Short-run policy commitment when investment timing is endogenous: "More harm than good?"

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Abstract: We introduce endogenous leadership in a game between government and firms, in which the government has short-run commitment power only and firms choose when to invest. We show that firms that delay investment in the absence of government intervention have an incentive to invest early and strategically under policy activism. Then, even though a policy scheme succeeds in correcting an existing distortion targeted by the government, it can create a new and potentially more harmful one. We investigate when the government may do better by adhering to laissez-faire than by engaging in active policy intervention.

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1. Introduction

It is widely recognised that commitment power, because it implies credibility, is often needed for the government to implement its policies successfully. In practice though, most real-world governments may not be able to commit far into the future. While this has been a prominent issue in the macroeconomic literature on monetary policy[1], the relationship between government commitment power and successful policy intervention has also been discussed in the context of microeconomic policy. It is to this field of microeconomic policy design that we hope to contribute with this paper.

The assumption that governments tend to lack long-run commitment power hardly needs justification. Perhaps the most obvious reason for limited commitment power is a public perception that a government is unstable or likely to succumb to the political pressures exercised by powerful interest groups. However, even governments that have managed to acquire a reputation of "benevolent welfare maximisers" are often unable to commit to policies in the longer run. Beside the fact that democratically elected governments have a mandate for a limited period of time only, the budgetary implications of their policies tend to be reassessed regularly, often leading to a fine-tuning if not a complete abandoning of some of the previously adopted policies.

This begs the question whether policy activism by a government with short-run commitment power only, will be effective or whether it will be doomed to fail. It becomes clear that this is a pertinent question when one recognises that the ability to commit to one's actions matters not only for policy makers but also for private agents. One important way through which firms especially can obtain commitment power is through irreversible investment[2]. Irreversibility implies that, if firms invest *before* policy is set, they commit to some of their actions before the government does.

The existing literature has treated the move order in games between government and private sector players as exogenous. Who moves first is determined by the relative

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[1] For instance, Kydland and Prescott (1977), Rogoff (1985) and Lohmann (1992).

[2] The strategic implications of the irreversibility of investment have been widely discussed in the industrial

strength of the players' commitment power. If the government has long-run commitment power (relative to the private sector), it can be called "autonomous" and is assumed to move first, thus being able to induce the private sector to carry out the desired behaviour. However, if it lacks long-run commitment power, it is assumed to move second and is "subordinate" to private agents, who will try to shape policies to their own advantage[3]. Our paper deviates from this standard approach by viewing the move order of government and private sector as the *outcome* of a game, rather than imposing it exogenously[4]. We demonstrate that who will lead –policy makers or firms– is endogenous and results from the interaction of two real-world features that are incorporated in our model. First, as argued earlier, governments are unlikely to be able to commit in the long run. Second, in a world characterised by uncertainty, firms have to decide *when* to make irreversible investment. When firms invest early, they move before policy makers and make the state "subordinate". However, early investment in a climate of uncertainty reduces a firm's flexibility. Firms may therefore want to wait and choose investment levels after having received more precise information about the profitability of the market. Investment delay, though it surrenders the ability to strategically alter government policy, has the advantage of retaining flexibility (as argued in the option value literature of investment)[5]. When firms delay investment, the outcome of the game entails the government moving first, acting as an "autonomous" state. Importantly, we demonstrate that a firm's trade-off between committing early and remaining flexible will be affected by the policy regime adopted by the government. Hence, whether policy

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organisation literature. Tirole (1988) provides a textbook treatment of this issue.

[3] The terms "autonomous" state and "subordinate" state were first suggested by Rodrik (1992) in a development policy setting. He contrasts the relatively autonomous Park regime in Korea with the earlier more subordinate Rhee regime. Under Park's rule, most of the government's decisions affecting business were implemented, while this was not true under Rhee (based on survey evidence reported by Jones and Sakong, 1980). In the political economy literature, private sector agents engage in "directly unproductive" rent-seeking behaviour in order to manipulate "subordinate" governments (see, among many others, Bhagwati (1982), Mayer (1984) and Grossman and Helpman (1994)). In some models in the trade policy literature, firms partially capture government policy by undertaking actions –such as choosing their investment levels– prior to governments setting export subsidies (see, for instance, Grossman and Maggi (1998) and Neary and Leahy (2000)).

[4] There are several papers in the industrial organisation literature that endogenise the move order between rival firms in oligopolistic industries (Hamilton and Slutsky (1990), Spencer and Brander (1992), Sadanand and Sadanand (1996)). This literature, however, remains silent on endogenous leadership in games between policy makers and firms.

[5] See Dixit and Pindyck (1994) for a discussion of the option value associated with investment delay.

makers will "steer" firms in the desired direction or, *vice versa*, firms will manipulate government policy, is endogenous in our set-up.

Turning to the more detailed characteristics of our model, we assume that, in the absence of government intervention, production is not at the socially optimal level, due to market failures or externalities; investment is efficient. The government targets the production inefficiency with an output subsidy or tax. However, the policy scheme creates a new distortion if it encourages firms to forgo flexibility and invest early and socially suboptimally in order to manipulate the subsidy; in the absence of active policy, firms delay investment until uncertainty is resolved.

In our model, a direct attempt to counter a distortion can make things worse. This is reminiscent of, but basically very different from Rodrik (1987). He argues that distortions that are created by optimising agents' behaviour in the first place, cannot simply be removed (and may even be exacerbated) by policies targeting that distortion by acting directly on the relevant margin. In his model, the reason why such policies fail is that their desirable effects are offset by unanticipated behaviour of private agents[6]. In our paper, the reason why policy intervention may do more harm than good, is essentially different. The policy scheme always corrects the initial distortion, but creates a new, possibly more damaging one. This distortion arises not because the government is myopic; policy makers have, in fact, perfect foresight. Neither does it occur because the government has insufficient policy instruments at its disposal. As we will argue, the structural cause for the new distortion lies in the effect of the policy scheme, employed by a government with short-run commitment power only, on the firms' trade-off between strategic commitment and flexibility.

Our set-up lends itself to a wide spectrum of microeconomic applications, including environmental policy aimed at reducing pollution, trade policy designed to boost

[6] Although discussed in a microeconomic policy framework, Rodrik's argument echoes the Lucas critique of macroeconomic policy.

domestic firms' share in key international markets, and development policy initiatives geared towards improving economic efficiency.

In section 2, we describe the general model with a single firm. Section 3 briefly discusses the first-best benchmark. The game between the government and the firm is solved in section 4. Section 5 compares welfare levels under non-intervention and the active policy regime of a government with short-run commitment power. In section 6, the model is extended to oligopolistic industries. Section 7 concludes by pointing out the policy lessons that can be drawn from our analysis.

2. The model

Consider a monopolist firm in a set-up with two periods. In the first period, there is uncertainty about the firm's demand, which is resolved at the start of period two[7]. The demand function is given by $p(Q,u)$ where *p* and *Q* respectively stand for market price and output. Denoting partial derivatives by subscripts, we have $p_Q < 0$. The demand function has a stochastic component, *u*, defined over the interval $[\underline{u}, \overline{u}]$ with mean zero and variance s^2. A positive u represents a positive demand shock, hence $p_u > 0$. Revenue is denoted by $R(Q,u) = pQ$. We assume that a positive demand shock raises the firm's marginal revenue $(R_{Qu} > 0)$[8]. The firm chooses both *when* and *how much* to invest; it sets its investment level (k) *either* in period one, when future demand is uncertain, *or* in period two, when demand is known, i.e., when u is observed. Production always takes place in period two, after uncertainty has been resolved. The firm is assumed to be risk neutral[9].

The firm's total costs depend on output and investment, and are given by $C(Q,k) = C^P(Q,k) + C^I(k)$, with C^P and C^I denoting production costs and investment

[7] The model yields the same qualitative results with cost uncertainty.

[8] In a very different model with demand uncertainty, Brander and Lewis (1986) label $R_{Qu} > 0$ as the "normal" case.

[9] Risk aversion complicates the analysis significantly without changing the qualitative nature of our results.

costs, respectively. Marginal production costs are positive ($C_Q = C_Q^P > 0$) and non-decreasing ($C_{QQ} = C_{QQ}^P \geq 0$). Importantly, investment is assumed to reduce both the production cost ($C_k^P < 0$) and the marginal cost of production ($C_{Qk} = C_{Qk}^P < 0$). Furthermore, the marginal investment cost is positive ($C_k^I > 0$). The total cost function is strictly convex in k ($C_{kk} = C_{kk}^P + C_{kk}^I > 0$) and has an interior minimum. So, for every level of production, there is an investment level that minimises total costs (i.e., at which $C_k = 0$), denoted by $k^{\min}(Q)$ and henceforth referred to as the "efficient" investment level. Thus, $C_k < 0$ for $k < k^{\min}(Q)$, in which case we will say that the firm *under*invests. Similarly, if $C_k > 0$, the firm *over*invests ($k > k^{\min}(Q)$)[10].

The firm's profits, p, are

$$p = R - C + sQ \tag{1}$$

The production subsidy (which can be positive or negative), *s*, is set by the government in order to maximise welfare, *W*, given by

$$W = p - sQ + \Gamma \tag{2}$$

Note that the government's objective function differs from profits in two respects. First, expression (2) contains profits net of subsidy costs (instead of gross profits). Second, production potentially generates social benefits or costs other than net profits, denoted by $\Gamma = \Gamma(Q)$. For instance, if output is consumed domestically, Γ includes consumer surplus. If Γ consist of consumer surplus only, then $\Gamma_Q > 0$ and, provided demand is not too convex, $\Gamma_{QQ} > 0$[11]. In addition, Γ may include production externalities. If the good is not consumed domestically and causes a negative externality (e.g., pollution), then $\Gamma_Q < 0$, while Γ_{QQ} is typically negative.

The firm and the government play a two-period three-stage game, which is depicted in Figure 1. In period one, the firm *either* sets its investment level if it chooses to invest

[10] This terminology is commonly used in the literature on strategic investment (see, e.g., Tirole, 1988).
[11] More specifically, if Γ consists of consumer surplus only, then $\Gamma_{QQ} > 0$ if $p_Q + Qp_{QQ} < 0$.

early, *or* decides to delay investment until period two (if the firm delays investment, it chooses its investment level in stage three, simultaneously with output)[12]. In period two, the government determines the subsidy (stage two). This reflects the government's inability to commit long-term. Why is this so? Suppose the government were, nonetheless, to announce its policy in period one. Since firms are aware of the fact that the government cannot guarantee that there will be no subsidy readjustments in period two, they would rightly perceive the policy announced in period one as "cheap talk" and hence ignore it. In short, any government attempt to set its output subsidy policy earlier than in period two is bound to fail. The government's limited credibility forces it to determine its policy in period two[13]. This is, nevertheless, not without advantages: unlike policy set in period one, the policy will now be chosen with full knowledge of demand.

[Figure 1 about here]

3. The first-best benchmark

Before solving the game, it proves useful to determine the first-best outcome. This gives us a benchmark against which the outcome of the endogenous timing game can be assessed. Using expression (1), expression (2) can be rewritten as $W = R - C + \Gamma$. The first-order conditions for socially optimal output and investment are obtained by maximising W (after u is observed) and are given by:

$$W_Q = R_Q - C_Q + \Gamma_Q = 0 \tag{3}$$

$$W_k = -C_k = 0 \tag{4}$$

Proposition 1 summarises these conditions.

[12] Although in the real world it is more realistic to have capital chosen before output, game-theoretically speaking it makes no difference whether the delaying monopolist firm chooses k prior to or simultaneously with output; so, there is no need to model the *delaying* firm's capital choice and its output choice sequentially. When we extend the model to include a second firm in section 6, the outcomes do depend on whether delaying firms choose k prior to or simultaneously with output. We then assume that delaying firms choose k prior to output, implying that the game then consists of four stages.

[13] By contrast, a government with long-run commitment power is able to commit to an output subsidy policy set in period one. Setting the output subsidy in period one has, however, the drawback that it is based on expected, not actual demand (see Dewit and Leahy (2004) for a discussion of the optimal policy of a government with long-run commitment power in a trade policy framework).

Proposition 1: The first-best is characterised (i) by a production level at which the marginal social net benefit is equal to zero ($R_Q - C_Q + \Gamma_Q = 0$) and (ii) by efficient investment ($C_k = 0$).

4. The endogenous timing game

We now solve the game in Figure 1. Output is chosen in the last stage of the game. When choosing its production level, the firm maximises its profits in period two, which yields the first-order condition:

$$\pi_Q = R_Q - C_Q + s = 0 \tag{5}$$

The equilibrium subsidy and the firm's investment level will depend on whether the monopolist delays or invests early. Before showing how a policy active government affects the firm's equilibrium investment timing, we start with a brief discussion of the firm's investment timing when faced with a policy inactive government.

4.1. The firm's investment timing under laissez-faire

Suppose the government is not policy active. Equilibrium output is then given by expression (5), setting *s* equal to zero. If the firm delays investment, it maximises profits with respect to k in *period two,* which implies $C_k = 0$. Hence, the firm's investment level is efficient. By contrast, if the firm invests early, it maximises expected profits in *period one*, choosing the efficient investment level for *expected* demand only: $EC_k = 0$; unlike with delay, investment is not chosen optimally for *actual* demand. So, $\pi^d \geq \pi^e$ for all values of *u*, and thus $E\pi^d \geq E\pi^e$, with *d* and *e* denoting investment delay and early investment, respectively (these superscripts will henceforth be used to denote the firm's investment-timing choice). Therefore, without government intervention the firm always adopts a "wait-and-see" approach and delays investment at all levels of uncertainty[14].

4.2. The firm's investment timing under the policy regime

We now allow the government to be policy active and derive the firm's capital and the government's subsidy choice when the firm delays investment and when it invests early, respectively (output is always determined by (5)). We then discuss when the firm decides to invest and show that the existence of the policy regime creates the possibility that the firm invests early.

4.2.1. Investment delay

If the firm delays investment, it chooses its investment level *after* the government has set the subsidy. Hence, the firm maximises profits in period two, taking the subsidy as given. The first-order condition for k is then $\pi_k = 0$, implying:

$$C_k = 0 \tag{6}$$

When setting the subsidy, the government maximises welfare (see expression (2)), taking into account how the firm's output and investment levels will react to the subsidy. This yields the following first-order condition:

$$W_s + W_Q \frac{dQ^d}{ds} + W_k \frac{dk^d}{ds} = 0 \tag{7}$$

with $W_s = \pi_s - Q = 0$ (since $\pi_s = Q$), $W_Q = \pi_Q + \Gamma_Q - s$ (with $\pi_Q = 0$ from expression (5)) and $W_k = \pi_k = -C_k = 0$ (from expression (6)). The optimal subsidy when investment is delayed is thus given by:

$$s^d = \Gamma_Q \tag{8}$$

The sign of the subsidy depends on that of the marginal social benefit of production (other than marginal industry profits), with $s^d > 0$ if $\Gamma_Q > 0$ and $s^d < 0$ if $\Gamma_Q < 0$.

4.2.2. Early investment

If the firm invests early, it chooses its investment level *before* the government has set the subsidy. Solving by backward induction, we determine the government's subsidy, taking into account how output will respond to the subsidy, but taking the firm's investment level as given. The first-order condition for welfare maximisation is then:

$$W_s + W_Q \frac{dQ^e}{ds} = 0 \tag{9}$$

[14] At certainty, the firm is indifferent between delaying and investing early.

Since $W_s = 0$ and $W_Q = \Gamma_Q - s$, the optimal subsidy when the monopolist chooses capital in the first period, s^e, is given by:

$$s^e = \Gamma_Q \tag{10}$$

Note that the expression for the optimal subsidy takes the same form as with investment delay (see expression (8)). But, since Γ_Q depends on output and there is no reason to believe that output levels with delay and early investment are the same, subsidy *levels* are likely to differ.

In period one, when choosing its investment level, the firm maximises expected profits, yielding the following first-order condition for k:

$$E\frac{d\pi}{dk} = E\left[\pi_k + \pi_Q \frac{dQ^e}{dk} + \pi_s \frac{ds^e}{dk}\right] = 0 \tag{11}$$

Since $\pi_Q = 0$ (see expression (5)), we have $E\pi_k = -E\left[\pi_s \frac{ds^e}{dk}\right]$. With $\pi_k = -C_k$ and $\pi_s = Q$, expression (11) reduces to

$$EC_k = E\left[Q\frac{ds^e}{dk}\right] \tag{12}$$

implying that the firm's capital investment is not socially efficient. Whether the firm over- or underinvests given expected output, depends on how k affects the subsidy. The expression for ds^e/dk (derived in Appendix A) is given by:

$$\frac{ds^e}{dk} = \frac{\Gamma_{QQ}C_{Qk}}{R_{QQ} - C_{QQ} + \Gamma_{QQ}} \tag{13}$$

Since $C_{Qk} < 0$ and the second-order conditions for the government's maximisation problem require $R_{QQ} - C_{QQ} + \Gamma_{QQ} < 0$, the sign of ds^e/dk is directly determined by the sign of Γ_{QQ}. The firm strategically underinvests ($EC_k < 0$) if the subsidy falls in k ($ds^e/dk < 0$ if $\Gamma_{QQ} < 0$). Conversely, when k raises the subsidy ($ds^e/dk > 0$ if $\Gamma_{QQ} > 0$), the firm strategically overinvests ($EC_k > 0$). A comparison of expressions (12) and (6) indicates how the firm's capital choice is different with delay than with early investment. Unlike with investment delay, with early investment k cannot be chosen to minimise costs, because it is set before actual demand is observed; nor is k chosen to minimise expected costs, as it is set strategically to manipulate s^e.

4.2.3. Investment delay versus early investment

We explain the firm's investment-timing choice under policy intervention in two steps. First, we discuss the investment-timing outcome at certainty (i.e., at $\sigma^2 = 0$). Subsequently, we study how uncertainty affects when the firm will invest.

Figures 2a and 2b show the firm's capital reaction function and the government's subsidy reaction function in (k,s)-space at *certainty.* (At every point in the diagram, the firm chooses output to maximise profits, i.e. $\pi_Q = 0$.) The figures illustrate the difference between the outcome of the game when the firm invests early and when it delays investment. In both diagrams, the firm's reaction function, $k(s)$ (along which $C_k = 0$), is positively sloped: the firm's cost-minimising investment level rises in the subsidy. The firm's isoprofit contours are shown as solid curves, with profits increasing as one moves to the right in the diagrams. The government's best response function is represented by $s(k)$ (along which $s = \Gamma_Q$). Isowelfare curves are depicted by complete dashed contours, with the highest welfare level represented by point *d*. We assume that $s(k)$ cuts $k(s)$ only once and –ensuring reaction function stability– that the absolute value of the slope of $s(k)$ is greater than that of $k(s)$. In Figure 2a, we illustrate the case in which the marginal social benefit of production (other than profits) is positive ($\Gamma_Q > 0$), implying $s > 0$, and increasing ($\Gamma_{QQ} > 0$), implying that the slope of $s(k)$ is positive. Figure 2b depicts the case in which $\Gamma_Q < 0$, implying $s < 0$, and $\Gamma_{QQ} < 0$, implying $ds/dk < 0$[15].

[Figures 2a and 2b about here]

With investment delay, the firm's chosen investment level lies on its best response function. Moving first, the government picks point *d*, the point on the firm's reaction function associated with the highest welfare level (at this point $s^d = \Gamma_Q$ (see expression (8); hence, point d *also* lies on the government's reaction function). When the firm invests early, it selects the point on the government's reaction function that yields the highest profit (i.e., point *e*). Compared to delay, both the firm's investment level and the subsidy differ from their levels with early investment.

Proposition 2: At certainty, under the policy regime, if the G-function is

(i) strictly convex ($\Gamma_{QQ} > 0$*), then* $k^e > k^d$ *and* $s^e > s^d$*;*

(ii) strictly concave ($\Gamma_{QQ} < 0$*), then* $k^e < k^d$ *and* $s^e > s^d$*;*

(iii) linear ($\Gamma_{QQ} = 0$*), then* $k^e = k^d$ *and* $s^e = s^d$.

Proof: See Appendix B.

When the marginal social benefit from production (other than industry profit) increases in Q ($\Gamma_{QQ} > 0$), the firm strategically overinvests when it sets k early, in order to obtain a higher subsidy. However, when $\Gamma_{QQ} < 0$, early investment is characterised by strategic underinvestment and a higher subsidy than with investment delay. Part *(i)* and *(ii)* of proposition 2 are respectively illustrated in Figure 2a and 2b. Note that, when $\Gamma_Q < 0$, production is taxed ($s < 0$). Finally, only when the government's subsidy does not respond to the firm's investment level, are investment and subsidy levels the same, irrespective of the firm's investment timing.

Early investment, enabling the firm to manipulate the subsidy through over- or underinvestment, results in a higher subsidy. Hence, under the active policy regime –at certainty–, unlike under laissez faire, the firm obtains higher profits when investing early than when delaying.

Proposition 3: At certainty, $p^e \geq p^d$ *under the policy regime.*

Proof: See Appendix B.

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[15] Obviously, other possible cases are $\Gamma_Q > 0$ with $\Gamma_{QQ} < 0$, and $\Gamma_Q < 0$ with $\Gamma_{QQ} > 0$. For brevity, we omit the figures for these cases.

So, at certainty the firm will invest early under the policy regime. The introduction of uncertainty ($s^2 > 0$) does not necessarily change the firm's investment-timing choice[16]. In fact, by continuity, there will be a range of uncertainty in which the monopolist invests early ($Ep^e > Ep^d$). So, the very presence of the subsidy scheme generates an incentive for early investment that was absent under laissez-faire.

Corollary 1: If $p^e > p^d$ at certainty, there exists a range of uncertainty for which the firm invests early under the policy regime.

4.3. Welfare

In this subsection we investigate what the policy regime implies for welfare. First-best output and investment are given by expressions (3) and (4). Since $p_Q = 0$ (from (5)), we have $R_Q - C_Q = -s$. Substituting this into (3) implies $s = \Gamma_Q$. The conditions $s = \Gamma_Q$ and $C_k = 0$ are identical to those derived in the case in which the firm *delays* investment until period two. Hence, EW^d is equal to expected welfare in the first-best outcome. When the firm invests *early*, the subsidy is $s^e = \Gamma_Q$ (and thus $R_Q - C_Q + \Gamma_Q = 0$). However, investment is –even at certainty– not set at the efficient level (see (12)). This implies that a new distortion is created and the first-best is not reached. These results are summarised in proposition 4 and corollary 2.

Proposition 4: Under the policy regime, the welfare obtained is the first-best level, provided that the firm delays investment.

Corollary 2: Under the policy regime, expected welfare with investment delay is at least as high as with early investment ($EW^d \geq EW^e$); if $\Gamma_{QQ} \neq 0$, then $EW^d > EW^e$.

Note that, even if the government were to have a whole array of other policy instruments at its disposal, the first-best would not be reached (except in the case in which firms delay). Investment subsidies (or taxes), for instance, will fail in preventing new

[16] One can use Figures 2a and 2b only to compare the deterministic components of profits and welfare. The diagrams are not suited to discuss the additional benefits of flexibility under uncertainty.

distortions being created[17]. Instead, the first-best policy package calls for an instrument that deters early investment. However, such a policy instrument tends to require long-run commitment power, which is precisely what the type of government discussed here lacks[18].

We have established that when the firm invests early under the policy regime, welfare falls below the first-best level. This does, however, not justify a general advocacy of laissez faire as a superior policy stance to government intervention. Obviously, the first-best will not be reached under the laissez-faire regime either (unless $\Gamma_Q = 0$[19]), since then the initial output distortion will remain. When neither laissez faire nor the policy regime gives rise to the first-best outcome, it is impossible to rank these two outcomes in the general model. In the next section, we explore the factors that determine which of these outcomes qualifies as the second-best. In order to do this, we need to turn to specific functional forms.

5. Laissez faire versus policy

The general model suggests some further questions. First, under the policy regime, what specific factors determine whether a firm invests early or delays? This question is important since it is only when the firm delays investment until after the output subsidy is set that policy can guarantee the first-best (see proposition 4 and corollary 2). Second, if policy fails to achieve a first-best welfare level by inducing early investment, would the laissez faire alternative attain an outcome that is socially preferred to the one realised by the policy regime? Even though the government cannot commit in the long run to its policies, it may be able to "buy" a specific commitment to non-intervention by subscribing to international agreements that explicitly prohibit active policy. Examples

[17] There is no more reason to assume that a government with short-run commitment power only, could commit to an investment subsidy in the long run, than that it could commit to an output subsidy. Even if it could, this would not alter the fact that capital under early investment is inflexible and not chosen in line with actual demand.
[18] Dewit and Leahy (2004) discuss how and when a government with long-run commitment power may want to deter early investment in a trade policy context.
[19] An example in which $\Gamma_Q = 0$ is the special case of a monopolist firm exporting all its output without generating any production externalities.

are preferential trade agreements, economic integration agreements, international agreements that prohibit state aid to firms and the free trade agreement of the WTO[20].

Turning to specific functional forms to answer the above questions, assume demand is given by:

$$p = a - Q + u \tag{14}$$

and the firm's total cost function is:

$$C = (c_0 - q\sqrt{k})Q + rk \qquad \text{with } q > 0 \text{ and } r > 0 \tag{15}$$

Production costs are $(c_0 - q\sqrt{k})Q$, with c_0 a positive constant and q the effectiveness of investment in reducing the marginal costs of production. Investment costs are rk. The cost function in (15) satisfies the restrictions in the general model: total costs depend both on output and investment, are convex in k and marginal production costs fall in k. It proves useful to define $h \equiv q^2 / 2r > 0$, denoting the "relative effectiveness" of investment; h measures how effective investment is in reducing marginal production costs relative to the cost of the investment. We further assume that the social benefits from production (other than profits) are given by:

$$\Gamma = e_0 Q + (e/2)Q^2 \tag{16}$$

with $\Gamma_Q = e_0 + eQ$, denoting the marginal social benefit of production that is not captured by profits, and with $\Gamma_{QQ} = e$; the parameters e_0 and e can be positive, negative or zero. The expressions for output, investment and subsidy levels, expected profits and expected welfare are reported in Table A.1 of Appendix C.

Under what circumstances will policy yield the first-best outcome for society? From proposition 4, we know that answering this question requires identifying the factors that cause the firm to delay investment in the presence of policy intervention. While retaining flexibility is clearly more important the greater the uncertainty, the value of early

[20] The superiority of laissez faire to intervention has been debated in alternative, more specific set-ups in the trade policy literature. In a strategic trade policy model, Grossman and Maggi (1998) show that free trade can be superior to a strategic export policy for the country. Staiger and Tabellini (1999) find evidence that GATT rules helped the US government to make domestic trade policy commitments that it could not have made in the absence of these rules.

investment increases if the scope for subsidy manipulation is greater. Let $\hat{\sigma}^2$ denote the critical level of uncertainty at which the firm under the active policy regime is indifferent between early investment and retaining flexibility through investment delay (i.e., σ^2 at which $E\pi^e = E\pi^d$). Above this threshold ($\sigma^2 > \hat{\sigma}^2$), the firm delays ($E\pi^e < E\pi^d$), while it invests early ($E\pi^e > E\pi^d$) below it ($\sigma^2 < \hat{\sigma}^2$). In Figure 3a, $\hat{\sigma}^2$ is shown as a function of ε (at $\varepsilon_0 = 0$ and $\eta = 0.1$)[21]. We see that $\hat{\sigma}^2$ increases both as ε rises above and falls below zero[22]; both larger positive and more negative values for ε raise the value of strategic subsidy manipulation associated with early investment relative to the flexibility value of investment delay[23]. This is because the possibility for subsidy manipulation depends on ds^e / dk, which in turn depends crucially on $\Gamma_{QQ} = \varepsilon$. The parameter η affects the critical uncertainty threshold at which a firm is indifferent between investing early and investment delay in a similar way. An increase in η raises the relative effectiveness of investment, boosting output and hence the subsidy, giving the firm a stronger incentive for strategic investment. The upward sloping $\hat{\sigma}^2$-locus is depicted in (σ^2, η)-space in Figure 3b (at $\varepsilon_0 = 0$ and $\varepsilon = 1$)[24]. For $\sigma^2 > \hat{\sigma}^2$ (area I in Figures 3a and 3b), the firm delays and active policy will yield the first-best welfare level. For $\sigma^2 < \hat{\sigma}^2$ (areas IIa and IIb in Figures 3a and 3b), the firm invests early and the first-best cannot be attained.

[Figures 3a and 3b about here]

Having established when policy will achieve the first-best outcome, we now turn our attention to the area below $\hat{\sigma}^2$, in which the first-best cannot be reached. As argued earlier, high values of either ε or η give the firm a stronger incentive for socially

[21] Figures 3a to 4c are normalised by setting $a - c_0 = 1$.

[22] Note that at $\varepsilon = 0$, the firm does not strategically invest ($k^e = k^d$) because it cannot affect the subsidy ($ds^e / dk = 0$).

[23] Note that an increase in ε_0 (the constant term in the Γ-function) shifts the $\hat{\sigma}^2$-locus up on either side of the origin. Ceteris paribus, an increase in ε_0 causes a larger change in output when the firm invests early than when it delays (provided that $\varepsilon \neq 0$). This will lead to more strategic overinvestment if $\varepsilon > 0$ and more strategic underinvestment if $\varepsilon < 0$, both causing a higher degree of subsidy manipulation.

[24] So, $\Gamma = Q^2 / 2$, which corresponds to the case in which Γ consists of consumer surplus only.

suboptimal early investment. While this benefits the firm, it renders intervention less socially beneficial relative to laissez faire. Both in Figures 3a and 3b, laissez faire and intervention with early investment yield the same welfare level along the locus that is denoted by w and that demarcates areas IIa and IIb; laissez faire is socially preferred to intervention $(EW(s=0) > EW(s^e))$ at high values of e and h (area IIb), while the opposite is true when e and h are small (area IIa)[25]. In the diagrams, each area is labelled with the best attainable outcome from a social perspective. For instance, in area I (above $\hat{s}^2$), policy intervention is preferred. In area IIa, policy intervention with early investment is the constrained social optimum, while laissez faire is the constrained social optimum in area IIb. Shaded labels indicate the areas in which intervention is the socially preferred policy stance.

6. Extension: Oligopoly

We now extend our analysis to the case in which there are multiple firms. For simplicity and because it fully captures the intuition for the multiple-firm case, we examine the case of two firms. Two symmetric firms produce identical products and behave à la Cournot. Demand is given by expression (14) (with $Q = q_1 + q_2$ and with $q_{i=1,2}$ denoting firm output) while the cost function for each firm is represented by expression (15) (replacing Q by q_i and k by k_i). Furthermore, to cut down on the taxonomy and to facilitate easy diagrammatic comparison with monopoly, we assume $e_0 = 0$ and $e = 1$ in expression (16) (i.e., $\Gamma = Q^2/2$, which is simply consumer surplus). Then, since $\Gamma_Q > 0$, the policy active government will choose a positive subsidy. The game now consists of four stages. If a firm delays, it chooses its investment in period two, but prior to setting output. Period two then consists of three stages: the government sets the subsidy in stage 2, firms that delay investment chose their capital level in stage 3 and outputs are set in stage 4 (see also footnote 12).

[25] An increase in e_0 shifts the w-locus to the right. In other words, it raises the merits of the active policy regime relative to laissez faire. The main effect of an increase in e_0 is that it worsens the initial output distortion, which raises the returns to policy intervention (admittedly –see footnote 23– it will also cause more subsidy manipulation, but this effect is secondary).

With two firms, there are four possible investment-timing combinations: both firms invest early, (e_i, e_j), both delay investment, (d_i, d_j), and one firm invests early while the other delays, (e_i, d_j), with $i \neq j$. Again, before turning to firms' investment timing under the policy regime, we first discuss investment-timing outcomes under laissez faire.

Unlike under monopoly, a firm may, even under *laissez faire*, invest early. Figure 4a shows firms' investment-timing outcomes under laissez faire in (s^2, h)-space. While both firms will delay if uncertainty is sufficiently high (area I in Figure 4a), at relatively low levels of uncertainty investment leadership prevails (area II)[26]. In order to explain the emergence of investment leadership, we must examine firms' investment-timing decisions. A firm's incentive to invest early depends on its rival's investment timing. *Given* rival *delay*, a firm faces a trade-off between early investment and delay, even without government intervention. If it invests early, committing to capital in period one, it benefits from the first-mover advantage associated with investment leadership. However, early commitment implies a loss in flexibility, which becomes larger as the level of uncertainty in period one rises. Hence, early investment will be chosen at low levels of uncertainty, whereas delay will be preferred as the uncertainty level exceeds a critical threshold. *Given* rival *commitment*, however, there is no trade-off between early investment and investment delay. Given that its rival's capital is irrevocably fixed at a specific level, firm i will neither gain strategically by committing in period one nor lose strategically by delaying investment. However, it will be more flexible if it delays. This implies that early investment by both firms cannot, except at certainty, be an equilibrium under laissez faire[27]. In fact, given rival commitment, a firm will assume the role of investment follower under non-intervention.

[Figures 4a and 4b about here]

[26] In the literature, leadership is found as the outcome of endogenous timing games when firms compete in quantity and moving early implies "action commitment" (i.e., timing and level of the quantity variable – such as output or investment– are chosen as a single action). See, for instance, theorem VII in Hamilton and Slutsky (1990) and Sadanand and Sadanand (1996). Importantly, neither of these papers considers the effect of policy (with or without long-run commitment) on firms' timing choices.

[27] Both (e_i, d_j) and (e_i, e_j) are equilibria at $s^2 = 0$. However, even a minute degree of uncertainty would cause (e_i, e_j) to collapse as an equilibrium.

Next, we discuss firms' investment timing under the *policy regime*, in which the government sets the production subsidy for the industry. The subsidy level depends on the investment-timing outcome, with $Es^{ee} > Es^{de} = Es^{ed} > Es^{dd}$; at certainty, firm *i*'s profit ranking is $p_i^{ee} > p_i^{ed} > p_i^{de} > p_i^{dd}$, implying that, at $s^2 = 0$, each firm will always invest early, irrespective of the rival's timing ($p_i^{ee} > p_i^{de}$ and $p_i^{ed} > p_i^{dd}$) (the first and the second superscript refer to firm *i*'s and firm *j*'s investment-timing, respectively). Hence, at certainty, the investment-timing outcome (e_i, e_j) is the unique equilibrium. Note that, in spite of the fact that both firms strategically overinvest, they are not in a prisoner's dilemma type of situation. In fact, each firm benefits not only from its own overinvestment but also from its rival's: both firms' strategic investment forces the government into setting a higher subsidy. Figure 4b depicts the investment-timing outcomes with policy intervention in (s^2, h)-space. The main point is that, unlike with laissez faire, for $s^2 > 0$, (e_i, e_j) is the unique investment-timing equilibrium even when uncertainty is quite high[28].

In Figure 4c, the socially preferred policy stance –intervention or laissez faire– is shown for the different demarcated areas (again, shaded labels indicate the areas in which policy intervention yields higher welfare than laissez faire). Under duopoly, the critical uncertainty level above which all firms in the industry delay (i.e., the locus separating area I and II in Figure 4c) is lower than under monopoly ($\hat{s}^2$ in Figure 3b). Furthermore, although, like under monopoly, intervention is preferable for low values of h (see areas I, IIa, IIIa and IVa) and laissez faire is better for high values of h (see areas IIb, IIIb and IVb), with duopoly, intervention is socially superior to laissez faire for a wider h-range than with monopoly (note that, with intervention, there are two equilibria in area II; in area IIb intervention is preferable to laissez faire only if both firms delay, while intervention is always superior to laissez faire in area IIa). Hence, the region in which policy intervention is superior to laissez faire is larger under duopoly than under

[28] As Figure 4b shows, delay by both firms can also be an equilibrium but only at very high levels of uncertainty.

monopoly. This can be easily seen from comparing Figures 3b and 4c: the areas with the shaded labels added together are (corrected for the different scales used in the diagrams) much larger in Figure 4c than in Figure 3b.

So why is it that, at certain combinations of s^2 and h, the policy regime is inferior to non-intervention under monopoly, while the opposite is true under oligopoly? This is explained by the fact that the subsidy is relatively less responsive to changes in investment if the industry is oligopolistic. There are two reasons for this. First, a change in industry output has a smaller impact on the subsidy under duopoly than under monopoly; because of the larger number of competitors under oligopoly, the output distortion in oligopolistic industries is smaller than the one in monopolistic sectors. Second, an individual firm's ability to manipulate industry output through its investment is smaller in the presence of competitors. In Cournot duopoly, a firm's output expansion induced by additional investment ($dq_i / dk_i > 0$) is accompanied by a cut-back in its rival's production ($dq_j / dk_i < 0$), which dampens the effect of the firm's investment on industry output; hence, $dq_i / dk_i > dQ / dk_i > 0$. By contrast, an output expansion by a monopolist is –by definition– reflected in an industry output expansion of the same size. In short, a weaker ability of the individual firm to influence industry output (through its investment) on the one hand, and a lower responsiveness of the government subsidy to industry output on the other hand, gives a firm under duopoly a weaker incentive to manipulate the government, leading to a smaller strategic distortion and thus causing the policy regime to be less harmful than under monopoly. In fact, as the number of firms in the industry goes up, the distortionary effects of policy intervention become smaller because the individual firm's incentive to manipulate the subsidy is increasingly weakened.

[Figure 4c about here]

Two important insights emerge from studying the multiple-firm case. First, in order to manipulate government policy more successfully, firms have (apart from the realisation of possible synergies and other benefits) an additional incentive to merge. Firms with a larger market share are better able to manipulate the government. Second, one can expect that manipulation of government policy is strongest and hence the distortionary side effects of policy are most severe in very concentrated industries. Hence, our analysis points to further reasons why merger regulation and an effective anti-trust policy are socially beneficial.

7. Concluding remarks

So, what are the policy lessons one should draw from our analysis? First, our model suggests that the policies of a government with short-run commitment power only, may be fully successful, but –perhaps paradoxically– only if implemented in a business environment that is very uncertain and in which investors value flexibility highly. Although real-world policy making in a climate of uncertainty involves many difficulties, we showed that one possible problem policy makers face, that is, the exploitation of short-run policy commitment power by firms, is likely to be lessened by uncertainty. This is good news for (non-corrupt) governments in less developed countries, especially in newly emerging economies and economies in transition, in which the market place is fraught with uncertainty and firms are keen to adopt a wait-and-see approach to investment. However, it is bad news for most governments in highly developed countries, in which the economic climate tends to be –at least most of the time– more certain. In those circumstances, firm are more likely to invest earlier in order to manipulate government policy strategically. Then, policy schemes that correct the initial distortion may make things worse by creating a new and more harmful one.

Second, policy manipulation by private agents is a far wider problem than one might suspect. It is well known that “soft” or “weak” states, referring to governments whose objective function is contaminated by political interests, are vulnerable to manipulation by private agents. Our analysis shows that even the policies of “hard” or “strong” states, i.e. governments that are benevolent pure welfare maximisers, may not remain insulated from private agents’ manipulation if they lack the ability to commit to their policies long-term.

Third, policy intervention is likely to do most damage in heavily concentrated industries. In those sectors, individual firms not only have more market power, they also have a stronger ability and thus a stronger incentive to manipulate policy. This suggests that countries that adhere to a rigorous competition policy may be able to implement tax and subsidy policies more effectively.

Finally, in practice there exists a serious danger that policies are evaluated as being successful, while they are in fact causing harm. Especially when the policy corrects the targeted distortion, the policy manipulating activities that generate new distortions may be easily overlooked, particularly when these do not involve directly unproductive rent-seeking behaviour, such as lobbying. So, the side effects of policy intervention by governments with limited commitment power may remain undetected, which makes policy activism all the more dangerous.

Appendix A

If the firm invests *early*, the government sets the subsidy *after* the firm chooses *k*; $s^e = \Gamma_Q$ (see expression (10)) with $\Gamma_Q = \Gamma_Q(Q)$. Since *Q* is chosen in the final stage (see expression (5)), we have $Q = Q(k, s, u)$ with

$$Q_k = -\pi_{Qk} / \pi_{QQ}, \; Q_s = -\pi_{Qs} / \pi_{QQ} \text{ and } Q_u = -\pi_{Qu} / \pi_{QQ}. \tag{A.1}$$

Second-order conditions for the firm require $\pi_{QQ} = R_{QQ} - C_{QQ} < 0$; furthermore, $\pi_{Qk} = -C_{Qk} > 0$, $\pi_{Qs} = 1$ and $\pi_{Qu} = R_{Qu} > 0$. Using (A.1), $\pi_{Qs} = 1$, $\pi_Q = 0$ and $s = \Gamma_Q$, total differentiation of the first-order condition for s^e yields:

$$\left[-(\pi_{QQ} + \Gamma_{QQ}) \left(\frac{\pi_{Qk} dk + \pi_{Qs} ds}{\pi_{QQ}} \right) + \pi_{Qk} dk \right] \frac{dQ}{ds} = 0, \text{ which implies } \frac{ds^e}{dk} = \frac{\Gamma_{QQ} C_{Qk}}{R_{QQ} - C_{QQ} + \Gamma_{QQ}}$$

(see expression (13)).

Appendix B

Proof of proposition 2:

Part *(i)* – The proof requires showing that the equilibrium with early investment in (k, s)-space lies above and to the right of the one with investment delay (as depicted in Figure

2a). We know that, along $k(s)$ (the firm's capital reaction function) the firm chooses – given *s*– its optimal, i.e. cost-minimising, k ($C_k = 0$). Since $Q_s > 0$ (see expression (A.1)), $k(s)$ must be upward sloping (starting at any point on $k(s)$ and keeping k constant, an increase in s implies an output increase, and since $C_{Qk} = C_{kQ} < 0$ an increase in Q pushes C_k below zero; hence –since $C_{kk} > 0$– k must rise to reach the new cost-minimising point for the higher output level). Thus, below $k(s)$, k is below $k^{\min}(Q)$ and hence $C_k < 0$; above $k(s)$, k is above $k^{\min}(Q)$ and hence $C_k > 0$.

Since k^d is chosen such that $C_k = 0$ (see expression (6)), k^d lies on $k(s)$, and since $s^d = \Gamma_Q$ (see expression (8)), s^d lies on $s(k)$. Hence, the equilibrium when the firm *delays* lies at the intersection of $s(k)$ and $k(s)$. Because $s(k)$ cuts $k(s)$ only once, the equilibrium is unique (see point d in Figure 2a). With *early* investment, $s^e = \Gamma_Q$ (see expression (10)), implying that s^e also lies on $s(k)$. However, from expressions (12) and (13) we know that at certainty $C_k > 0$ when $\Gamma_{QQ} > 0$. Given that Γ is strictly convex, $s(k)$ is monotonically increasing and cuts $k(s)$ from below. Hence, the equilibrium when the firm invests early (point *e* in Figure 2a) lies above and to the right of the equilibrium when the firm delays (point *d*), implying $k^e > k^d$ and $s^e > s^d$.

The proofs for part *(ii)* and part *(iii)* are analogous.

Proof of proposition 3:

Irrespective of the firm's investment timing, the subsidy is always chosen such that $s = \Gamma_Q$ and hence both the equilibrium with delay and the one with early investment lie along $s(k)$. If the firm invests early, it can choose k^d, implying the pair (k^d, s^d). However, it chooses k^e instead (with $k^e \neq k^d$ if $\Gamma_{QQ} \neq 0$), implying the pair (k^e, s^e). This must imply $p^e \geq p^d$ at $s^2 = 0$.

Appendix C

[Table A.1 about here]

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Figure 1: The game

t=1 ***Uncertainty***	*Stage 1:*	Firm chooses whether to invest now or in *t=2;* if firm chooses to invest now, it determines its investment level.
t=2 ***Certainty***	*Stage 2:*	Government sets output subsidy.
	Stage 3:	• If firm delayed investment (in stage 1), it determines its investment level; • Firm chooses output.

Figure 2a: Early investment versus investment delay under the policy regime at certainty: $\mathbf{G}_Q>0$ and $\mathbf{G}_{QQ}>0$

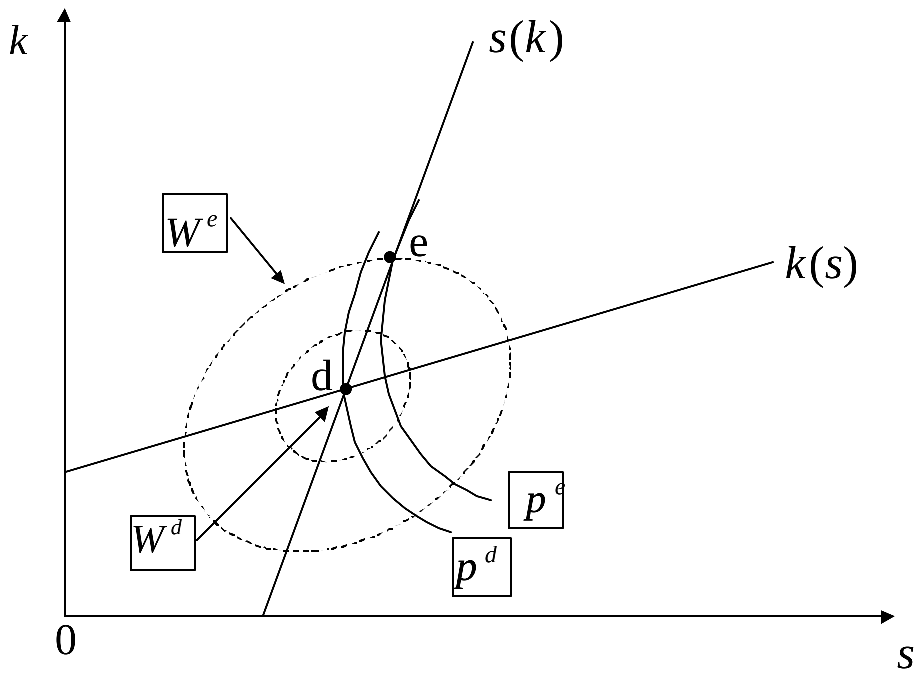


Figure 2b: Early investment versus investment delay under the policy regime at certainty: $\mathbf{G}_Q<0$ and $\mathbf{G}_{QQ}<0$

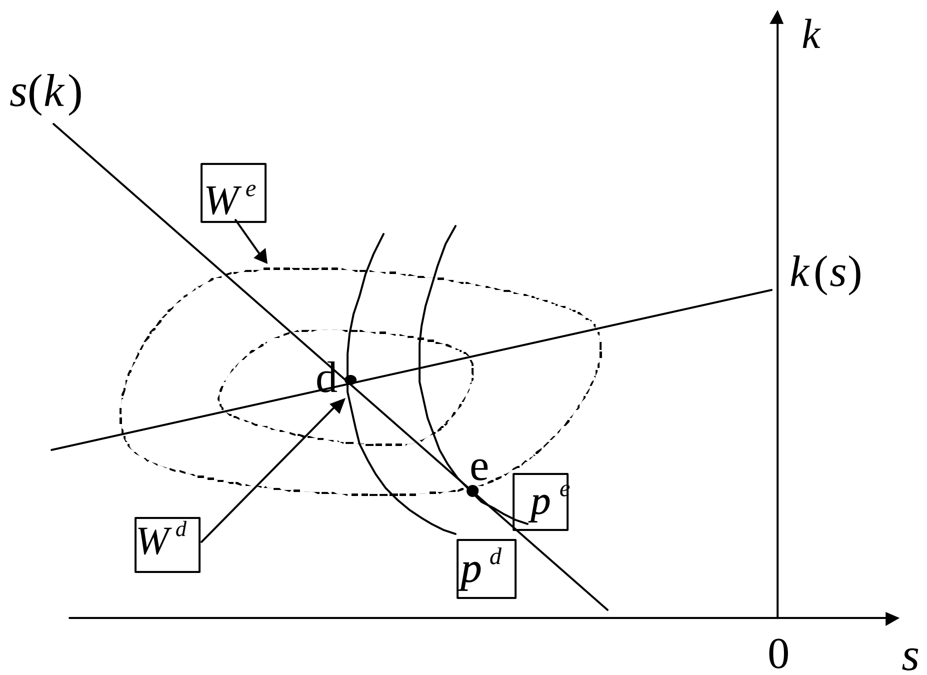


Figure 3a: Policy intervention versus laissez faire
(h=0.1, e_0=0)

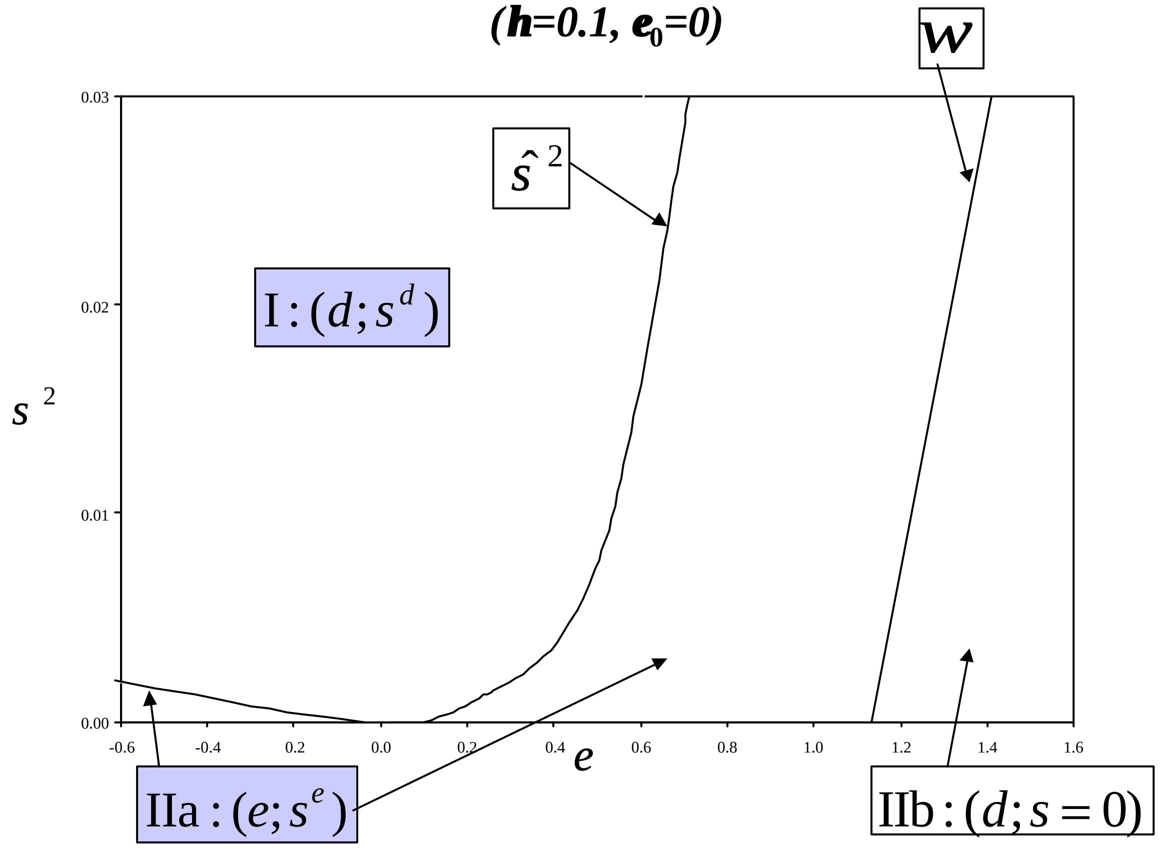
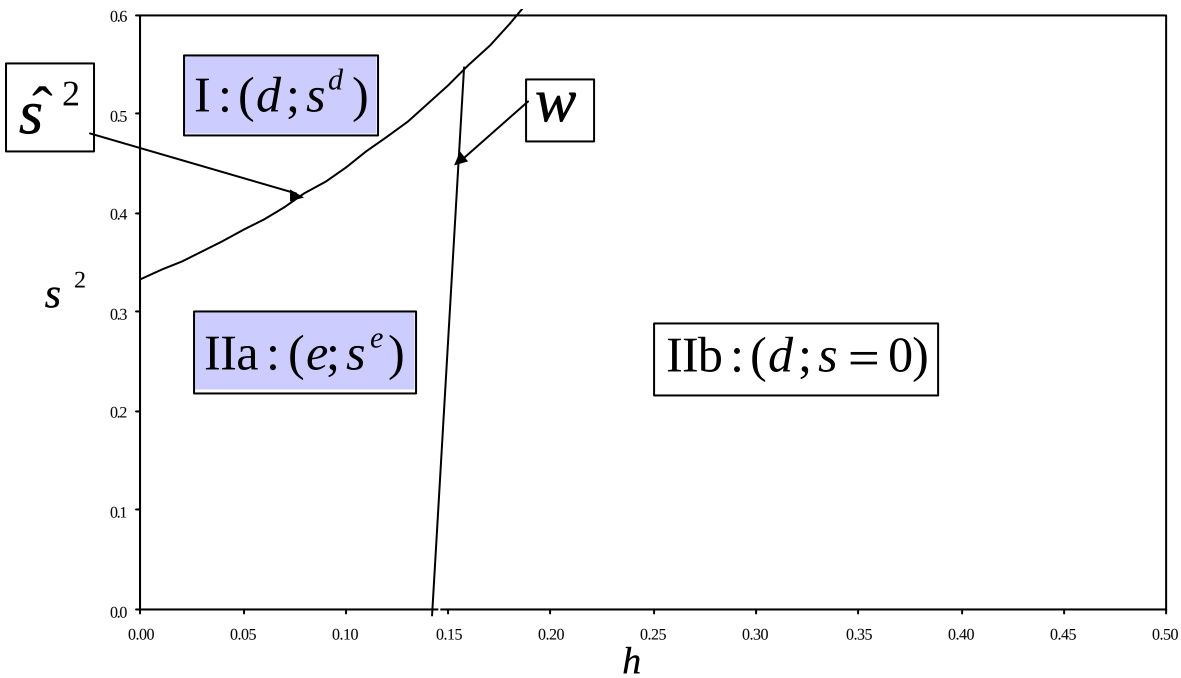


Figure 3b: Policy intervention versus laissez faire
(e=1, e_0=0)



Note: Strictly speaking $\hat{s}^2$ is only defined at $h > 0$; $h = 0$ is ruled out since at that point k would be zero.

Figure 4a: Duopoly - Investment timing under laissez faire
(e_0=0, e=1)

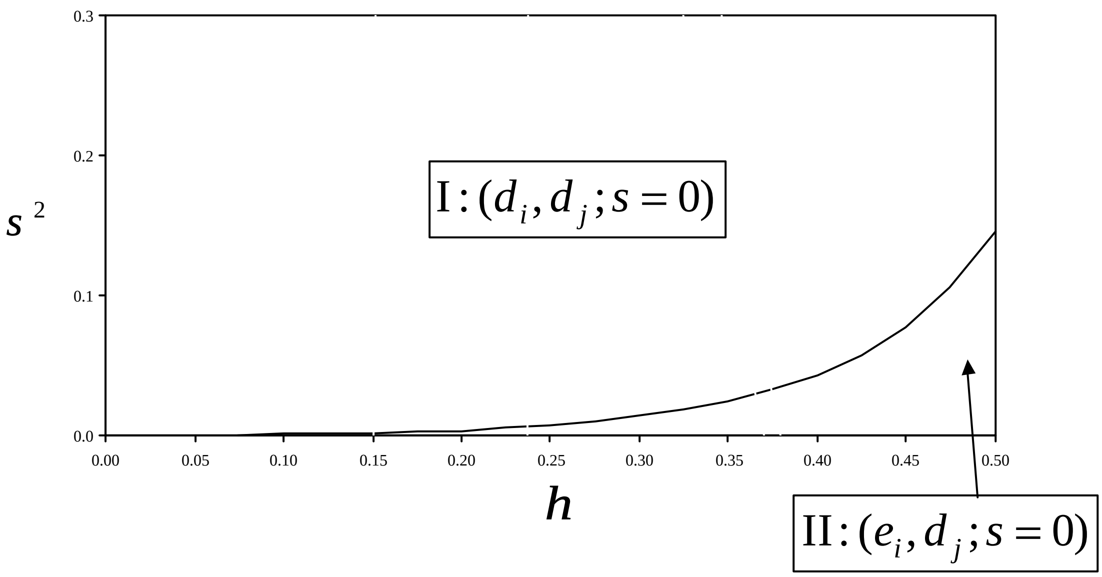


Figure 4b: Duopoly – Investment timing under policy intervention
(e_0=0, e=1)

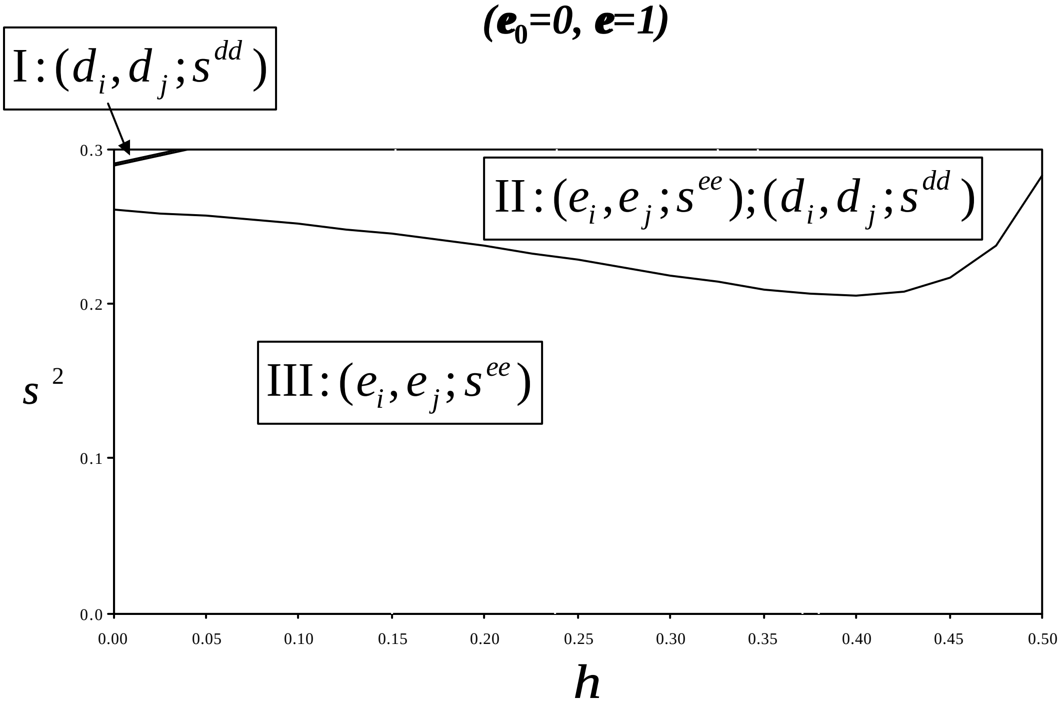


Figure 4c: Duopoly - Policy intervention versus laissez faire (e_0=0, e=1)

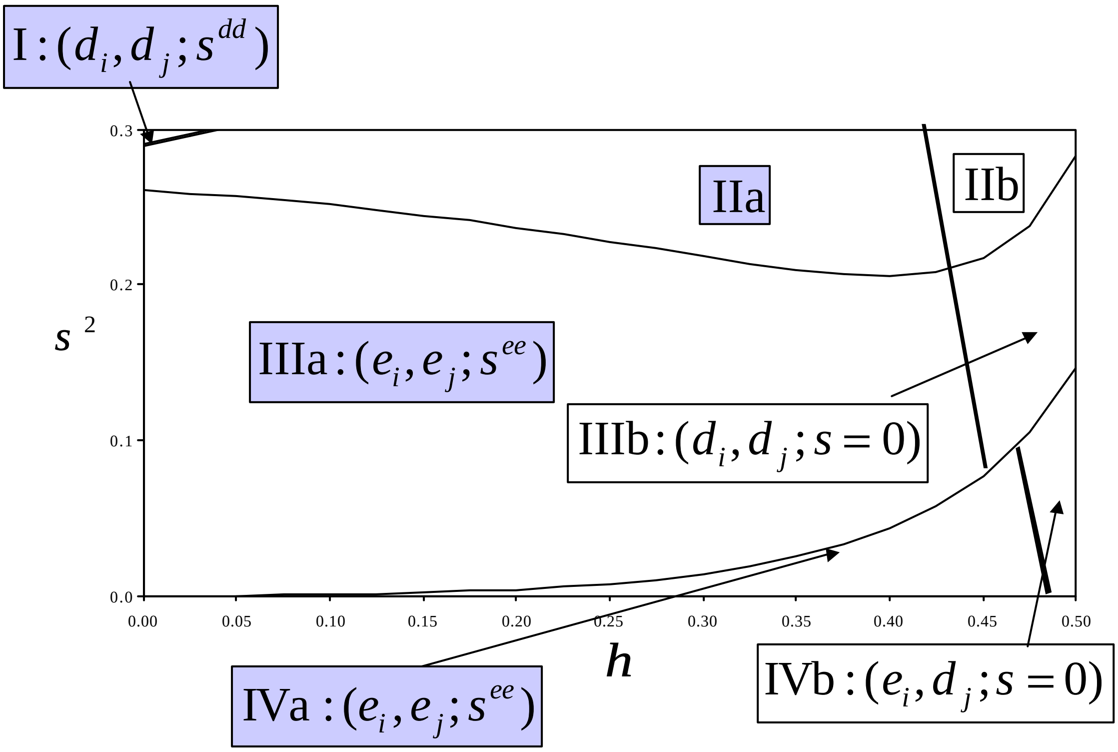


Table A.1: Laissez-faire versus the policy regime with a monopolist firm with $p = a - Q + u$, $C = (c_0 - q\sqrt{k})Q + rk$ ***and*** $\Gamma = e_0 Q + (e/2)Q^2$

	LAISSEZ FAIRE (always Investment Delay)	***POLICY***	
		Investment Delay	***Early Investment***
Q	$\frac{A+u}{2-h}$	$\frac{A+e_0+u}{2-h-e}$	$\frac{(2-e)(A+e_0)}{(2-e)^2-2h}+\frac{u}{2-e}$
k	$\left[\frac{h}{q}Q\right]^2$	$\left[\frac{h}{q}Q\right]^2$	$\left[\frac{2}{2-e}\frac{h}{q}EQ\right]^2$
s	-	e_0+eQ	e_0+eQ
Ep	$\left(1-\frac{h}{2}\right)[EQ]^2+\frac{(1-(h/2))}{(2-h)^2}s^2$	$\left(1-\frac{h}{2}\right)[EQ]^2+\frac{(1-(h/2))}{[2-h-e]^2}s^2$	$\left[1-\frac{h}{2}\left(\frac{2}{2-e}\right)^2\right][EQ]^2+\frac{s^2}{[2-e]^2}$
EW	$e_0EQ+\left(1-\frac{h}{2}+\frac{e}{2}\right)[EQ]^2 + \frac{\left(1-\frac{h}{2}+\frac{e}{2}\right)}{(2-h)^2}s^2$	$\left(1-\frac{h}{2}-\frac{e}{2}\right)[EQ]^2+\frac{\left(1-\frac{h}{2}-\frac{e}{2}\right)}{[2-h-e]^2}s^2$	$\left[1-\frac{h}{2}\left(\frac{2}{2-e}\right)^2-\frac{e}{2}\right][EQ]^2+\frac{s^2}{2[2-e]}$

Note: $h \equiv \frac{q^2}{2r} > 0$; furthermore, parameters are restricted to guarantee interior solutions.