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Chicken or Egg. Which Should Come First, Privatisation or Liberalisation?

Giovanni De Fraja*

ABSTRACT. This paper identifies an industrial policy instrument in the *timing* of privatisation, relative to the *timing* of liberalisation of a public firm's market, defined as the lifting of legal barriers to entry by other firms. It is shown that the long run market competitiveness and the privatised firm efficiency are highly sensitive to this decision, and that the choice whether privatisation should precede liberalisation or vice versa depends on the government's preferences and on the relationship between competitive pressure and cost efficiency of the privatised firm. We identify conditions under which the case in which liberalisation preceeding privatisation Pareto dominates the opposite timing.

La poule ou l'œuf. Dans quel ordre. Privatisation ou libération du marché ?

RÉSUMÉ. – Cet article voit dans le « timing » des mesures pour la privatisation d'une entreprise publique, un instrument de politique industrielle. La question qui est abordée est celle de savoir s'il faut libérer le marché, c'est-à-dire, lever les barrières légales à l'entrée, avant ou après la privatisation.

En tenant compte de deux objectifs : la competitivité du marché à long terme, et l'efficacité de l'entreprise privatisée, notre analyse montre que l'ordre des deux modalités d'intervention est crucial, et que la meilleure décision est fonction d'une part des préférences du gouvernement et d'autre part de l'effet de la compétitivité du marché sur les coûts de l'entreprise privatisée. Nous identifions des conditions dans lesquelles la libération du marché avant privatisation dominerait au sens de Pareto la politique alternative.

* G. De Fraja : Department of Economics, University of York, Heslington YO1 5DD.
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1 Introduction

Recent years have witnessed large programmes of sale to private investors of public enterprises and of lifting of statutory monopolies in many industrialised countries. Moreover privatisation and liberalisation are at the top of the agenda in the countries of the former Soviet bloc, and are becoming increasingly important in developing countries as well. While often linked in policy statements, privatisation and liberalisation are distinct decisions both conceptually and in practice: one may be taken independently of the other. For example, in UK, British Gas and the Electricity Boards have been privatised without losing their monopoly in the household market; conversely, many European airlines have lost their legal monopoly on national flights without undergoing any change in ownership. When both privatisation and liberalisation do take place, they need not occur simultaneously: in the case of British Telecom the privatised company was allowed a period of legal monopoly for certain of its services, whereas the Post Office and publicly-owned bus companies compete with private firms, at least in some of the markets where they operate.

This paper shows that the order in which privatisation and liberalisation take place may have important consequences on the performance, in terms of productive and allocative efficiency, of the industry. It therefore suggests that, in view of the potentially long lasting effects of the provision of a competitive framework, care should be taken in deciding when privatisation should take place, relative to the opening of the market to competition [1].

We analyse the question of the relative timing of the two decisions by means of a stylised model, where the privatised firm simply reduces its production costs as a consequence of privatisation. Without entering the debate of whether privatisation is really necessary for this reduction in cost to take place [2], we simply assume that the firm we consider is one where a reduction in production cost is possible, and where the government believes that the best way of achieving it is through privatisation. In short, the privatised firm, now aiming at maximising profit and free from political interference, will carry out a widespread re-organisation of its internal structure, and will reduce its managerial slack (X-inefficiency in the LEIBENSTEIN [1966] sense).

The main insight provided by the model of this paper is that the extent of this reduction in the incumbent firm's slack may be affected by strategic entry

1. In Germany, for example, the privatisation agency, *Treuhandanstalt*, proceeds by reorganising the firm until it is ripe for privatisation, that it is can be sold (Bös, 1991 b, p. 185). No reference seems to be made to the order of privatisation and liberalisation.
2. It may be claimed that such re-organisation could be carried out while keeping the firm in public ownership. In practice, if an extensive re-organisation is carried out in a public firm this is usually in the expectations of privatisation (a good example is British Steel). It could be argued that, when massive changes are required, a change in ownership could greatly help ease the resistance to change.

deterrence considerations, which in turn may be influenced by the policy decision about the relative timing of privatisation and the lifting of the firm's legal monopoly. We focus on the timing of these two policies measures to the extreme degree of leaving aside any other aspect of privatisation. In particular, we do not model explicitly any government intervention in the industry considered; while aware that such intervention will clearly affect the likely costs and benefits of the reduction in slack, we feel justified in assuming that any such intervention is fully taken into account by the market participants.

The paper may have important policy implications: Eastern European countries have started an extensive privatisation programme, which, if it has begun with the sale of firms operating in competitive markets, is likely to involve, at some stage, the sale of public utilities, or of other firms operating in a situation of legal monopoly (e.g. airlines and utilities). Important decisions are being made with respect for example, to the relative timing of privatisation of such firms and the authorisation granted to foreign firms to enter these markets. Given the extent of the potential gains (and losses) to be made in these markets, it is extremely important to get it right, and that, once the decision to proceed with both privatisation and liberalisation has been made, the consequences of their relative timing are carefully studied.

The paper is organised as follows. Section 2 gives an intuitive outline of the model, and discusses the main results obtained. Section 3 introduces the model formally, while Section 4 describes the outcome in the two possible scenarios the government can choose: privatisation followed by liberalisation, and liberalisation followed by privatisation. These are compared in Section 5, while Section 6 illustrates a specific example and some comparative statics results. Section 7 is a brief conclusion, and the Appendix contains the least immediate proofs.

2 Outline of the Main Results

The model is described in the next Section, and we give here an informal discussion and outline the main conclusions. We have in mind a situation where a public firm is at present operating under conditions of legal monopoly. The government wishes to privatise it, in the belief that an improvement in productive efficiency could take place; moreover, the possibility of introducing product market competition is also considered, but it is not known whether entry could take place, or whether the industry is really a natural monopoly.

A new management team is appointed, either by the government, if the firm remains for the time being in the public sector, or by the new shareholders, if the firm is privatised. This team will be referred to as "the incumbent" in the remainder of the paper, and it is assumed to act to maximise expected profits. It does so by choosing the value of a variable s,

$s \in [\underline{s}, \overline{s}] \subseteq \mathbb{R}$, which affects the payoff of all three players. s could be given a number of interpretations: in general, it is any variable which incumbents can use strategically to deter entry, or to try to alter the conditions of entry to their advantage. As is the case with the rest of the entry deterrence literature, once chosen this variable cannot be easily modified again: taking this to its extreme consequences, we assume here that it cannot be modified at all. In an analysis of privatisation, the interpretation of s as reduction of managerial slack or improved productive efficiency seems quite natural, but several other interpretations are possible, and are briefly mentioned in Section 6.

The government chooses the *timing* of the entry game between entrant and incumbent, that is, it selects whether entry should precede or follow the incumbent's choice of s. It does that simply by choosing when to revoke the legal monopoly granted to the incumbent: it could revoke it before the new team is appointed, or after the re-organisation of the privatised firm has been completed.

The entrant chooses, whenever it is allowed to, whether to enter the market considered or to stay out. Notice that the entrant may choose to delay entry, namely to enter after the incumbent's choice of s even when it could enter before it (and it does indeed do so, in some circumstances).

The crucial asymmetry of information lies in the fact that the efficiency of the potential entrant is known only to the potential entrant itself. The government and the incumbent only know that this entrant can have high cost with probability x, and low cost with probability $(1 - x)$. Therefore, when selecting the value of s, the incumbent must weigh up the fact that, for example, a very low value of s, which is costly, may not be needed because the entrant has high cost and would not enter anyway, against the fact that, by keeping a high value of s, it exposes its flank to fierce competition by an aggressive low cost entrant. As the paper show, the government may alter the incumbent's beliefs about its opponent, by allowing entry to occur straight away, and this may benefit all those involved.

A brief discussion of our simplifying assumptions may be in order. The hypothesis of two values only for the entrant's cost is standard and its relaxation would make the analysis more involved, without adding anything of substance to it. Secondly, we do not model explicitly the regulatory regime which will be in operation after privatisation has taken place. If regulation does occur, we simply assume implicitly that there is an asymmetry of information between the incumbent firm and the regulatory agency, and that the chosen value of s will reflect such asymmetry of information [3]. Alternatively, it may be the case that the government and the firms know that no regulation will take place after privatisation, for example because of weaknesses in the regulatory agencies. Be it as it may, all those involved have the ability to predict the outcome of the regulatory

3. As shown by LAFFONT and TIROLE [1986], if managers have a preference for leisure, then the optimal regulatory mechanism will allow some slack, the extent of which depends on the cost and demand functions.

mechanism (if any) which will operate after entry has taken place, or after it is clear that no entry will take place. In one of the few other references to entry in a mixed duopoly, Bös and Nett [1990], study the government's use of the regulatory instrument, without considering the timing of entry; a more complete analysis would merge the two approaches.

The way in which the chosen value of s affects the players' payoff is also a natural consequence of its interpretation as X-inefficiency. Other things equal, the government prefers lower slack (since it implies lower prices and higher output), the potential entrant higher slack (since it is preferable to compete against a rival with higher costs). As far as the incumbent is concerned, we assume that there is an optimal value for s: other things equal slack reduction would only be pushed to a certain level, and not further. This may be due to managerial preference for leisure, or simply to the fact that reducing slack has costs as well as benefits: redundancy payments, workforce resistance, low staff moral, plant decommissioning, and so on.

A final important simplification we introduce regards the information structure of the game: while we model an informational advantage for the entrant, whose cost is not known to the other two players, we depart from the standard usage in assuming symmetric information between incumbent and government. This is a strong hypothesis, and some of our results may depend on it. A more complete analysis would need to relax it, but we feel justified to introduce it here on two grounds. Firstly, the symmetry of information case may constitute a useful benchmark for further analysis where the incumbent is better informed than the government about some crucial features of the industry. Secondly, symmetry of information between government and incumbent is an extreme case of an important feature of these industries: the government has better information about the incumbent than about the entrant. This appears to be realistic, due to the fact that it may be relatively easy to acquire information about a publicly owned or regulated firm [4] or to the fact that the entrant could be a firm already operating in a foreign market, so that no special investigation to ascertain its cost function could be undertaken. At any rate, further research will be needed to establish the role of the hypothesised symmetry of information between government and incumbent.

In detail, our analysis distinguishes the cases in which entry deterrence is profitable from the case in which it is not. In the first case, whenever is given the chance, the incumbent will deter entry: this is shown in Proposition 1, and is an established result in industrial economics. In this case, the model points to the presence of a trade-off between productive efficiency and competition: if the incumbent is allowed to choose its value of s strategically, then it will set a low value, thus choosing a high level of productive efficiency, precisely to deter entry: even an efficient competitor will not stomach a fight against an incumbent with such a low production cost, and will stay out: whether this is welfare enhancing or not depends

4. For example, in UK, the regulator may request information from British Telecom, which it does not have the power to obtain from Mercury.

on the government preferences. Thus, if the government welfare function gives a large weight to productive efficiency in the industry considered, then it makes sense to allow the incumbent a "period of adjustment" in which it can shape up to the climate of competition before abolishing its legal monopoly [5]. If on the other hand, few improvements in efficiency are believed feasible, or if product market competition is reputed to be more beneficial than such improvements, then entry should be allowed immediately, in order to prevent costly and wasteful entry deterring strategies on the incumbent's part. In the example of Section 6, we however show that it is only for extreme values of the parameters that allowing a period of restructuring for the public firm while keeping its statutory monopoly is welfare improving: in general it is better to liberalise straight away, and then privatise and let the shareholders restructure the firm.

We obtain more general results for the possibly more interesting case in which the incumbent would accommodate entry: the level of s necessary to deter entry is so low, that the incumbent prefers to compete, with a positive probability, with a low cost duopolist, than to incur the costs necessary to bring s down as much as needed to keep it out. As Proposition 4 shows, under mild (sufficient) conditions, the outcome where liberalisation precede privatisation is Pareto superior (strictly in many cases) to the reverse order of events: entry is equally likely, slack is lower (which implies higher consumers' surplus), and both the entrant and the incumbent have higher profits. If the fact that consumers and entrant both benefit when entry is allowed immediately is plausible, that the incumbent should be better off if it does not have the opportunity to deter entry may appear surprising: shouldn't a larger choice set always be preferable? A brief reflection shows however that it is reasonable. When entry deterrence would not occur, then the incumbent prefers to be able to adjust its level of s according to the type of competitor it faces: in this case, as Proposition 3 shows, if entry does not occur at its first possibility, then it will not occur, and the monopoly optimal choice of s is selected. Conversely, if entry occurs, the incumbent will choose the "best" s, given that it faces an efficient competitor. If however the incumbent is forced to choose s before entry could take place, then a compromise between the optimal monopoly value and the optimal duopoly value is needed. This gives a lower profit than the possibility to fine tune the level of s according to the type of market where the incumbent will operate. In other words, there are two elements in the choice of s: on the one hand, the possibility of using it as an entry deterring device, on the other hand, the desire to select it according to the market structure in which the firm will operate. When the need to deter entry is absent, that is when the level of s needed to deter an efficient entrant is too low for the incumbent, then the latter factor prevails, and the incumbent is better off

5. The UK government's policy followed in the privatisation of British Telecom has often been criticised for not pushing liberalisation far enough (Vickers and Yarrow 1988, pp. 235 ff). The government defence may be that in the telecommunications industry the overwhelming priority was to re-organise the firm and make the most of the technological improvements, and that sacrificing product market competition for a fuller achievements of these goals was not inconsistent with the maximisation of a social welfare function.

if it can choose s after having learnt its opponent true type, which it does simply by observing whether entry occurs or not.

3 The Model

We study here a three player game of incomplete information; the three players are the government, the private shareholders or the managers of the privatised firm, and a potential competitor of the latter. The uncertainty relates to the entrant's cost. The entrant's cost function is characterised by one parameter, c, the value of which is known to the entrant but unknown to both the government and the incumbent. What is common knowledge is the distribution from which this parameter is drawn: for the sake of simplicity this has been assumed to be binomial:

$$c \in \{c_{\mathrm{L}},\, c_{\mathrm{H}}\} \qquad c_{\mathrm{L}} < c_{\mathrm{H}} \qquad \mathrm{Prob}\,(c = c_{\mathrm{H}}) = x$$

where a low value of the parameter c denotes low cost [6].

Figure 1 describes the game. At node 0, Nature chooses the entrant's type, choosing between low cost and high cost. At information set 1, the government selects the timing of the possible entry, choosing between the following two alternatives:

– it can allow the management of the privatised firm to choose s, and *then*, once s is known to all those concerned, allow entry into the market;

– it can allow entry, *then* allow the restructuring of the privatised firm, that is its selection of s; after the selection of s, entry can again happen, if it has not already occurred. [7]

In Figure 1, the government available branches are labelled PL, which stands for "Privatisation followed by Liberalisation", and LP, "Liberalisation followed by Privatisation". The nodes included in the information sets where the incumbent chooses (information sets 2, 5, and 7) are denoted by an arc, to indicate that this player can choose from a continuum, the interval $[\underline{s},\, \overline{s}]$. The entrant chooses in the set {In, Out}, where "In" denotes the choice of entry; entry is irreversible. The terminal nodes describe the payoff pair of the two firms; their payoff is simply given by their profit, while the government's payoff is not specified explicitly. In general, it will be a function of the value of s, of the probability of entry, and of the firms' profit; in Section 6 we consider a specific example for the government payoff function. The profit functions of the two firms are given in Figure 1 as

6. A more general distribution function could also be considered, but little would be added to the main conclusions of the analysis.

7. Conceivably, the incumbents choise of s and the entrant choice of entry could also take place simultaneously: realism however, would suggest that this possibility should not considered, as, in practice, the long term nature of these choices rules it out.

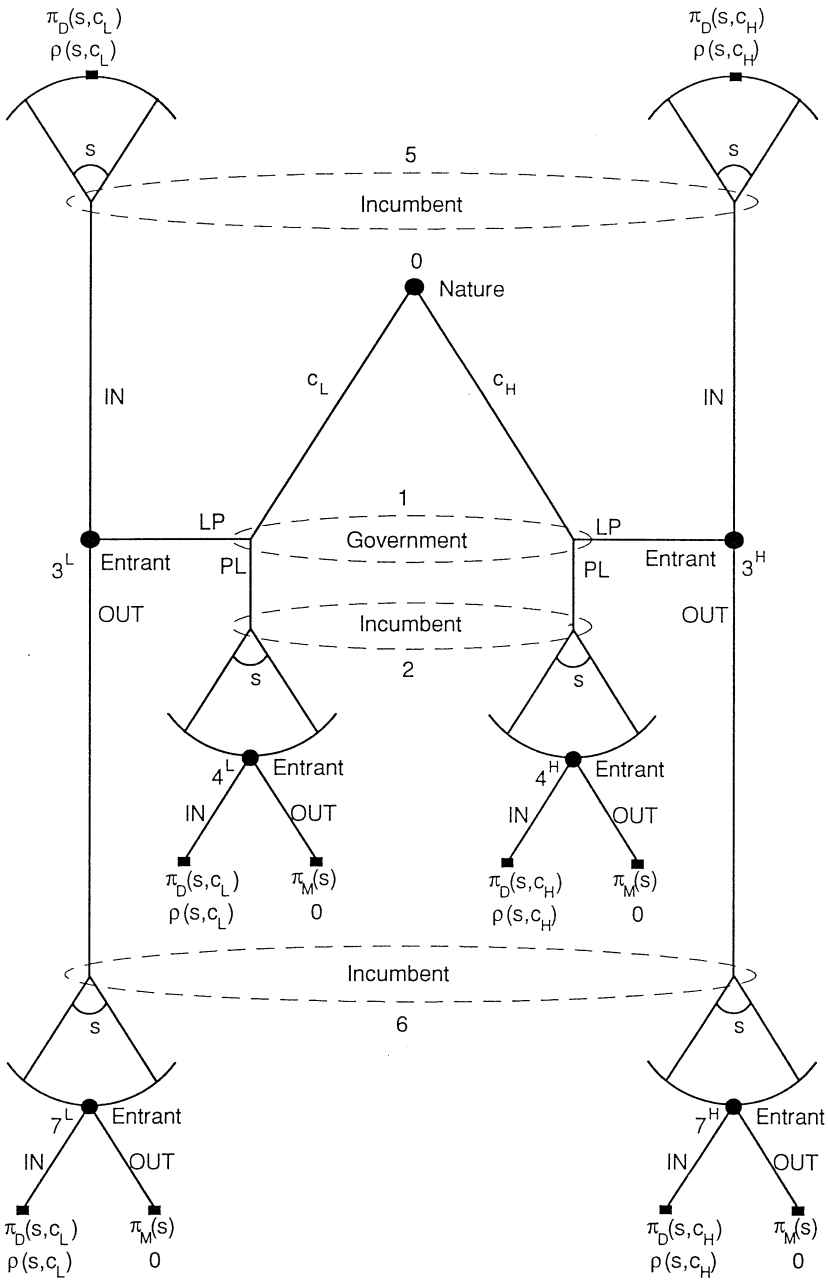

FIGURE 1

The Extensive Form of the Game Studied.

follows: the incumbent's profit if an entrant with cost c enter is $\pi_D(s, c)$, s being the incumbent's choice (the subscript D refers to duopoly); if no entry occurs, the incumbent's profit function is $\pi_M(s)$ (M for monopoly). The entrant's profit is given by a function $\rho(s, c)$; the three functions π_{D}, π_{M}, and ρ are differentiable in all their arguments. The following assumptions specify a number of simplifications for the two firms' payoff functions.

Assumption 1: (i) $\partial\rho(s, c)/\partial s > 0$, (ii) $\partial\rho(s, c)/\partial c < 0$

The first part says that the entrant's profit is higher the higher the managerial slack in the incumbent, the second that it is larger the lower its own cost.

Assumption 2: For all $s \in [\underline{s}, \overline{s}]: \ \pi_{\mathrm{M}}(s) > \pi_{\mathrm{D}}(s, c_{\mathrm{H}}) > \pi_{\mathrm{D}}(s, c_{\mathrm{L}})$

This is natural: it says that a monopolists makes more profit than a duopolist facing a high cost competitor, who in turn makes more profit than a duopolist facing a low cost competitor. We define the following magnitudes:

– s_{H}, defined by $\rho(s_{\mathrm{H}}, c_{\mathrm{H}}) = 0$
– s_{L}, defined by $\rho(s_{\mathrm{L}}, c_{\mathrm{L}}) = 0$
– $s_{\mathrm{M}} = \arg\max_{s} \pi_{\mathrm{M}}(s)$
– $s_{\mathrm{D}} = \arg\max_{s} \pi_{\mathrm{D}}(s, c_{\mathrm{L}})$

Thus, s_{H} and s_{L} are the values of the incumbent's choice which would, if selected, make the high cost entrant and the low cost entrant, respectively, just indifferent between being out of the market and competing with the incumbent. Notice that, by virtue of Assumption 1, $s_{\mathrm{H}} > s_{\mathrm{L}}$. s_{M} and s_{D} , on the other hand, are the incumbent's optimal choices when no entry ever occurs, and when entry by the low cost competitor is certain to occur. Next define the incumbent's expected profit, as a function of s:

$$
\begin{aligned}
\mathrm{E}\,\pi(s) &= \pi_{\mathrm{M}}(s) && \text{if} \quad s \le s_{\mathrm{L}} \\
&= x\,\pi_{\mathrm{M}}(s) + (1-x)\,\pi_{\mathrm{D}}(s, c_{\mathrm{L}}) && \text{if} \quad s_{\mathrm{L}} < s \le s_{\mathrm{H}} \\
&= x\,\pi_{\mathrm{D}}(s, c_{\mathrm{H}}) + (1-x)\,\pi_{\mathrm{D}}(s, c_{\mathrm{L}}) && \text{if} \quad s_{\mathrm{H}} < s
\end{aligned}
$$

and define:

$$
s(x) = \arg \max_{s \in [s_{\mathrm{H}}, s_{\mathrm{L}}]} \left[x\,\pi_{\mathrm{M}}(s) + (1-x)\,\pi_{\mathrm{D}}(s, c_{\mathrm{L}})\right]
$$

$s(x)$ is the optimising choice of s as function of x restricting the incumbent's choice to those values of s such that the low cost entrant enters and the high cost one doesn't.

Assumption 3: For every $x \in [0, 1]: \ s(x) \in (s_{\mathrm{L}}, s_{\mathrm{H}})$

While fairly restrictive, this assumption simplifies the analysis to a considerable extent, as it rules out the need to study a number of corner solutions in which $s(x)$ equals s_{H} or s_{L}. Figure 2 depicts some of the functions introduced: Assumption 3 ensures that the dashed line always reaches a maximum in the open interval $(s_{\mathrm{L}}, s_{\mathrm{H}})$. The incumbent's expected profit, $\mathrm{E}\,\pi(s)$ is given by $\pi_{\mathrm{M}}(s)$ for s lower than s_{L}, and by the dashed line for s in $(s_{\mathrm{L}}, s_{\mathrm{H}})$. The following Corollary illustrates some of the implications of the above assumptions.

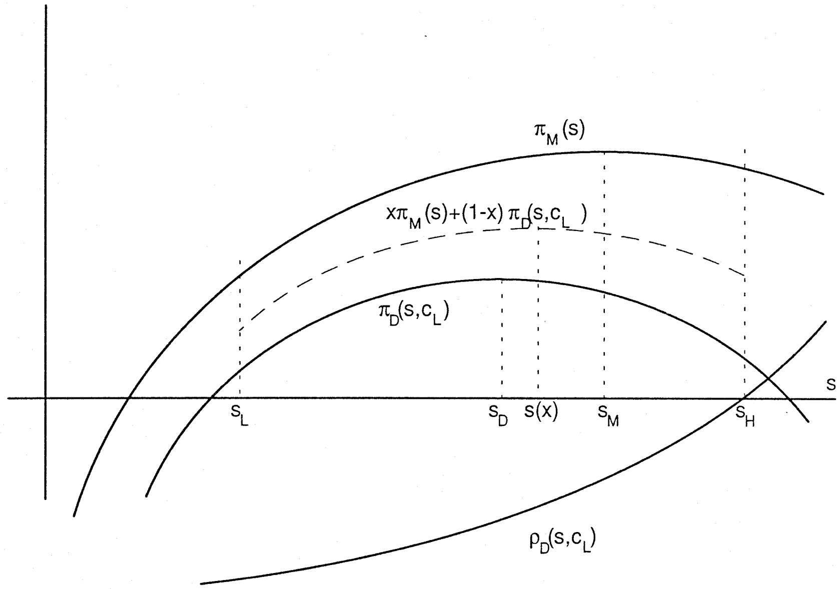

FIGURE 2

The Incumbent's and the Entrant's Profit as Functions of the Incumbent's Choice of s.

COROLLARY 1 : Let $\pi_{\mathrm{E}}(x) = x\,\pi_{\mathrm{M}}(s(x)) + (1-x)\,\pi_{\mathrm{D}}(s(x),\, c_{\mathrm{L}})$. Then:
(i) $s(0) = s_{\mathrm{D}}$;
(ii) $\pi_{\mathrm{E}}(0) = \pi_{\mathrm{D}}(s_{\mathrm{D}},\, c_{\mathrm{L}})$;
(iii) $s(1) = s_{\mathrm{M}}$;
(iv) $\pi_{\mathrm{E}}(1) > \pi_{\mathrm{M}}(s_{\mathrm{L}})$;
(v) $\pi'_{\mathrm{E}}(x) > 0$.

Proof: (i), (ii) and (iii) are obvious, (iv) follows from the fact that, because of Assumption 3 $\pi'_{\mathrm{M}}(s_{\mathrm{L}}) > 0$, and (v) from taking

$$\pi'_{\mathrm{E}}(x) = \left[x\,\frac{d\pi_{\mathrm{M}}(s)}{ds} + (1-x)\,\frac{\partial \pi_{\mathrm{D}}(s,\, c_{\mathrm{L}})}{\partial s}\right] s'(x) + \\ + \left[\pi_{\mathrm{M}}(s(x)) + \pi_{\mathrm{D}}(s(x),\, c_{\mathrm{L}})\right]$$

The first square bracket is zero because of Assumption 3, the second is positive in view of Assumption 2. □

ASSUMPTION 4: $s(x)$ is monotonic.

This final assumption implies that the line joining the points $(s_{\mathrm{D}},\, \pi_{\mathrm{D}}(s_{\mathrm{D}},\, c_{\mathrm{L}}))$ and $(s_{\mathrm{M}},\, \pi_{\mathrm{M}}(s_{\mathrm{M}}))$ in Figure 2 does not change (horizontal) direction, and denotes a certain regularity in the behaviour of the profit functions.

The equilibrium behaviour of the two firms differ depending on the slope of the function $s(x)$, both in this general case, and in the specific model adopted in Section 6. It is therefore useful to distinguish the following two cases.

ASSUMPTION 4a: (Competition reduces slack). $s'(x) < 0$.

ASSUMPTION 4b: (Competition reduces cost reducing effort). $s'(x) > 0$.

Which of these cases will occur in practice depends on the relative strength of the two effects of an increase in the probability that the entrant has low cost: when x is reduced, entry becomes more likely. On the one hand, this implies that the incumbent is more likely to face a low cost competitor, which gives an incentive to cut costs. A more X-efficient organisation is better equipped to face competition, and as competition becomes more likely, the incumbent will try to prepare better to its consequences. On the other hand, as entry becomes more likely, the expected size of the incumbent's product market is reduced, and therefore so is the benefit of a given reduction in marginal cost, making a low value of s less desirable than when the incumbent is very likely to be a monopolist. If the former effect prevails, then Assumption 4a holds, competition reduces slack, vice versa, in the opposite case, Assumption 4b holds.

4 Equilibria in the Entrant-Incumbent Game

In order for the government to choose between its two available alternatives, it must work out which outcome will emerge, along the two alternative branches, as a consequence of the interaction between the two remaining players.

The equilibrium concept we adopt is perfect Bayesian equilibrium (PBE in the rest of the paper). This concept, in the present two-type model is equivalent to sequential equilibrium (see FUDENBERG and TIROLE, 1991, p. 346). To describe an equilibrium, it is necessary to describe each player's action at every information set in Figure 1, (even those which are not reached at the candidate equilibrium), and the beliefs of the players whose information is incomplete, on which they base their choices: for a strategy vector to be a PBE, each player's actions must be optimal responses to the opponents, *and* their beliefs about the opponents type must be consistent (in the Bayes sense) with the opponents' strategies [8]. As the description of a PBE may be a bit tedious, we relegate it to the proofs, including in the statement of the proposition only the *equilibrium path*, namely the outcome of the players interaction.

The equilibrium path is relatively simple along the PL branch.

8. For a fuller description see any advanced game theory text, e.g., FUDENBERG and TIROLE, 1991, Chs. 6 and 8.

PROPOSITION 2 : Let Assumptions 1-3 hold. Along any PBE path where the government chooses branch PL:
(i) if $\pi_{\mathrm{M}}(s_{\mathrm{L}}) > \pi_{\mathrm{E}}(x)$, the incumbent chooses s_{L}, and no entry occurs;
(ii) if $\pi_{\mathrm{M}}(s_{\mathrm{L}}) < \pi_{\mathrm{E}}(x)$, the incumbent chooses $s(x)$, and only the low cost entrant enters.

Proof: Given the government choice of PL, the unique PBE is given by:
– the incumbent chooses s_{H} if $\pi_{\mathrm{M}}(s_{\mathrm{L}}) > \pi_{\mathrm{E}}(x)$; $s(x)$ otherwise;
– the low cost entrant enters if and only if $s > s_{\mathrm{L}}$;
– the high cost entrant enters if and only if $s > s_{\mathrm{H}}$.

To see this, proceeding backwards, given the incumbent's choice of s at Information set 2 in Figure 1, the entrant, when choosing what to do at Node 4, having observed the incumbent's choice of s, enters if and only if $\rho(s, c) > 0$. Thus along the PL branch both types enter if $s > s_{\mathrm{H}}$, only the low cost firm enters if $s_{\mathrm{H}} \geq s > s_{\mathrm{L}}$, no entry occurs if $s \leq s_{\mathrm{L}}$ [9]. Aware of this decision rule, the incumbent will simply select between s_{L}, in which case no entry occurs and it receives a payoff of $\pi_{\mathrm{M}}(s_{\mathrm{L}})$, $s(x)$, with entry by the low cost entrant, and s_{H}, with entry by both types of entrants.

The only thing that remains to be checked is that the incumbent will never want to select s_{H}, allowing both types of firms in the market. This follows simply from:

$$\begin{aligned}\pi_{\mathrm{E}}(x) &> x\,\pi_{\mathrm{M}}(s_{\mathrm{H}}) + (1-x)\,\pi_{\mathrm{D}}(s_{\mathrm{H}}, c_{\mathrm{L}}) \\ &> x\,\pi_{\mathrm{D}}(s_{\mathrm{H}}, c_{\mathrm{H}}) + (1-x)\,\pi_{\mathrm{D}}(s_{\mathrm{H}}, c_{\mathrm{L}})\end{aligned}$$

The first inequality is due to the fact that $s(x)$ maximises

$$x\,\pi_{\mathrm{M}}(s) + (1-x)\,\pi_{\mathrm{D}}(s, c_{\mathrm{L}}),$$

the second to the fact that it is always better to be a monopolist than a duopolist. □

This proposition holds in both cases 1 and 2, and even when Assumption 3 does not hold. In the study of the LP branches the distinction between Assumptions 4 a and 4 b needs explicit consideration. The next two propositions deal with the two cases in turns.

PROPOSITION 3: Let Assumptions 1-3 and 4 a hold. Along any PBE path in which the government chooses LP,
(i) if $\pi_{\mathrm{M}}(s_{\mathrm{L}}) < \pi_{\mathrm{E}}(x)$, no entry occurs before the choice of s, the incumbent chooses $s(x)$, and, subsequently, the low cost firm enters.
(ii) if $\pi_{\mathrm{M}}(s_{\mathrm{L}}) > \pi_{\mathrm{E}}(x)$,
– the low cost firm enters initially with probability α;
– if entry occurs, the incumbent chooses s_{D};
– if entry does not occur, the incumbent chooses $s(\gamma)$ with probability σ, s_{L} with probability $(1-\sigma)$;

9. When one player is indifferent between two choices, we follow the convention of breaking the indifference in the most convenient way, from the modelling point of view, except, clearly, where this may affect the resulting equilibrium: in this particular case, we assume that, if indifferent, an entrant stays out: to justify this we could assume that, instead of, say, s_{H}, the incumbent chooses $s_{\mathrm{H}} - \varepsilon$

– the low cost entrant enters if $s = s(\gamma)$, stays out if $s = s_{\mathrm{L}}$; where α, σ and γ are the unique solution of:

$$\pi_{\mathrm{M}}(s_{\mathrm{L}}) = \pi_{\mathrm{E}}(\gamma)$$

$$\alpha = 1 - \frac{x}{1-x}\frac{1-\gamma}{\gamma}$$

$$\sigma = \frac{\rho(s_{\mathrm{D}}, c_{\mathrm{L}})}{\rho(s(\gamma), c_{\mathrm{L}})}$$

Proof: See Appendix. □

Proposition 3 displays a fairly complex type of equilibrium, where players use mixed strategies. To get an intuitive grasp of the outcome, consider the low cost entrant at node 3. It has a stark decision to make, whether to enter, sinking the necessary investment or to postpone the decision until after the choice of s. If it enters straight away, it knows what to expect: the incumbent will choose s_{D}. If it waits, the incumbent may keep it out of the market, by choosing s_{L}, or it may decide to select a level of slack, $s(\gamma)$, which is higher than s_{D}. It other words, the entrant faces the choice, between a middling profit, $\rho(s_{\mathrm{D}}, c_{\mathrm{L}})$, for certain, and a lottery between a high profit, $\rho(s(\gamma), c_{\mathrm{L}})$, and nothing. The entrant is indifferent between the two, and therefore $s(\gamma)$ must be higher than s_{D}. Consider the incumbent's decision when entry has not occurred (if entry occurs, there is little to choose). This is what goes in the incumbent's mind: "The lack of entry may mean either that (i) the entrant is really high cost; or that (ii) the entrant is low cost, but it is holding back, in the hope that I set a favourable (for it) choice of s". The incumbent must be indifferent between setting this higher value of slack, γ, and its entry deterring value s_{L}, otherwise the entrant would know which would be chosen. Hence they must give it exactly the same profit: $\pi_{\mathrm{M}}(s_{\mathrm{L}}) = \pi_{\mathrm{E}}(\gamma)$. In Figure 2, when $\pi_{\mathrm{M}}(s_{\mathrm{L}}) < \pi_{\mathrm{E}}(x)$, γ is such that the maximum of the dashed curve has the same ordinate as s_{L}. But when, given that it allows entry, would the incumbent select a value of s equal to $s(\gamma)$? Only when it believes that the potential entrant is high cost with probability γ. This gives the probability with which (the incumbent must believe that) the low cost entrant randomises between entering and staying out.

Finally, consider Assumption 4b. The analysis of this case is quite simple, and it is given in Proposition 4.

PROPOSITION 4 : Let Assumption 1-3 and 4b hold. In any PBE path in which the government chooses LP, the low cost entrant enters, then the incumbent chooses s_{M} if entry has not occurred, and s_{D} if it has.

Proof: The PBE is given by:

The high cost entrant chooses "Out" at node 3^{H} , and "Out if and only if $s \leq s_{\mathrm{H}}$" at node 7^{H}.

The low cost entrant chooses "In" at node 3^{L} (and "Out if and only if $s \leq s_{\mathrm{L}}$" at node 7^{L}).

The incumbent chooses $s = s(1) = s_{\mathrm{M}}$ if entry has not occurred, and $s = s(0) = s_{\mathrm{D}}$ if entry has occurred. This is supported by the belief that if entry does not occur, then the entrant is high cost with probability 1, and that the entrant is high cost with probability 0 if entry has occurred.

That the proposed strategy pair is a PBE is obvious. Suppose there is another equilibrium, involving the low cost entrant staying out with some probability. The incumbent will choose a value of s smaller than $s(0)$, and the low cost entrant would always prefer to enter at node 3^{L}. Hence, at any equilibrium the low cost entrant enters at node 3^{L}. As the high cost entrant always stays out, this shows that the proposed equilibrium is the unique PBE. □

Table 1 summarises the expected values of four relevant magnitudes, probability of entry, X-inefficiency, and profit for the two firms, along the equilibrium path described by Propositions 2-4

The comparisons illustrated in Table 1 are quite plausible: along the branch PL, the government does allow the new management team of the incumbent firms to select s strategically, in order to deter entry. Logically, whenever it is profitable for the incumbent, namely whenever $\pi_{\mathrm{E}}(x) < \pi_{\mathrm{M}}(s_{\mathrm{L}})$, entry is successfully deterred, and the incumbent's profit is higher along the PL branch.

This concludes the analysis of the game involving the two competing firms; the next section compares the government's alternatives.

5 The Government's Choice

The government, in choosing between the two possible actions open to it, LP and PL, will simply calculate the expected value of its payoff function and choose the branch which gives a higher value (assuming risk neutrality). A standard formulation for the government payoff function is given by the weighted sum of consumers' surplus, and the incumbent's and the entrant's profit. Denoting by EW the government expected payoff, we can therefore write:

$$\mathrm{EW} = \mathrm{E}(\mathrm{CS}) + \beta_1 \mathrm{E}(\pi) + \beta_2 \mathrm{E}(\rho)$$

where the expectations are taken over the possible values of x and, where appropriate, the players' mixed strategies. The weights β_1 and β_2 reflect the different importance of the three components of welfare [10].

10. There may be reasons why β_1 and β_2 could differ from 1. Distributive reasons, or the foreign nationality of a proportion of the shareholders, on the one hand suggest that, profits need not have the same weight as consumer's surplus; on the other hand, if the public firm is sold at a price reflecting the expected present value of the profit stream, higher profit for the incumbent would result in a higher price paid to the Treasury, which, if public funds have a shadow price greater than 1, reflecting distortionary taxes elsewhere in the economy, implies $\beta_1 > 1$. Or, again, if the government sees competition as positive *per se*, then we would have $\beta_2 > 1$.

TABLE 1

The Solution of the Game Studied.

$s'(x) < 0, \quad \pi_E(x) > \pi_M(s_L)$

	Branch LP		Branch PL
Probability of entry	$1-x$	=	$1-x$
Expected value of s	$xs_M + (1-x)s_D$	>	$s(x)$
Incumbent's expected π	$x\,\pi_M(1) + (1-x)\,\pi_D(s_D, c_L)$	>	$\pi_E(x)$
LoCost Ent's expected π	$\rho(s_D, c_L)$	>	$\rho(s(x), c_L)$

$s'(x) < 0, \quad \pi_E(x) < \pi_M(s_L)$

	Branch LP		Branch PL
Probability of entry	$1-x$	>	0
Expected value of s	$xs_M + (1-x)s_D$	>	s_L
Incumbent's expected π	$x\,\pi_M(1) + (1-x)\,\pi_D(s_D, c_L)$	<	$\pi_M(s_L)$
LoCost Ent's expected π	$\rho(s_D, c_L)$	>	0

$s'(x) > 0, \quad \pi_E(x) > \pi_M(s_L)$

	Branch LP		Branch PL
Probability of entry	$1-x$	=	$1-x$
Expected value of s	$s(x)$	=	$s(x)$
Incumbent's expected π	$\pi_E(x)$	=	$\pi_E(x)$
LoCost Ent's expected π	$\rho(s(x), c_L)$	=	$\rho(s(x), c_L)$

$s'(x) > 0, \quad \pi_E(x) < \pi_M(s_L)$

	Branch LP		Branch PL
Probability of entry	$(1-x)[\alpha + \sigma(1-\alpha)]$	>	0
Expected value of s	$(1-\alpha+\alpha x)[\sigma s(\gamma) + (1-\sigma)s_L]$ $+\alpha(1-x)x_D$	>	s_L
Incumbent's expected π	$[\sigma x + (1-\sigma)\gamma(1-\alpha+\alpha x)\pi_M(s(\gamma))$ $+\alpha(1-x)\pi_D(s_D, c_L)$ $+[(1-\sigma)(1-\gamma)(1-\alpha+\alpha x)$ $+\sigma(1-x)(1-\alpha)]\,\pi(s(\gamma), c)$	<	$\pi_M(s_L)$
LoCost Ent's expected π	$\rho(s_D, c_L)$	>	0

Consumers' surplus, whether in duopoly or monopoly, depends on the value of s; it is natural to assume that a high value of s determines a higher market price and thus lower consumers' surplus. Conversely, for any given value of s, consumers' welfare is higher in duopoly than in monopoly.

Although, in general, which branch the government prefers depends on the relative weight of the terms of the welfare functions, in one important case, we can give a general result.

PROPOSITION 5: Let Assumptions 1-4 hold. Let $\pi_E(x) > \pi_M(s_L)$. Let $s(x)$ be concave. Then LP Pareto dominates PL.

Proof: If Assumption 4 b holds, then the two branches are equivalent. Let Assumption 4 a hold. As we showed in the previous section both firms earn higher profit along the LP branch. From the Table, notice that the probability of entry is the same along the two branches, but if $s(x)$ in concave, then $s(x) \geq xs(1) + (1 - x)s(0)$, that is, slack is higher, in expected terms, along the PL branch. It follows that all three components of welfare are higher in the LP case, strictly so for the firms' profit. □

Concavity of the function s depends in general on the specific relation between the two firms' profit function. However, the case considered in Proposition 5 is likely to be relevant in practice: it assumes that competition reduces slack and that the incumbent monopoly would not wish to deter entry of all types of competitors. In this case we obtain the important conclusion that liberalisation should always precede privatisation.

When, however, $\pi_{\mathrm{E}}(x) < \pi_{\mathrm{M}}(s_{\mathrm{L}})$, that is when, given the chance, the incumbent would always deter entry, it is not possible to obtain such general result: the preferred outcome depends on the relative weights of the components of welfare. In general, the PL branch gives lower slack and lower competition, or in other words higher productive efficiency and lower allocative efficiency: depending on the trade-offs between them either branch may be preferred. Thus, for example, if consumer surplus is more favourably affected by competition than by lower production costs in the incumbent monopolist, branch LP should be chosen. The government may therefore decide that the low degree of competition which follows successful entry deterrence is a price worth paying for the benefit of a substantial cost reduction in the privatised firm. By playing the incumbent's incentive to deter entry to its favour, the government can induce it to become more efficient, if it is socially optimal to do so. But if entry deterrence is a wasteful activity, then the government has an incentive to curb it, and it can do so by allowing entry before any such activity can start.

6 An Example: Linear Cost and Demand

In this section we analyse the general model considered above with a linear specification of the functional forms for demand and cost, with the aim of obtaining explicit solutions for the equilibrium choices of the players. The study of a specific model enables us to obtain specific comparative statics results, and to interpret explicitly the role of exogenous economic changes.

In details, we assume that the incumbent is engaged in the production of a good sold in a market with demand:

$$q = 1 - p$$

and produced with a technology which determines a total cost of:

$$\mathrm{C}(q) = k(s) + sq \quad s \in [\underline{s}, \overline{s}]$$

where:

$$k(s) = \frac{s^2}{2} - \mu s \qquad \mu > 0 \qquad s \in [-1, \mu]$$

Thus k measures the *cost of marginal cost reduction*. It could be given by agency costs, or by the costs needed to restructure the firm after privatisation (redundancy payments, plants closures, and so on); in the spirit of SPENCE's [1977] and DIXIT's [1979 and 1980] early models of strategic entry deterrence it could constitute fixed capacity costs, the firms technology exhibiting a trade off between fixed and marginal costs [11]. Finally, $k(s)$ could be interpreted as R & D investment, which reduces the firm's marginal cost, as in DASGUPTA and STIGLITZ [1979]. $k(s)$ is a decreasing function, $k'(s) < 0$; to generate an interior solution to all the maximisation problems considered, k is assumed to be sufficiently convex: $k''(s) > \frac{8}{9}$. This corresponds to sufficiently decreasing returns of the cost reducing activity, and seems a natural assumption to make. Notice that, as the assumptions of linear demand and cost functions allow a certain amount of normalisation, neither $k(s)$ nor s need to be non-negative. The parameter μ determines the cost of marginal cost reductions, from a starting value of $s = 0$; we also allow an increase in cost to happen: $s > 0$. If μ is close to zero, it is relatively cheap for the incumbent to reduce its marginal cost; as μ increases a given level of marginal cost reduction becomes more expensive to achieve.

The entrant has zero marginal cost, and only incurs a fixed cost of entry, non-recoverable. The latter is not known to the incumbent, and it represent the cost parameter c of the previous Sections:

$$c \in \{c_{\mathrm{L}}, c_{\mathrm{H}}\} \qquad [\mathrm{Prob}(c = c_{\mathrm{H}}) = x] \qquad x \in (0, 1)$$

If entry does not occur, the incumbent chooses quantity $\frac{(1-s)}{2}$. In the event of entry the two firms play a Cournot game. Notice that, the incumbent's uncertainty being relative only to the entrant's entry cost, if entry does occur the Cournot game which follows it is a complete information one, that is it is a traditional Cournot duopoly game, with linear demand and constant marginal costs, given by s and 0. This yields quantity choices of $\frac{(1-2s)}{3}$ and $\frac{(1+s)}{3}$, for the incumbent and the entrant respectively. The entrant's profit is therefore given by:

$$\rho(s, c) = \frac{1}{9}(1+s)^2 - c$$

The other functions defined in Section 4 are given here by:

$$\pi_{\mathrm{M}}(s) = \frac{1}{4}(1-s)^2 - k(s)$$

$$\pi_{\mathrm{D}}(s, c) = \frac{1}{9}(1-2s)^2 - k(s)$$

11. The paper by WARE [1986], explicitly studies the effects of privatisation on capacity choice; he shows that, if the public firm does not expects privatisation to occur, then it might build excess capacity (see BÖS, 1991a, p. 76).

$$s(x) = \frac{\dfrac{x}{2} + \dfrac{4(1-x)}{9} - \mu}{\dfrac{x}{2} + \dfrac{8(1-x)}{9} - 1}$$

Thus Assumption 4 a holds if $\mu < \frac{3}{7}$, that is when the cost of marginal cost reduction does not increase too quickly. Other magnitudes defined in Section 4 are:

$$s(0) = s_{\mathrm{D}} = 9\mu - 4$$

$$s(1) = s_{\mathrm{M}} = 2\mu - 1$$

$$s_{\mathrm{H}} = 3\sqrt{c_{\mathrm{H}}} - 1$$

$$s_{\mathrm{L}} = 3\sqrt{c_{\mathrm{L}}} - 1$$

$$\mathrm{E}\,\pi(x) = \frac{2x^2 + 3x - 2x\mu + 18\mu^2 - 16\mu + 4}{2(7x+2)}$$

$$\pi_{\mathrm{M}}(s_{\mathrm{L}}) = \frac{1}{2} - \frac{9}{4}c_{\mathrm{L}} + 3\mu\sqrt{c_{\mathrm{L}}} - \mu$$

It is relatively simple to obtain analytical conclusions for the probability of entry, the expected profit of the incumbent and the value of marginal cost, s. Proposition 6 illustrates the comparative statics for the probability of entry. The other comparative statics conclusions are straightforward, and have the expected sign. With a slight abuse of notation, let γ be the solution of $\mathrm{E}\,\pi(\gamma) = \pi_{\mathrm{M}}(s_{\mathrm{L}})$.

PROPOSITION 6: Let Assumption 4 a hold; let $x < \gamma$. The probability of entry increases as c_{L} increases and as μ decreases.

Proof: See Appendix.

Thus, in this case, the probability of entry increases as the cost of the low cost entrant increases. This may be seen as counterintuitive: one would expect a lower cost to determine *ceteris paribus*, a higher probability of entry, as this makes the entrant's life easier. However, by allowing entry to occur before the selection of s, the government reverses this intuition: when c_{L} increases, it becomes easier and hence more tempting for the incumbent to deter entry *if it hasn't occurred already*: thus a higher value of c_{L} makes entry more likely, as the low cost entrant anticipates the higher likelihood of entry deterring behaviour, and becomes more likely to enter immediately. Notice that this does not depend in any way on the fact that a lower cost for the competitor might imply a more aggressive competition and hence more incentive for entry deterrence: if entry occurs, the incumbent's profit is independent of c_{L}. By staying out the low cost entrant is trying to induce the incumbent to choose a higher value of s than it would be chosen if entry occurred: it does so by trying to let the incumbent believe that it is high cost, and hence that the attempt to deter entry is a wasteful overinvestment in capacity, as entry would not occur anyway. But, if the probability of high cost is very low in the first place, then this plot is only believed if the entrant stays out with a very low probability: thus $\alpha'(x) < 0$; as x

increases, the possibility that absence of entry denotes a genuine high cost potential entrant becomes more likely, and the low cost entrant can try to pretend to be high cost "more often". Notice that the overall probability of entry by the low cost potential entrant, $\alpha(x)\,\sigma$, is therefore a decreasing function of x: a higher number of high cost entrants reduces the chances of successful entry by the low cost competitor. If however entry deterrence is not profitable $(\pi_{\mathrm{M}}(s_{\mathrm{L}}) < \pi_{\mathrm{E}}(x))$, then entry does not happen in the first stage, as the entrant knows that s_{L} will not be chosen, and that it will surely be able to enter the next time, at more favourable conditions.

Finally, consider the third parameter of the model, μ. According to Proposition 6, an increase in the cost of marginal cost reductions (for example, an increase in R & D costs) implies a reduction in the probability of entry. As entry deterrence becomes more costly, entry becomes less likely. This again is exactly the opposite of what one would expect. It is, however, a natural result when one considers that the incumbent needs to induce the entrant to delay entry, and that, by making entry deterrence more costly, if μ is higher a low cost entrant is more willing to take the gamble of delaying entry and running the risk of being locked out of the market in exchange for a more advantageous, lower level of s.

As far as the government choice is concerned, we have already analysed the case in which entry deterrence is profitable $(\pi_{\mathrm{M}}(s_{\mathrm{L}}) < \pi_{\mathrm{E}}(x))$, obtaining general conclusions in Proposition 5 in the previous section. When $(\pi_{\mathrm{M}}(s_{\mathrm{L}}) > \pi_{\mathrm{E}}(x))$, the type of equilibrium depends on whether $s'(x)$ is greater than or less than zero; in the simpler case in which Assumption 4 a holds, $s'(x) < 0$, and the government's payoff along the two branches is given by:

$$\mathrm{EW}_{\mathrm{LP}} = 4 - 3\,x - 2\,(8 - 7\,x)\,\mu - c_{\mathrm{L}} + \left(18 - \frac{33}{2}\,x\right)\mu^2 + xc_{\mathrm{L}}$$

$$\mathrm{EW}_{\mathrm{PL}} = (1 - \mu) - \frac{9}{8}\,c_{\mathrm{L}} - 3\left(\frac{1}{2} - \mu\right)\sqrt{c_{\mathrm{L}}}$$

With the assumption of equal weights for the three components of social welfare; it is simple to see that either branch can give higher welfare. However, the PL branch is preferred to the LP only for rather extreme values of the three relevant parameters: very high μ and very low x [12]. This is because the incumbent's profit needs to compensate for the loss of consumers' welfare caused by the successful deterrence of entry. This happens when the low cost competitor is very likely (low x) and cost reducing activities relatively expensive.

12. For example, with $c_{\mathrm{L}} = .1$, $\mu = 11/28$ (close to its maximum value of 3/7), x must be lower than 0.01, for PL to be the government preferred choice.

7 Conclusion

In identifying an important, hitherto neglected policy variable, the paper makes a contribution to the theoretical analysis of privatisation, and more generally to the analysis of industrial policy in markets where public and private firms are potential or actual competitors. The conclusions obtained can be summarised schematically by saying that unless entry deterrence is profit maximising for the incumbent, and productive efficiency is considerably more important than product market competition liberalisation should always precede privatisation. The privatised firm should be given a period in which to adjust to the chill winds of competition.

This analysis is relevant not only for the Eastern European economies, where privatisation is under way and may soon involve monopolistic firms, but also in Western European countries, where the possibility of opening up markets traditionally considered suited for public monopoly to competition to anyone who is willing to enter them is considered more and more often.

Proof of Proposition 3: The following lemma describes in detail the PBE of the game. Given the lemma, Proposition 3 is immediate.

LEMMA 7 : Let Assumptions 1-3 and 4 a hold. When the PBE is such that the government chooses branch LP the choices of the other two players are given by[13]:
(i) If $\pi_{\mathrm{E}}(x) > \pi_{\mathrm{M}}(s_{\mathrm{L}})$
– The high cost entrant chooses "Out" at node 3^{H} , and "Out if and only if $s \leq s_{\mathrm{H}}$" at node 7^{H}
– The low cost entrant chooses "Out" at node 3^{L}, and "Out if and only if $s \leq s_{\mathrm{L}}$" at node 7^{L}.
– The incumbent chooses $s = s(x)$ if entry has not occurred, and $s = s_{\mathrm{D}}$ if entry has occurred. This is supported by the belief that if entry does not occur, then the entrant is high cost with probability x, and by any belief if entry has occurred.
(ii) If $\pi_{\mathrm{E}}(x) < \pi_{\mathrm{M}}(s_{\mathrm{L}})$
– The high cost entrant chooses "Out" at node 3^{H}, and "Out if and only if $s \leq s_{\mathrm{H}}$" at node 7^{H} (as in (i)).
– The low cost entrant chooses "Out" with probability $(1-\alpha)$ at node 3^{L}, and "Out if and only if $s \leq s_{\mathrm{L}}$" at node 7^{L}.
– The incumbent chooses $s(\gamma)$ with probability σ, s_{L} with probability $(1-\sigma)$ if entry has not occurred, chooses s_{D} if entry has occurred.
– The incumbent's belief which supports this equilibrium are that if entry occurs then the entrant is low cost with probability 1, if entry doesn't occur then entry is low cost with probability $\dfrac{(1-\alpha)(1-x)}{x+(1-\alpha)(1-x)} = 1-\gamma$

Proof: Part (i) first. Clearly this is the incumbent's optimal strategy, as the observation of no entry does not indicate anything about the nature of the entrant, and $s(x)$ is the optimal choice when the entrant is high cost with probability x: since $\pi_{\mathrm{E}}(x) > \pi_{\mathrm{M}}(s_{\mathrm{L}})$ deterring entry, although feasible is not optimal. A high cost entrant could only make a loss if it chose a different strategy. As far as a low cost entrant is concerned, if it deviates at node 3^{L} and enters, then it would make less profit, as $s_{\mathrm{D}} < s(x)$, and ρ is increasing in s.

A brief reflection shows that there are no equilibria where the low cost entrant enters at node 3^{L} with any positive probability. Consider now part (ii). We first show that there cannot be a pure strategy equilibrium. Suppose, by contradiction, that there is a pure strategy equilibrium; let the low cost entrant enter at node 3^{H} . Then the incumbent must choose s_{D} (it is not possible that the high cost entrant wants to enter). But, given that the high cost entrant will not enter, at node 7^{H} , the incumbent's optimal choice at

13. There might be other PBE's where the incumbent's believes that the high cost entrant is more likely to enter than the low cost one. We ignored this possibility.

information set 6 is the selection of s_{M}. Thus if a pure strategy equilibrium exists where the low cost entrant enters at node 3^{L} , then it must be the case that the incumbent responds to lack of entry with a selection of s_{M}. However, as $s_{\mathrm{M}} = s(1) > s(0) = s_{\mathrm{D}}$, the low cost entrant would be better off by staying out. Suppose therefore that, at the pure strategy equilibrium, the low cost entrant chooses "Out" at node 3^{L}. As the high cost entrant also chooses "Out" at node 3^{H} , the incumbent will, at the equilibrium choose $s(x)$. If entry occurs, however, the incumbent will choose s_{D}, which is higher than $s(x)$, thus the low cost entrant (unlike the high cost one) would be better off by entering at node 3^{L}.

There remains to be shown that the strategy vector proposed in the statement is indeed an equilibrium. We first establish that at any mixed strategy equilibrium the following must hold:

(1) $$\gamma = \frac{x}{x + (1-\alpha)(1-x)}$$

(2) $$\rho(s(\gamma), c_{\mathrm{L}})\,\sigma = \rho(s_{\mathrm{D}}, c_{\mathrm{L}})$$

(3) $$\pi_{\mathrm{E}}(\gamma) = \pi_{\mathrm{M}}(s_{\mathrm{L}})$$

Clearly, given the incumbent's strategy, the high cost entrant can't do any better. Consider the low cost entrant. The choice at node 7^{L} is clearly optimal. Consider node 3^{L}. As it randomises between "In" and "Out", it must be indifferent between these two alternatives: if it enters, the incumbent will respond with s_{D}, which implies a payoff of $\rho(s_{\mathrm{D}}, c_{\mathrm{L}})$, if it stays out, the payoff is 0 with probability σ (because the incumbent chooses s_{L} with this probability) and $\rho(s(\gamma), c_{\mathrm{L}})$ with probability $(1-\sigma)$. Thus the low cost entrant is indifferent between "In" and "Out" if and only if (2) holds. Consider the incumbent. If entry occurs, then the entrant must be low cost, thus s_{D} is the best thing to do. If entry doesn't occur, and information set 6 is reached, the strategies chosen by the two types of players imply that the probability of facing a high cost competitor is $\dfrac{x}{x + (1-\alpha)(1-x)} = \gamma$, which implies a choice of s given by $s(\gamma)$. Finally, notice that (3) must hold, because otherwise the incumbent would not want to randomise between $s(\gamma)$ and s_{L}, which it must do, with weights σ and $(1-\sigma)$, if the low cost entrant is to be indifferent between "In" and "Out".

Finally, let us calculate the specific values for α, γ, and σ. From (3):
$$\frac{d\pi_{\mathrm{E}}(x)}{dx} = \frac{d\pi_{\mathrm{M}}(s_{\mathrm{L}})}{dx} = 0$$
As $\pi_{\mathrm{M}}(s_{\mathrm{L}})$ is independent of x. The LHS of the above is $\pi_{\mathrm{E}}(x)$ *total* derivative with respect to x, given by:
$$\frac{d\pi_{\mathrm{E}}(x)}{dx} = \pi'_{\mathrm{E}}(\gamma)\frac{d\gamma}{dx}$$
and as $\pi'_{\mathrm{E}}(\gamma) > 0$, Case 1 being considered, it follows that $\dfrac{d\gamma}{dx} = 0$. That is, γ is constant over $(0, \hat{x}]$. α and σ are now easily calculated from (1) and (2) respectively.

Finally, to show that α, σ and γ are uniquely determined, notice that γ can be found first by solving $\pi_{\mathrm{E}}(x) = \pi_{\mathrm{M}}(s_{\mathrm{L}})$ in x. This has a unique solution because $\pi'_{\mathrm{E}}(x) > 0$ and $\pi_{\mathrm{M}}(s_{\mathrm{L}})$ does not depend on x. Substitution yield immediately α and σ. □

Proof of Proposition 6: From the proof of Proposition 3, when $x \in (0, \gamma]$, the probability of entry is given by $p(x) = [\gamma - x + \sigma x (1 - \gamma)]/\gamma$. Differentiating with respect to c_{L}, and simplifying:

$$\frac{dp(x)}{dc_{\mathrm{L}}} = \frac{x}{\gamma^2} \frac{d\gamma}{dc_{\mathrm{L}}} (1 - \sigma)$$

Thus the sign of $dp(x)/dc_{\mathrm{L}}$ is the same as the sign of $d\gamma/dc_{\mathrm{L}}$. The latter can be obtained by totally differentiating (3), in the proof of Proposition 3 above:

$$\pi'_{\mathrm{E}}(\gamma)\, d\gamma = \frac{d\pi_{\mathrm{M}}(s_{\mathrm{L}})}{ds_{\mathrm{L}}} \frac{ds_{\mathrm{L}}}{dc_{\mathrm{L}}} dc_{\mathrm{L}}$$

Thus:

$$\frac{d\gamma}{dc_{\mathrm{L}}} = \frac{\dfrac{d\pi_{\mathrm{M}}(s_{\mathrm{L}})}{ds_{\mathrm{L}}} \dfrac{ds_{\mathrm{L}}}{dc_{\mathrm{L}}}}{\pi'_{\mathrm{E}}(\gamma)}$$

All three factors on the RHS are positive. The same procedure can be used for μ.

$$\pi'_{\mathrm{E}}(\gamma)\, d\gamma + \frac{d\pi_{\mathrm{E}}(\gamma)}{d\mu} d\mu = \frac{d\pi_{\mathrm{M}}(s_{\mathrm{L}})}{d\mu} d\mu$$

where:

$$\frac{d\pi_{\mathrm{E}}(\gamma)}{d\mu} = s_{\mathrm{L}} \qquad \frac{d\pi_{\mathrm{M}}(s_{\mathrm{L}})}{d\mu} = s(x)$$

Thus:

$$\frac{d\gamma}{dc_{\mathrm{L}}} = \frac{s_{\mathrm{L}} - s(x)}{\pi'_{\mathrm{E}}(\gamma)} < 0$$

Which establishes the Proposition. □

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