Besanko-Spulber type of effect and our analysis should therefore be considered complementary to theirs.

2 A Policy Game

Consider then a three stage game between a (private) agent and a (government) authority. In the first stage of the game, the authority determines the policy that is to be applied in the following stages of the game. A policy is summarised by a welfare standard $\overline{W}$ and a regulatory capacity α. The welfare standard is the minimum increase (or maximum decrease) in public welfare caused by a project that the authority will tolerate. If a project increases public welfare by less than the welfare standard the authority will block it. Hence, a higher $\overline{W}$ is associated with a stricter policy. Regulatory capacity is a summary index for the difficulty the agent meets in taking actions designed to influence the authority's decision about a given project. By increasing the authority's investigating powers, its capacity or efficiency, or by introducing explicit regulations governing the set of actions agents may take before a proposed project is approved, the agent's room for manoeuvre is restricted. Hence, a higher α is associated with a stricter policy towards potentially opportunistic behaviour.

In the second stage of the game, the profitability of a (potential) project $\widetilde{\pi}$ is revealed. Based upon project profitability and the established policy, the agent decides whether to propose the project. If he decides to do so, the agent may also make a (strategic) investment k. The investment has no productive value. It may be interpreted as the cost of restoring the ex ante situation; that is, k is the cost of blocking the project.

In the third and final stage of the game, the authority evaluates any proposed project and decides whether or not to block it. A proposed project will be blocked if and only if the change in public welfare following the project - account taken of any strategic investment - exceeds the welfare standard as set out in the policy decided upon in the first stage of the game.

Note that we do not allow the policy to be directly conditioned on the investment k. A possible interpretation is that while the authority can observe the sum $\widetilde{\pi} + k$ it cannot distinguish between individual components. Alternatively, k may be unverifiable, or the authority's powers may have been limited for some other reason.

2.1 Agent payoff

The agent's gain is given by

$$\Pi = \widetilde{\pi} - C(k, \alpha). \tag{1}$$

Here $\widetilde{\pi}$ is a stochastic variable, the value of which is known to the agent at the time when he makes his decisions about the project and the investment. Project profitability $\widetilde{\pi}$ is distributed on $[\underline{\pi}, \overline{\pi}]$, $\underline{\pi} \leq 0 < \overline{\pi}$, according to the distribution function $F(\pi)$ with corresponding density function $f(\pi)$. If the agent decides to propose the project, he may make an (irreversible) investment $k \geq 0$ at a (sunk) investment cost $C(k, \alpha)$. Such an investment consequently reduces the gain from the project. If no investment is made investment cost is set to zero for all values of α, i.e. $C(0, \alpha) \equiv 0$. Investment cost is increasing in both size of investment and regulatory capacity; in particular, C_k, $C_\alpha > 0$.[5]

The dependence of investment cost on regulatory capacity is meant to capture the following idea: The investment involves actions that the agent can take to increase the cost of reversing the project, or stopping it from going through. k only includes actions for which an agent will not be directly penalised (that is, policy cannot be conditioned upon k).[6] However, the set of such actions from which the agent can choose may depend upon decisions made by the authority. For instance, if the length of time required to reach a decision on a particular case is reduced, only actions that can be implemented quickly will have any effect. Alternatively, regulations may be put in place that explicitly limit the behaviour of agents until a project has been approved. In either case, agents will find it more difficult to inflict a certain welfare cost of blocking a proposed project.

2.2 Public welfare

Policy is chosen so as to maximize public welfare. If no project is proposed, public welfare is normalized to 0. If a project is proposed, and is allowed to go through, the change in welfare W^m is given as the sum of project profitability

[5] We use subscripts to denote partial derivatives; in particular, $C_k \triangleq \frac{\partial C}{\partial k}$ and $C_\alpha \triangleq \frac{\partial C}{\partial \alpha}$.

[6] In a more general set up one might allow for the possibility that k could be observed imperfectly, such that merger policy could (to a certain extent, or with some probability) be made contingent upon k. In that case firms would face an uncertain cost of choosing a positive k.

and the (external) effect on third parties W^E (in the merger example, third parties would include consumers as well as competitors of the merging firms, cf. Farrell and Shapiro, 1990):

$$W^m = \widetilde{\pi} + W^E. \tag{2}$$

The external effect is assumed to be a negative constant, i.e. $W^E < 0$.[7] To make the problem interesting, we also assume that $\underline{\pi} < -W^E < \overline{\pi}$; in other words, there is a positive probability for either of the events that (i) a project is socially desirable (i.e., $\overline{\pi} + W^E > 0$) and (ii) that it is socially undesirable (i.e., $\underline{\pi} + W^E < 0$).

While, in their set up, Besanko and Spulber (1993) considered a model in which (in our notation) both project profitability $\widetilde{\pi}$ and external effect W^E were state dependent, our assumption that W^E is a constant is purely to simplify the analysis.[8] Note, however, that if the external effect were observable and verifiable - so that policy could be made dependent upon its realisation - only the conditional distribution of $\widetilde{\pi}$ would be of any relevance. In particular, the distribution function F could then be interpreted as describing the distribution of $\widetilde{\pi}$ conditional upon the realisation (or, more precisely, the authority's assessment) of W^E; that is, $F(\pi) = \Pr(\widetilde{\pi} \leq \pi \mid W^E)$.[9]

Note that the investment k has no welfare effect when the project is allowed. If the project is blocked, however, the impact on welfare is

$$W^b = -k, \tag{3}$$

so that, as discussed above, $k \geq 0$ may be interpreted as the cost of reversing the process and restoring the pre-project situation. This cost is saved if the project is allowed to go through. Since we have assumed that $C(k, \alpha)$ is sunk before the authority considers the merit of a particular project, investment cost does not affect the decision about whether to block the project. The project is accepted if and only if increase in public welfare is equal to, or exceeds, the welfare standard; that is, if and only if

$$W = W^m - W^b = \widetilde{\pi} + W^E + k \geq \overline{W}. \tag{4}$$

[7] Since projects with $\widetilde{\pi} < 0$ will never be proposed, restricting attention to cases in which $W^E < 0$ is without loss of generality.

[8] Extending the analysis to a stochastic external effect would be straightforward, at least as long as the agent can observe the state of the world. Otherwise an element of regulatory uncertainty would be introduced, as the agent could not perfectly foresee the authority's assessment of the external effect and hence its decision on the project (if the agent is risk neutral this might not matter much).

[9] Under this intepretation one may consider the choice of welfare standard as a choice of relative welfare weights, as in Spulber and Besanko (1993).

As mentioned above, a larger $\overline{W}$ implies a stricter policy. Note also that, since all policies involving $\overline{W} \leq W^E$ lead to the same outcome (in particular, any proposed project will be allowed and no investment will ever take place), we can restrict attention to policies satisfying $\overline{W} \geq W^E$.[10] A policy is 'restrictive' if it does not approve all proposed projects (i.e., $\overline{W} > W^E$). It is 'prohibitive' if no projects are accepted.

A project is 'ex ante socially desirable' (undesirable) if $\widetilde{\pi} + W^E > (<)\, 0$. Note that if $\overline{W} = 0$, implying the approval of all projects that increase public welfare ex post, some ex ante socially undesirable projects will be accepted when $k > 0$. Conversely, when investment takes place at equilibrium, setting the welfare standard sufficiently above zero will be necessary to ensure that only ex ante socially desirable projects go through. As will be shown below, such a policy is in general not optimal.

3 Equilibrium analysis

In this section we consider subgame perfect equilibria of the game described above. As is customary practice, we solve the game backwards. Since the solution to the Stage 3 subgame is basically trivial (viz., the authority approves a proposed project if and only if the gain in public welfare meets the standard), we proceed immediately to Stage 2, in which the agent make project decisions.

3.1 Project decision

If the agent decides to propose a project he may at the same time make an investment k. Since such an investments is costly it will be made only if (i) it is needed in order to prevent the authority from blocking the project, and (ii) the project remains profitable after the necessary investment has been made. As there is no uncertainty about the outcome of the authority's decision about the project - given its choice of policy and the profitability of the project - a profit maximising investment will be tailored such as to just ensure that the project will be allowed. The necessary investment is determined implicitly by the condition

$$\widetilde{\pi} + W^E + k = \overline{W}. \tag{5}$$

[10] When $\bar{W} \leq W^E (< 0)$, a project will be blocked whenever $\tilde{\pi} + k < \bar{W} - W^E \leq 0$. However, a project with $\tilde{\pi} < 0$ will never be proposed, and $k \geq 0$. Consequently, under the above assumption, all projects with positive profititability will be proposed, and there will be no need for strategic investment to prevent the authority from blocking the project.

Now, define π^L as follows:

$$\pi^L - C(\overline{W} - \pi^L - W^E, \alpha) = 0. \tag{6}$$

π^L is the level of project profitability at which the agent is indifferent between not proposing the project (and earning a reservation payoff of 0), and proposing the project and making the necessary investment to allow the project to go through. For $\pi < \pi^L$, the profit maximising strategy is not to propose the project. Note that π^L is increasing in both the welfare standard $\overline{W}$ and regulatory capacity α; in particular,

$$\frac{d\pi^L}{d\overline{W}} = \frac{C_k}{1 + C_k} > 0, \tag{7}$$

$$\frac{d\pi^L}{d\alpha} = \frac{C_\alpha}{1 + C_k} > 0. \tag{8}$$

Next, define π^U by

$$\pi^U + W^E = \overline{W}. \tag{9}$$

π^U is the level of project profitability at which no investment is necessary to have the project accepted. Consequently, for $\widetilde{\pi} > \pi^U$ the agent proposes the project but make no investment, while for $\widetilde{\pi} \leq \pi^U$ strategic investment will be required to have a proposed project accepted. Note that π^U is increasing in the welfare standard $\overline{W}$, but is independent of regulatory capacity α; in particular,

$$\frac{d\pi^U}{d\overline{W}} = 1, \tag{10}$$

$$\frac{d\pi^U}{d\alpha} = 0. \tag{11}$$

We have the following result:

Proposition 1 *Assume that policy is restrictive but not prohibitive. Then (i) not all projects with positive profitability will be proposed, i.e.,* $\pi^L > 0$*; and (ii) strategic investment takes place in some contingencies, i.e.,* $\pi^U > \pi^L$*.*

Proof. Let $\Pi(\pi) = \pi - C(\overline{W} - \pi - W^E, \alpha)$. From the assumptions concerning C, it follows that Π is increasing and continuous. Then, since $\Pi(0) = -C(\overline{W} - W^E, \alpha) < 0$ and $\Pi(\pi^U) = \pi^U - C(\overline{W} - \pi^U - W^E, \alpha) = \overline{W} - W^E > 0$, there exists a unique solution π^L to Equation (6) that satisfies $0 < \pi^L < \pi^U$. ■

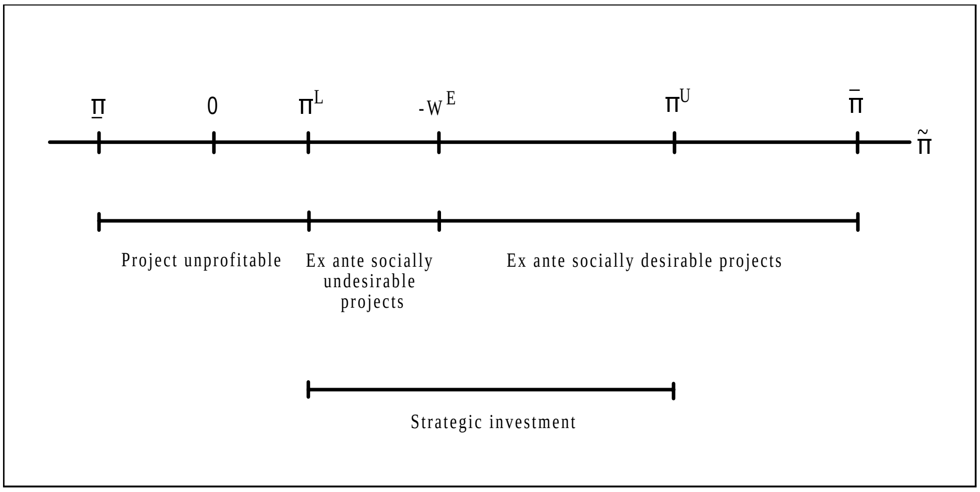

Figure 1: Agent's project decision

An example of the outcome of the agent's project decision is illustrated in Figure 1. In the example, we have assumed $\pi^L < -W^E < \pi^U < \overline{\pi}$. However, more generally, we may have $\pi^U \gtrless -W^E$ depending upon whether $\overline{W} \gtrless 0$. We also can not rule out the possibility that $\pi^L \geq -W^E$ (implying that only ex ante socially desirable projects would be allowed), but note that this would require $\overline{W} \gg 0$; in particular, if the welfare standard is set at the first best level, i.e., $\overline{W} = 0$, then some socially undesirable projects will be accepted. Lastly, there is the possibility that no projects are profitable enough to be accepted without strategic investment taking place; that is, if $\overline{W}$ is sufficiently large, we may have $\pi^U \geq \overline{\pi}$.

Note that an implication of the above result is that full separation is not an equilibrium feature. The reason is straightforward: while project characteristics are continously distributed the agent's action choice is binary. Hence, while the agent's decision reveals whether project profitability is above a certain threshold, its exact value is not disclosed.

3.2 Optimal policy

Initially, at Stage 1, the authority has to take into account the costs of implementing a particular policy. We assume that this cost depends on regulatory capacity only. In particular, the cost of establishing a regulatory capacity α is $g(\alpha)$, where g is a strictly increasing and convex function, i.e., $g' > 0$, $g'' \geq 0$. We think of g as representing the additional, direct and indirect, cost of providing the authority with extra resources, or with introducing specific regulations, that are deemed necessary to combat opportunistic behaviour, but would otherwise not be warranted.

Then, assuming that the agent responds rationally to the choice of policy, as described above, when $\pi^U < \overline{\pi}$ expected public welfare from a policy $\{\alpha, \overline{W}\}$ is given by[11]

$$\Omega\left(\overline{W}, \alpha\right) = \int_{\pi^L}^{\pi^U} \left[\pi - C(\overline{W} - \pi - W^E, \alpha) + W^E\right] dF(\pi) + \int_{\pi^U}^{\overline{\pi}} \left[\pi + W^E\right] dF(\pi) - g(\alpha). \tag{12}$$

The interpretation is the following: When project profitability falls below π^L the project does not take place and both agent profits and public welfare equal the reference level of 0. When project profitability falls within the range $[\pi^L, \pi^U]$ the project is proposed and the agent invests so as just to ensure that the project is not stopped. Public welfare equals the sum of the agent profits (taking into account the costs of strategic investment) and the external effect on third parties. When project profitability exceeds π^U the project is proposed but no investment is necessary to have the project approved. Consequently, in this event, public welfare equals the sum of project profitability and the external effect. The cost of policy g has to be born regardless of the realised value of project profitability.

Expected public welfare may alternatively be written

$$\Omega = \Pr(\tilde{\pi} \geq -W^E) \cdot E\left(\tilde{\pi} + W^E \mid \tilde{\pi} \geq -W^E\right) - \int_{\pi^L}^{-W^E} \left[-W^E - \pi\right] dF(\pi) - \int_{\pi^L}^{\pi^U} C\left(\overline{W} - W^E - \pi, \alpha\right) dF(\pi) - g(\alpha). \tag{13}$$

The first element on the left-hand side now constitutes expected gross gain from all ex ante socially desirable projects. From this three types of costs must be subtracted. In addition to the cost of establishing an enhanced

[11] We shall throughout restrict attention to cases in which (when the optimal policy is not prohibitive) there are some projects profitable enough that no strategic manipulation is necessary to ensure that they will be allowed; that is, $\pi^U < \overline{\pi}$. Extending the analysis to the case $\pi^U \geq \overline{\pi}$ is straightforward and leads to similar results.

regulatory capacity, $g(\alpha)$, there are two sources of inefficiency. First, there are projects that are ex ante socially undesirable (albeit privately profitable), but which will nevertheless be approved.[12] The cost of these are captured by the second element in the expression. Second, there is wasteful strategic investment undertaken for projects with profitability falling in the range $\left[\pi^L, \pi^U\right]$. This cost is captured by the third element.

This delineation between types of costs may be related to the disctinction made between categories of 'influence costs'. Milgrom and Roberts (1988), for instance, distinguish between three types of such costs. Firstly, there are costly activities aiming at affecting the distribution of benefits rather than creating value. In our model, strategic investment falls within this category. Secondly, there are costs of making suboptimal decisions as a consequence of influence. The cost of allowing ex ante socially undesirable projects may be categorised here. Lastly, there is degradation of performance from limiting influence activities. The cost of regulatory capacity may be considered within this particular category.

In studies of influence costs, it has typically been found that, although all three categories of costs are allowed for, only one or two will be present at equilibrium. As we shall see immediately below, this is not the case in our set up. Here, all types of costs may, an often will, be present at equilibrium.

The optimal policy is the set of values of $\alpha^* \geq 0$ and $\overline{W}^* \geq W^E$ that maximises expected public welfare, or, alternatively, minimises total costs. The first-order conditions for an interior solution may be written:[13]

$$\overline{W} \quad : \quad -W^E f(\pi^L)\frac{d\pi^L}{d\overline{W}} = \int_{\pi^L}^{\pi^U} C_k dF(\pi) \tag{14}$$

$$\alpha \quad : \quad -W^E f(\pi^L)\frac{d\pi^L}{d\alpha} = \int_{\pi^L}^{\pi^U} C_\alpha dF(\pi) + g' \tag{15}$$

The left-hand side of the two equations show the gain, and the right-hand side the cost, of a stricter policy. On the one hand, increasing the welfare standard (or regulatory capacity) leads to fewer low-profit projects being proposed. Since, for marginal projects, the entire gross profits are dissipated on costly investments (i.e., $\pi^L - C = 0$), the net welfare gain from stopping these equals the (absolute) value of the external effect on third parties ($-W^E$). On the other hand, a stricter welfare standard (or a larger

[12] In the case that $\pi^L > -W^E$, the inefficiency is associated with ex ante socially desirable projects being blocked.

[13] Second-order conditions for a local maximum are discussed in the appendix.

regulatory capacity) increases the opportunistic efforts required to ensure that a proposed project will be allowed to go through. In the consideration of an increase in regulatory capacity the additional policy costs must be taken into account also.

We have the following result:

Proposition 2 *An optimal policy is restrictive; that is,* $\overline{W}^* > W^E$*.*

Proof. Since $\pi^U = \pi^L = 0$ when $\overline{W} = W^E$, we have

$$\frac{\partial\Omega(W^E, \alpha)}{\partial\overline{W}} = -W^E f(0)\frac{C_k(0, \alpha)}{1 + C_k(0, \alpha)} > 0. \tag{16}$$

Consequently, $\overline{W} > W^E$ at equilibrium. ■

The intuition for this results is the following. When $\overline{W} = W^E$, implying that any project with a positive project profitability will be approved, strategic investment never takes place. Consequently, raising the welfare standard marginally has no first-order effect on strategic investment costs. However, an increase in the welfare standard does lead to a first-order gain due the reduced incidence of ex ante socially undesirable projects. Hence an entirely permissive policy is never optimal.

While we conclude that an optimal policy is always restrictive, we cannot rule out the possibility that it is prohibitive. By banning projects completely a no-change in public welfare can be ensured; no projects will be proposed and no strategic investment will be undertaken, and hence no costly increases in regulatory capacity are necessary. In particular, we have $\Omega(\infty, 0) = 0$. Consequently, for a non-prohibitive policy to be optimal we need $\Omega(\overline{W}, \alpha) \geq 0$ for some $\alpha \geq 0$ and $W^E < \overline{W} < \infty$.

If the optimal policy is prohibitive, obviously no increase in regulatory capacity is warranted. However, $\alpha^* = 0$ is possible also when optimal policy is not prohibitive. The reason is that the costs of increasing regulatory capacity, including those resulting from induced strategic investment, may well exceed the gain from discouraging welfare-reducing projects. This will be the case if the external effect on third parties is sufficiently small compared to the marginal cost of strategic investment and regulatory capacity.

To investigate this possibility in more detail, as well as deriving other more precise results, we need to add more structure to our problem. We proceed, therefore, by considering a series of examples. We start with an example that will serve as a base case.

4 An example

Our first example has essentially linear technologies. In particular, we assume that $\widetilde{\pi}$ is uniformly distributed on $[0,1]$, so that $F(\pi) = \pi$ and $f(\pi) = 1$. The assumption concerning the external effect on third parites - introduced to avoid a trivial problem by ensuring that some, but not all, projects are potentially welfare increasing - then becomes $-1 < W^E < 0$. Furthermore, we let $C(k,\alpha) = [c+\alpha]\,k$, with $c \geq 0$, and $g(\alpha) = \gamma\alpha$, with $\gamma > 0$.

Under these assumptions, we find from the implicit definitions of π^L and π^U in Equations (6) and (9):

$$\pi^L = \frac{c+\alpha}{1+c+\alpha}\left[\overline{W} - W^E\right], \tag{17}$$

$$\pi^U = \overline{W} - W^E. \tag{18}$$

Inserting the above expressions into the definition of expected change in public welfare, given in Equation (12), and simplifying, leads to

$$\Omega\left(\overline{W},\alpha\right) = \frac{1}{2}\left[1 + 2W^E - \frac{c+\alpha}{1+c+\alpha}\left\{\left[\bar{W}\right]^2 - \left[W^E\right]^2\right\}\right] - \gamma\alpha. \tag{19}$$

From this expression, the first-order conditions for an optimal policy are easily derived:[14]

$$\frac{\partial\Omega}{\partial\bar{W}} = -\frac{c+\alpha}{1+c+\alpha}\bar{W} = 0, \tag{20}$$

$$\frac{\partial\Omega}{\partial\alpha} = \frac{-1}{2\left[1+c+\alpha\right]^2}\left\{\left[\bar{W}\right]^2 - \left[W^E\right]^2\right\} - \gamma = 0. \tag{21}$$

As is evident from Equation (25), and confirmed by the condition in Equation (20), expected public welfare is minimised at $\overline{W} = 0$. It follows that $\pi^L < \pi^U = -W^E$. So, we have the following result:

Proposition 3 *Assume $F(\pi) = \pi$, $C(k,\alpha) = [c+\alpha]\,k$ and $g(\alpha) = \gamma\alpha$. Then, if the optimal policy is not prohibitive, the welfare standard is set at its first best level, i.e., $\overline{W}^* = 0$. Some ex ante socially undesirable projects are approved and strategic investment takes place at equilibrium.*

[14]It is straightforward to check that the second-order (local) conditions for an interior maximum are satisfied; see the appendix for details.

Given that $\overline{W} = 0$, Equation (21) reduces to

$$[1 + c + \alpha]^2 \gamma = \frac{1}{2} \left[-W^E\right]^2. \tag{22}$$

We can use this condition to solve for the optimal regulatory capacity, which becomes

$$\alpha^* = \max\{0, \frac{-W^E}{\sqrt{2\gamma}} - [1 + c]\}. \tag{23}$$

For α to be positive, we need $-W^E > \sqrt{2\gamma}\,[1 + c]$; that is, unless the gains from stopping marginal projects (viz., their external effect on third parties) are sufficiently large, it is not worthwhile to undertake costly expansions of regulatory capacity. It follows that, for an interior solution to exist at which $\alpha^* > 0$, we have the following restriction on parameter values:

$$\sqrt{2\gamma}\,[1 + c] \leq -W^E < 1, \tag{24}$$

which implies $c < \frac{1}{\sqrt{2\gamma}} - 1$ and $\gamma < \frac{1}{2}$.

We summarise the above discussion in the following result:

Proposition 4 *Assume $F(\pi) = \pi$, $C(k, \alpha) = [c + \alpha]\,k$ and $g(\alpha) = \gamma\alpha$. Then, if the external effect on third parties is small relative to the costs of strategic investment and regulatory capacity - in particular, if $-W^E \leq \sqrt{2\gamma}\,[1 + c]$ - optimal regulatory capacity equals the first best, i.e., $\alpha^* = 0$. If $\alpha^* > 0$, optimal regulatory capacity is larger the smaller are the marginal cost of strategic investment (c) and the marginal cost of regulatory capacity (γ), and the larger is (the absolute value of) the external effect on third parties ($-W^E$).*

Note that, when $-W^E \leq \sqrt{2\gamma}\,[1 + c]$, optimal policy equals first best policy; there is no increase in regulatory capacity and projects are approved if and only if they are welfare enhancing. In Figure 2, parameter values (c, γ) that satisfy the condition $-W^E = \sqrt{2\gamma}\,[1 + c]$ are plotted for the case $W^E = -0.5$; consequently, $\overline{W}^* = \alpha^* = 0$ for parameter values above the line, and $\overline{W}^* = 0 < \alpha^*$ for parameter values below.[15]

As pointed out in the previous section, the authority, by setting a sufficiently high welfare standard $\overline{W}$, can always guarantee the reference level of no change in public welfare; in particular, $\Omega(\infty, 0) = 0$. Consequently, to ensure that the policy $\{0, \alpha^*\}$ is in fact optimal, we need expected public

[15] As is easily ascertained (see below), a prohibitive policy is never optimal when $W^E = -0.5$.

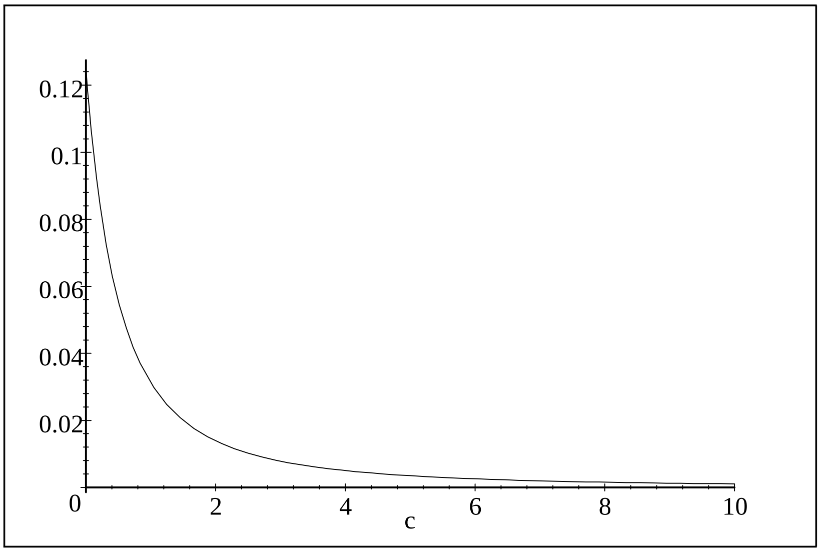

Figure 2: $\sqrt{2\gamma(c)}\,[1+c] = -W^E$, $W^E = -0.5$

welfare from this policy to be non-negative. Specifically, for the case in which $\alpha^* > 0$, we need,[16]

$$\Omega(0,\alpha^*) = \frac{1}{2} + [1+c]\,\gamma + \left[1 + \sqrt{2\gamma} + \frac{1}{2}W^E\right] W^E \geq 0. \tag{25}$$

Clearly, this constraint restricts further the set of parameter values that are consistent with an interior equilibrium. To see this, note first that

$$\Omega(0,\alpha^*)|_{W^E=-1} = [1+c]\,\gamma - \sqrt{2\gamma} < 0, \tag{26}$$

where the inequality follows from (24). It follows that the policy $\{0, a^*\}$, with $\alpha^* > 0$, is optimal only if $-W^E$ is not too large (in other words, if the external effect on third parties is large compared to project profitability, a complete ban on projects (i.e., $\overline{W} = \infty$) would be in order). Furthermore, we have

$$\Omega(0,\alpha^*)|_{W^E=-\sqrt{2\gamma}[1+c]} = \frac{1}{2} + [1+c]\left[c\gamma - \sqrt{2\gamma}\right]. \tag{27}$$

Note that the expression in Equation (27) is negative for $c = 0$ and $\gamma = \frac{1}{2}$. Therefore, even when the external effect on third parties is relatively small, a

[16] For the case $\alpha^* = 0$, the corresponding condition is $\Omega(0,0) = \frac{1}{2} + W^E + \frac{c}{1+c}\left[W^E\right]^2 \geq 0$, which implies similar conclusions to those discussed below.

permissive policy is optimal only if the marginal cost of regulatory capacity is sufficiently small and the marginal cost of strategic investment sufficiently large.

Lastly in this section, we note that at (an interior) optimum expected public welfare is increasing in the marginal cost of strategic investment (c) and decreasing in the marginal cost of regulatory capacity (γ) and the external effect ($-W^E$):

$$\frac{d\Omega\left(0,\alpha^*\right)}{dc} = \gamma > 0, \tag{28}$$

$$\frac{d\Omega\left(0,\alpha^*\right)}{d\gamma} = 1 + c + \frac{2W^E}{\sqrt{2\gamma}} < 0, \tag{29}$$

$$\frac{d\Omega\left(0,\alpha^*\right)}{dW^E} = 1 + W^E + \sqrt{2\gamma} > 0. \tag{30}$$

5 Costs of strategic investment

A notable feature of the above example is that while opportunistic behaviour may be met by an increase in regulatory capacity the welfare standard is not affected; that is, the optimal standard is set at the first best level and any proposed project is allowed if and only if it leads to a gain in public welfare. In this section and the next we extend the example to investigate the robustness of this result. We start by considering a more general formulation for investment costs. In the next section we consider more general distributions of project types.

Assume now that the costs of strategic investment take the form $C\left(k,\alpha\right) = \left[c+\alpha\right]k^{\beta}$, with $\beta > 0$. Then $C_k = \beta\left[c+\alpha\right]k^{\beta-1}$ and $C_{kk} = \beta\left[\beta-1\right]\left[c+\alpha\right]k^{\beta-2}$, implying that $C(k,\alpha)$ is convex (concave) in k if $\beta > 1$ ($\beta < 1$). We retain the other assumptions of the example analysed in Section 4; in particular, we let $F(\pi) = \pi$ and $g(\alpha) = \gamma\alpha$.

Under these assumptions, inserting the relevant expression in (12) and simplifying, we find

$$\Omega = \tfrac{1}{2}\left\{\left[1+W^E\right]^2 - \left[\pi^L + W^E\right]^2\right\} - \tfrac{c+\alpha}{\beta+1}\left[\overline{W} - \pi^L - W^E\right]^{\beta+1} - \gamma\alpha. \tag{31}$$

The first-order conditions for an interior optimum become[17]

$$\pi^L\left[1 + \frac{\beta W^E}{\overline{W} - W^E - \left[1-\beta\right]\pi^L}\right] = 0, \tag{32}$$

[17] Again, discussion of second-order conditions are relegated to the appendix.

$$\frac{-1}{1+\beta}\left[\overline{W}-W^E-\pi^L\right]^{\beta+1}\left[1+\frac{[1+\beta]\,W^E}{\overline{W}-W^E-[1-\beta]\,\pi^L}\right]=\gamma, \tag{33}$$

where we have used the following results, derived from the definition of π^L in (6),

$$\frac{d\pi^L}{d\overline{W}}=\frac{\beta\pi^L}{\overline{W}-W^E-[1-\beta]\,\pi^L}, \tag{34}$$

$$\frac{d\pi^L}{d\alpha}=\frac{\left[\overline{W}-W^E-\pi^L\right]^{\beta+1}}{\overline{W}-W^E-[1-\beta]\,\pi^L}. \tag{35}$$

Since $\overline{W}>W^E$, and hence $\pi^L>0$, for Equation (32) to be satisfied we need the expression in brackets to equal 0. It follows that, when $\beta\neq 1$, the solution for π^L is uniquely given by

$$\pi^L=-W^E-\frac{1}{\beta-1}\bar{W}. \tag{36}$$

Assuming that $\alpha^*>0$, we can then find a closed-form solution for $\overline{W}^*$ from Equations (33) and (36);[18]

$$\overline{W}^*=\frac{\beta-1}{\beta}\left\{\beta\,[\beta+1]\,\gamma\right\}^{\frac{1}{\beta+1}}. \tag{37}$$

From this expression, we derive the following result:

Proposition 5 *Assume $F(\pi)=\pi$, $C(k,\alpha)=[c+\alpha]\,k^\beta$ and $g(\alpha)=\gamma\alpha$. Then, if the optimal policy is not prohibitive, $\overline{W}^*\gtreqless 0\Longleftrightarrow\beta\gtreqless 1$.*

Consequently, raising the welfare standard above the first best level is optimal if the investment cost function is convex, and vice versa. The intuition for this is the following. When the welfare standard is raised, the gain comes from the discouragement of socially undesirable projects while the cost is associated with higher manipulative effort exerted by those firms that do act strategically. When β is large, the investment cost curve is steep and hence the discouraging effect on projects that are on the margin of being privately profitable is strong. Also, when β is large, marginal costs are falling

[18] In the case that $\alpha^*=0$, we can use Equations (6) and (32) to derive the condition $c\left[\frac{\beta}{\beta-1}\overline{W}\right]^\beta=\pi^L>0$. The analysis of this case leads to similar conclusions to those reported for the case $\alpha^*>0$.

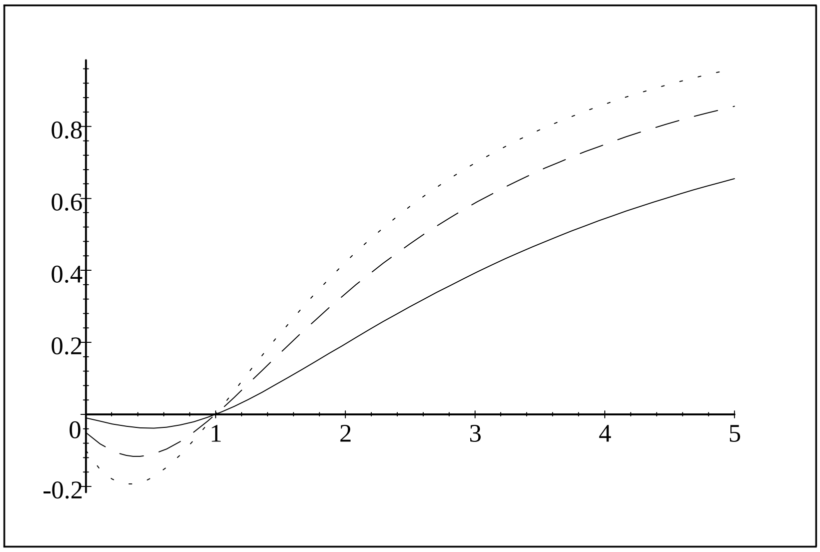

Figure 3: $\overline{W}^*(\beta)$; $\gamma = 0.01$ (solid), $\gamma = 0.05$ (dashed) and $\gamma = 0.1$ (dotted)

off over the range of projects for which strategic investment occurs and so the increase in cost from higher investment is on average small. Therefore, as the gain from increasing the welfare standard tends to be large relative to the cost, a higher standard is called for. Figure 3 displays $\overline{W}^*$ as a function of β for some numerical examples.[19]

The optimal value of α becomes

$$\alpha^* = \max\left\{0, \frac{1}{\beta}\left\{\beta\left[\beta+1\right]\gamma\right\}^{\frac{-\beta}{\beta+1}}\left[-\beta W^E - \left\{\beta\left[\beta+1\right]\gamma\right\}^{\frac{1}{\beta+1}}\right] - c\right\} \quad (38)$$

which we have derived from Equation (6) after substitution of the closed-form solution for π^L (found by substituting the expression for $\overline{W}$ in Equation (37) into Equation (36)):

$$\pi^L = -W^E - \frac{1}{\beta}\left\{\beta\left[\beta+1\right]\gamma\right\}^{\frac{1}{\beta+1}}. \quad (39)$$

The relationship between α^* and β is quite complicated also. For very small values of β, as well as for large values, the optimal regulatory capacity is small. For intermediate values of β, however, optimal regulatory capacity is larger.

[19] In all of these examples, $\alpha^* > 0$ and $0 < \pi^L < \pi^U < 1$ can be satisfied by suitable choices of parameter values.

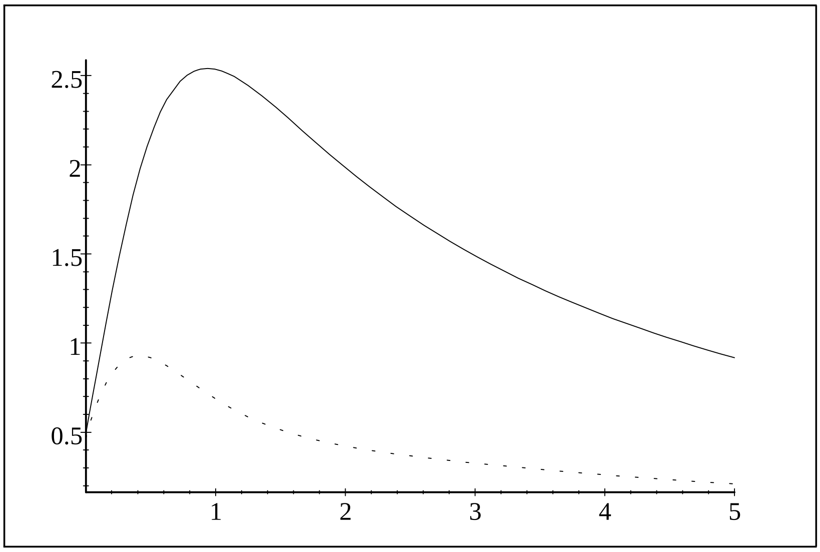

Figure 4: $\alpha^*(\beta)$; $W^E = -0.5$, $c = 0$, $\gamma = 0.01$ (solid) and $\gamma = 0.05$ (dotted)

What is perhaps more interesting, however, comparing Figures 3 and 4, is the relationship between optimal policy and the cost of regulatory capacity. More generally, we have the following result:

Proposition 6 *Assume $F(\pi) = \pi$, $C(k, \alpha) = [c + \alpha] k^\beta$ and $g(\alpha) = \gamma\alpha$. Then, if policy is not prohibitive and $\alpha^* > 0$, optimal regulatory capacity α^* is decreasing in γ, while the welfare standard $\overline{W}^*$ is increasing in γ if $\overline{W}^* > 0$ $(\beta > 1)$ and decreasing in γ otherwise.*

Consequently, we find that, in this case, there is a certain substitutability between regulatory capacity and welfare standard. In particular, if regulatory capacity becomes more expensive, and so should be reduced, the welfare standard will be distorted further away from the first best. In this sense, increasing regulatory capacity and distorting the welfare standard are policy alternatives.

6 Project profitability

In the last of our examples, we investigate how the distribution of project profitability may affect the choice of policy. In this section we assume that project profitability is distributed on $[0, 1]$ according to the distribution function $F(\pi) = \pi^\rho$, $\rho > 0$. $\rho = 1$ corresponds to the uniform distribution considered above. When $\rho < 1$, relatively more probability mass is put on low realisations of π; that is, the distribution is skewed towards less profitable projects. Conversely, when $\rho > 1$, projects with a high profitability are relatively more likely than projects with a low profitability. Otherwise we retain the assumptions of the linear example; in particular, we let $C(k, \alpha) = [c + \alpha] k$ and $g(\alpha) = \gamma\alpha$.

Substituting into the expression for expected public welfare in Equation (12), and solving, we find

$$\begin{aligned} \Omega\left(\overline{W}, \alpha\right) &= \tfrac{\rho}{\rho+1} + W^E - W^E \left[\frac{c+\alpha}{1+c+\alpha}\right]^\rho \left[\overline{W} - W^E\right]^\rho \\ &\quad + \frac{c+\alpha}{\rho+1}\left\{\left[\frac{c+\alpha}{1+c+\alpha}\right]^\rho - 1\right\}\left[\overline{W} - W^E\right]^{\rho+1} - \gamma\alpha. \end{aligned} \tag{40}$$

Note that, since c always occurs additively with α, and since regulatory capacity costs are linear, under the assumption that the optimum solution is interior (in particular, $\alpha^* > 0$) we can without loss of generality set $c = 0$; specifically, a given increase in c will merely reduce a^* by the same amount. The first-order conditions for an interior solution may then be written:

$$-\rho W^E \left[\frac{\alpha}{1+\alpha}\right]^\rho + \alpha\left\{\left[\frac{\alpha}{1+\alpha}\right]^\rho - 1\right\}\left[\overline{W} - W^E\right] = 0, \tag{41}$$

$$\begin{aligned} -\left[\frac{\alpha}{1+\alpha}\right]^{\rho-1} \frac{\rho W^E \left[\overline{W} - W^E\right]^\rho}{[1+\alpha]^2} + \left\{\left[\frac{\alpha}{1+\alpha}\right]^\rho - 1\right\}\frac{\left[\overline{W} - W^E\right]^{\rho+1}}{\rho+1} \\ + \left\{\left[\frac{\alpha}{1+\alpha}\right]^\rho - 1\right\}\frac{\rho\left[\overline{W} - W^E\right]^{\rho+1}}{[\rho+1][1+\alpha]} - \gamma = 0. \end{aligned} \tag{42}$$

Using Equation (41) to simplify the expression in Equation (42), the two first-order conditions reduce to:

$$\frac{-\rho W^E \alpha^{\rho-1}}{[1+\alpha]^\rho - \alpha^\rho} = \overline{W} - W^E, \tag{43}$$

$$\left\{\left[\frac{\alpha}{1+\alpha}\right]^{\rho+1} - 1 + \frac{\rho+1}{1+\alpha}\right\}\left[\overline{W} - W^E\right]^{\rho+1} = \gamma[\rho+1]. \tag{44}$$

We have not found closed-form solutions for the policy variables. Indeed, it is difficult to make use of the above relationships analytically. We proceed, therefore, by means of numerical methods.

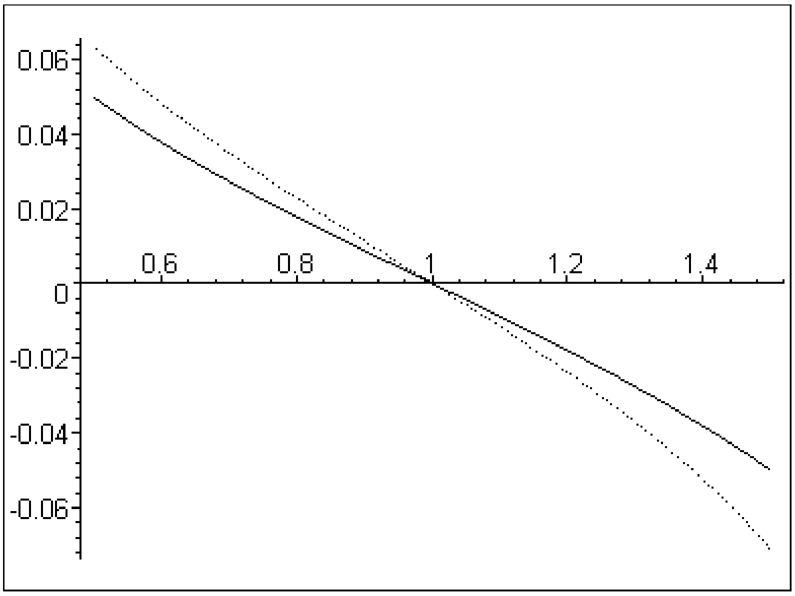

Figure 5: $\overline{W}^*(\rho)$; $W^E = -0.5$, $c = 0$, $\gamma = 0.01$ (solid), $\gamma = 0.015$ (dotted)

Figures 5 and 6 display the optimal policy $\{\alpha^*, \overline{W}^*\}$ as a function of ρ for two particular numerical examples. $\overline{W}^*$ is decreasing for all values of ρ; in particular, $\overline{W}^* \gtreqless 0 \Longleftrightarrow \rho \lesseqgtr 1$. α^*, however, takes on its maximum value for ρ close to 1 and is monotone on either side of the maximum.

The above results appear to be robust for a wide range of parameter values. We suggest, therefore, that a high welfare standard is optimal when projects are more likely to be of low rather than of high profitability, and vice versa. The intuition for this result is the following: The benefit of raising the welfare standard is that fewer ex ante socially undesirable projects will be proposed. The cost of such a policy change is that more effort is wasted in the event that strategic manipulation does occur. In relative terms, the gain is large when the incidence of low-profitability projects is high and correspondingly small when the incidence of such projects is low.

A comparison of Figures 5 and 6, reveals that, while the optimal regulatory capacity α^* is decreasing in the marginal cost of regulatory capacity γ, the optimal welfare standard $\overline{W}^*$ is increasing in γ when it is above the first best level (i.e., $\overline{W}^* > 0$), and decreasing otherwise. Consequently, also in this example we find that as regulatory capacity is used less the welfare standard is used more.

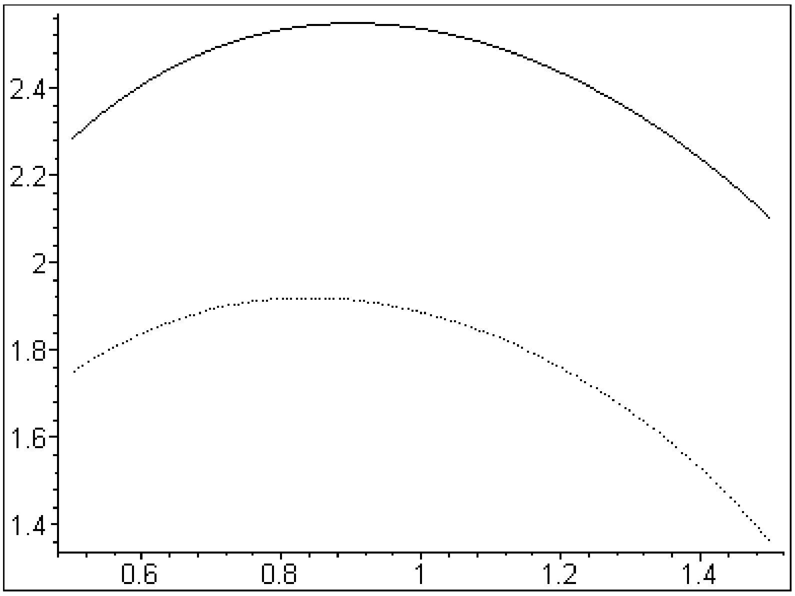

Figure 6: $\alpha^*(\rho)$; $W^E = -0.5$, $c = 0$, $\gamma = 0.01$ (solid), $\gamma = 0.015$ (dotted)

7 Conclusion

We have considered a setting in which projects involving private benefits and public costs are subject to government approval. The decision about whether to approve a proposed project is made in a decentralised fashion by comparing its costs and benefits to a predetermined standard; a project is approved if and only if the net welfare gain exceeds a certain threshold. Importantly, we introduce the possibility that parties proposing a project can take costly actions that affect the enforcement agency's assessment of the project; that is, the bureaucratic decision rule may potentially be subject to opportunistic manipulation.

We have found that, notwithstanding the costs of having regulatory decisions distorted, specific measures introduced to make opportunistic behaviour difficult may not be warranted. Such measures carry their own costs, not only because they restrict private actions, or because they involve enforcement cost, but also because, by raising the stakes, they lead to more waste in those cases in which opportunistic behaviour inevitably does occur. Measures to combat opportunistic behaviour are optimal, therefore, only if the external effects involved are large compared to the costs of increasing regulatory capacity.

We have found also that in the presence of potential manipulation it may be optimal to adjust the standard by which decisions are made. However, whether the standard should be reduced - so that obtaining approval becomes easier - or whether it should be raised, depends finely on the particularities of the problem. Compared to the first best - i.e., a case in which opportunistic behaviour is not an issue - raising the standard tends to be optimal if private benefits are more likely to be low than high, and if the private cost of opportunistic behaviour increases rapidly with the intensity of such efforts.

Lastly, we have detected a certain substitutability between increasing regulatory capacity and adjusting the welfare standard. In particular, if regulatory capacity becomes more costly, and so should be reduced, it is optimal to distort the welfare standard further away from the first best.

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A Second-order conditions

The (local) second-order conditions for an interior solution to the authority's problem of finding an optimal policy are

$$\frac{\partial^2 \Omega}{\partial \overline{W}^2} \leq 0, \tag{45}$$

$$\frac{\partial^2 \Omega}{\partial \alpha^2} \leq 0, \tag{46}$$

$$\frac{\partial^2 \Omega}{\partial \overline{W}^2} \frac{\partial^2 \Omega}{\partial \alpha^2} - \left[\frac{\partial^2 \Omega}{\partial \overline{W} \partial \alpha} \right]^2 \geq 0, \tag{47}$$

evaluated at $\{\alpha^*, \overline{W}^*\}$. Troughout we have assumed that these conditions are satisfied. It turns out, however, that it is in general difficult to relate these conditions to the underlying primitives of the model. Here we briefly consider this problem.

In order to simplify expressions, we define the following probabilities and conditional expectations:

$$p^L = \Pr\left(\pi \leq \pi^L\right) = F\left(\pi^L\right) \tag{48}$$

$$p^U = \Pr\left(\pi \leq \pi^U\right) = F\left(\pi^U\right) \tag{49}$$

$$\overline{C} = E\left\{C(\bar{W} - W^E - \pi, \alpha) \,|\, \pi^L < \pi < \pi^U\right\} \tag{50}$$

$$\overline{C}_i = E\left\{C_i(\bar{W} - W^E - \pi, \alpha) \,|\, \pi^L < \pi < \pi^U\right\}, \;\; i = k, \alpha \tag{51}$$

$$\overline{C}_{ij} = E\left\{C_{ij}(\bar{W} - W^E - \pi, \alpha) \,|\, \pi^L < \pi < \pi^U\right\}, \, i, j = k, \alpha \tag{52}$$

The first-order derivatives of expected public welfare, as given in Equation (12), can then be written:

$$\frac{\partial \Omega}{\partial \overline{W}} = -W^E \frac{\partial p^L}{\partial \overline{W}} - \left[p^U - p^L\right] \overline{C}, \tag{53}$$

$$\frac{\partial \Omega}{\partial \alpha} = -W^E \frac{\partial p^L}{\partial \alpha} - \left[p^U - p^L\right] \overline{C}_\alpha - g'(\alpha), \tag{54}$$

while the second-order derivatives are:

$$\frac{\partial^2 \Omega}{\partial \overline{W}^2} = -W^E \frac{\partial^2 p^L}{\partial \overline{W}^2} - \left[C_k^0 \frac{\partial p^U}{\partial \overline{W}} - C_k^L \frac{\partial p^L}{\partial \overline{W}} \right] - \left[p^U - p^L\right] \overline{C}_{kk}, \tag{55}$$

$$\frac{\partial^2 \Omega}{\partial \alpha^2} = -W^E \frac{\partial^2 p^L}{\partial \alpha^2} + C_\alpha^L \frac{\partial p^L}{\partial \alpha} - \left[p^U - p^L\right] \overline{C}_{\alpha\alpha} - g''(\alpha), \tag{56}$$

$$\frac{\partial^2 \Omega}{\partial \alpha \partial \overline{W}} = -W^E \frac{\partial^2 p^L}{\partial \alpha \partial \overline{W}} + C_k^L \frac{\partial p^L}{\partial \alpha} - \left[p^U - p^L\right] \overline{C}_{\alpha k}, \tag{57}$$

where we have defined $C_k^0 = C_k(0,\alpha)$ and $C_i^L = C_i\left(\bar{W} - W^E - \pi^L, \alpha\right)$.

We have

$$\begin{aligned} \frac{\partial p^L}{\partial \overline{W}} &= f(\pi^L)\frac{\partial \pi^L}{\partial \overline{W}} > 0, &(58)\\ \frac{\partial p^L}{\partial \alpha} &= f(\pi^L)\frac{\partial \pi^L}{\partial \alpha} > 0, &(59)\\ \frac{\partial p^U}{\partial \overline{W}} &= f(\pi^L)\frac{\partial \pi^U}{\partial \overline{W}} > 0, &(60)\end{aligned}$$

and, furthermore,

$$\frac{\partial^2 p^L}{\partial \overline{W}^2} = f'\left(\pi^L\right)\left[\frac{\partial \pi^L}{\partial \overline{W}}\right]^2 + f\left(\pi^L\right)\frac{\partial^2 \pi^L}{\partial \overline{W}^2} \quad (61)$$

$$\frac{\partial^2 p^L}{\partial \alpha^2} = f'\left(\pi^L\right)\left[\frac{\partial \pi^L}{\partial \alpha}\right]^2 + f\left(\pi^L\right)\frac{\partial^2 \pi^L}{\partial \alpha^2} \quad (62)$$

$$\frac{\partial^2 p^L}{\partial \overline{W}\partial \alpha} = f'\left(\pi^L\right)\frac{\partial \pi^L}{\partial \alpha}\frac{\partial \pi^L}{\partial \overline{W}} + f\left(\pi^L\right)\frac{\partial^2 \pi^L}{\partial \alpha \partial \overline{W}} \quad (63)$$

From the implicit definition of π^L we find

$$\begin{aligned} \frac{\partial^2 \pi^L}{\partial \bar{W}^2} &= \frac{C_{kk}}{\left[1 + C_k\right]^3}, &(64)\\ \frac{\partial^2 \pi^L}{\partial \alpha^2} &= \frac{C_{\alpha\alpha}\left[1 + C_k\right]^2 - \left[1 + C_k\right]\left[C_\alpha + C_k\right]C_{k\alpha} + C_{kk}C_\alpha C_k}{\left[1 + C_k\right]^3}, &(65)\\ \frac{\partial^2 \pi^L}{\partial \alpha \partial \bar{W}} &= \frac{C_{k\alpha}\left[1 + C_k\right] - C_{kk}C_\alpha}{\left[1 + C_k\right]^3}, &(66)\end{aligned}$$

where $C_k, C_\alpha, C_{kk}, C_{\alpha\alpha}$ and C_{ka} are evaluated at $k = \bar{W} - W^E - \pi^L$.

It is clear that the second-order conditions do put restriction on admissible functional forms. However, the relationship between these conditions and the underlying primitives of the model does not seem straightforward.

A.1 Linear technologies

Assume $F(\pi) = \pi$, $C(k, \alpha) = [c + \alpha] k$ and $g(\alpha) = \gamma\alpha$. Then second-order derivatives of expected public welfare Ω reduce to

$$\frac{\partial^2 \Omega}{\partial \overline{W}^2} = -\frac{c + \alpha}{1 + c + \alpha}, \tag{67}$$

$$\frac{\partial^2 \Omega}{\partial \alpha^2} = \frac{1}{[1 + c + \alpha]^3} \left\{ \left[\overline{W}\right]^2 - \left[W^E\right]^2 \right\}, \tag{68}$$

$$\frac{\partial^2 \Omega}{\partial \overline{W} \partial \alpha} = \frac{-1}{[1 + c + \alpha]^2} \overline{W}. \tag{69}$$

Note that $\frac{\partial^2 \Omega}{\partial \overline{W}^2} < 0$ for all admissible values of α and $\overline{W}$, while $\frac{\partial^2 \Omega}{\partial \alpha^2} < 0$ and $\frac{\partial^2 \Omega}{\partial \alpha^2} = 0$ at $\overline{W} = 0$.

A.2 Non-linear investment costs

Assume $F(\pi) = \pi$, $C(k, \alpha) = [c + \alpha] k^\beta$ and $g(\alpha) = \gamma\alpha$. Then, at a point where the first-order conditions are satisfied, the second-order derivatives of Ω reduce to

$$\frac{\partial^2 \Omega}{\partial \overline{W}^2} = \frac{1 - \beta}{\beta} \left\{ 1 + \frac{W^E}{\overline{W} + [\beta - 1] W^E} \right\} \left[\frac{\partial \pi^L}{\partial \overline{W}} \right]^2, \tag{70}$$

$$\frac{\partial^2 \Omega}{\partial \alpha^2} = \frac{\beta - 1}{\beta} \left[\frac{W^E}{\overline{W}} - 1 \right] \left[\frac{d\pi^L}{d\alpha} \right]^2, \tag{71}$$

$$\frac{\partial^2 \Omega}{\partial \alpha \partial \overline{W}} = -\frac{\beta - 1}{\beta} \frac{d\pi^L}{d\overline{W}} \frac{d\pi^L}{d\alpha}. \tag{72}$$

$\frac{\partial^2 \Omega}{\partial \overline{W}^2} < 0$ follows from the fact that $0 < \pi^L = -W^E - \frac{1}{\beta - 1} \overline{W} < -W^E$, while $\frac{\partial^2 \Omega}{\partial \alpha^2} < 0$ follows from the facts that $W^E < 0$, $\overline{W} > W^E$ and $\overline{W} \gtreqless 0 \iff \beta \gtreqless 1$.

The condition

$$\frac{\partial^2 \Omega}{\partial \overline{W}^2} \frac{\partial^2 \Omega}{\partial \alpha^2} - \left[\frac{\partial^2 \Omega}{\partial \overline{W} \partial \alpha} \right]^2 \geqslant 0 \tag{73}$$

is equivalent to

$$\left[1 - \frac{W^E}{\overline{W}} \right] \left\{ 1 + \frac{W^E}{\overline{W} + [\beta - 1] W^E} \right\} \geqslant 1. \tag{74}$$

To see that this is satisfied, note that $\overline{W}\left\{\overline{W}+[\beta-1]\,W^E\right\}<0$, and hence the above expression is equivalent to

$$\left[\overline{W}-W^E\right]\left[\overline{W}+\beta W^E\right]\leq\overline{W}\left\{\overline{W}+[\beta-1]\,W^E\right\} \tag{75}$$

which is clearly true.