Public Utilities: Privatization without Regulation

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Abstract In the last decades, transitional countries of Central and Eastern Europe have engaged in strong privatization programs of public utilities. However, a large part of them did not meet legal and economic conditions needed for a market economy to take place. In this paper, we study how a firm producing a public utility and moving from a public ownership to privatization and thus adopting a profit-maximizing criterion defines its production plans, when an appropriate regulatory environment is still lacking.

Keywords Privatization, public utilities, dynamic programming
JEL classification C61, D21, L11, L33

1. Introduction

This paper studies the problem of capacity investment in a public utility when a state owned firm producing it moves from public ownership to privatization, and when an appropriate regulatory environment is still lacking.

In the last decades, transitional countries of Central and Eastern Europe have engaged in strong privatization programs of public utilities and, more generally, in a dramatic change of political and institutional setting. As Hirschhausen and Opitz (2001, p. 8) aptly put: "An entire sub-continent, including one former superpower, had decided to abandon the state planning system and to replace it by something else, tentatively a market economy. The transformation required the introduction of law as a stable system of legally and judicially protected entitlements, in contrast to temporary and volatile governmental commands; moreover, it needed the institutionalization of an economic constitution, providing incentives for individuals to set up independent, profit-oriented enterprises in a monetized environment."

At the time when this privatization started, public utility sectors were faced with significant qualitative problems. Security standards, environmental pollution constraint emissions, etc. were not satisfied. Further, due to severe budget deficits, not even investments for renewal or incrementing capacity were undertaken. These privatization programs were intended as a reaction to the difficulty of state-owned entities to meet the growing needs of customers and to catch the upgrading chances made available by technological advancements. Indeed, at that time, the idea that private ownership had

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efficiency advantages over public ownership and could guarantee a wider access to basic services was commonly accepted. However, quite often these programs were undertaken when the whole set of conditions at the basis of a market economy (competition and/or regulation) were not yet filled up. As a result, a growing public dissatisfaction with the effects of privatization has emerged.

In this paper, by looking at the components of the optimization problem faced by a firm producing a utility, under different types of ownership structures (public ownership versus privatization), we try to disentangle the effects which are induced by a privatization reform which is undertaken outside any regulation constraint. To this aim, we study hereafter the optimal production plans over time when the possibility of price manipulation of demand through price is opened to the firm under analysis. This possibility, which was not accessible to the originally state owned company producing a public utility, is at the basis of the profit-maximization behavior for a private monopolist operating in a privatized sector. Consequently, this study is necessary whenever we wish to compare from a theoretical view point firm's behaviour under state versus private ownership structures.

Quite surprisingly, scarce attention has been paid by the theoretical literature to this topic. Of course, a large body of microeconomic contributions addresses the question of why ownership matters (Vickers and Yarrow 1988; Stiglitz 1993; Laffont and Tirole 1993; Willig 2000; Tirole 1994; World Bank 1995; Shleifer and Vishny 1996; Hart, Shleifer and Vishny 1997). While clarifying that efficiency losses of public ownership are due to agency problems and political interference in the management of firms, none of these studies specifically takes into account the characteristics of public utilities. Not even this literature is concerned in any detail, if at all, with the timing of reforms of public utilities privatization, regulation and competition, and its role in producing the intended results.

Here, after discussing some stylized facts and the theoretical framework in which the analysis is conceived in Section 2, we move to present the model in Section 3. Then, we proceed considering the optimal policy as it is determined by a privatized utility's profit-maximizing firm in Section 4. In Section 5, we compare the capacity expansion of the privatized firm with the one arising if this firm would be managed by the government and given this we develop some welfare considerations. We summarize our findings in the conclusion and propose some paths for further research. Details on computations are in the Appendix.

2. A model for privatized utilities

2.1 Some stylized facts

Privatization effects in transitional economies are quite complex and country-specific. While the most part of literature concerned with privatization of medium and large size firms shows that privatization positively affect firms' performance (Claessens et al. 1997; Frydman et al. 1999; Beven, Estrin and Schaffer 1999; Nellis 1999), the debate over privatization in utility sectors is still open. The transformation in these sectors has been very slow and quite often its pattern has been altered or further slack-

ened by interest group pressures (Izaguirre 1998; Slay and Capelik 1998). Further, the transition economies involved in privatization did not share the same starting economic and political conditions (i.a. Nellis 2003; Sheshinski and López-Calva 2003; Zhang et al. 2005). As a consequence, their reform paths cannot be easily described within a unified framework.

Nevertheless, several features, in particular a general trend towards increasing prices, seem to be quite diffused, and changes in profitability in the competitive sector are generally larger than in the non-competitive sector (Hall 1998; Ran Kim and Horn 1999). In the process design, profit-maximizing entities would have been responsible to provide high-quality services, to improve the infrastructure networks and renewal the existing production capacity, even at higher prices (Hare et al. 1999). Indeed, proponents of privatization were sure that a private involvement in utility services, while changing the price structure, would have led to stronger investment and thus to greater capacity and wider coverage. However, the empirical evidence on the reform process gathered so far does not provide unanimously accepted results on the production capacity expansion and not even on its renewal coupled with increasing prices. Although investment data are notoriously difficult to get, the evidence so far points to a very modest investment size in the maintenance and expansion of utility networks as a general rule (Gassner et al. 2008).

Ran Kim and Horn (1999, p. 3–4) summarize: "The recent public finance crises in many countries, combined with huge investment requirements, have made private-sector participation necessary. Furthermore, the poor performance of most public enterprises and their inability to offer a quality service and meet demand have encouraged many governments to turn to the private sector for the provision of infrastructure services, leading to the need for reforms. However, large companies in developing and transition economies that were privatized were often sold as monopolies or near-monopolies. Instead of creating greater competition in the concerned sectors before privatization, all that has been accomplished is substitution of a private monopoly for a public one. … Moreover, much of the so-called 'privatization' has really been the transfer of ownership rights from the federal to regional governments. The problem is that such transfers have introduced additional elements of confusion into corporate governance, and created conflicting incentives for federal and regional agencies that function both as owners and as regulators."

2.2 The model in the literature

With the aim to disentangle the rationale at the basis of production plans as they are defined by a privatized firm producing a public utility, we develop hereafter a model which is close in spirit to the so called *plant size problem*. This problem typically arises in industries with 'natural monopoly' characteristics where it is possible to compensate the cost of committing substantial resources for further capacity by the advantage of investing in advance to demand increases, in order to benefit from large economies of scale. (Typical examples are given by energy industries, communication networks, and water resources systems.)

Since the sixties, a considerable amount of work on the plant-size problem, formu-

lated originally by Chenery (1952) and Manne (1961, 1967), has been developed, and several variants of the capacity expansion model were used in the operations research field with several applications to public services (Gabszewicz and Vial 1972; Nickell 1977; Freidenfelds 1981; Chaouch and Buzacott 1994; and Ryan 2004). Also, we refer the interested reader to Luss (1982) and Nam and Logendran (1992) for a survey of the capacity expansion problem in operational research and its main applications.

The deterministic model by Manne (1961) is concerned with the optimal degree of excess capacity to be built into a new facility when an exogenous persistent growth in demand for capacity is anticipated. In a simplified infinite horizon model, he analyses the problem faced by a public utility when it is required to meet a linearly growing demand at a minimum cost and no undercapacity is admitted. Capacity increments for meeting demand are performed at a diminishing marginal costs (namely, economies of scale arise) and the cost structure is assumed to last forever (no technological progress). Typically, this firm has to define its optimal policy in terms of expenditure streams, taking into account that if it builds a single large plant, then it can take advantage of economies of scale in construction. Alternatively, if it decides to build several smaller plants at different points of time, there is advantage of delaying a portion of the total investment and investing the corresponding funds in the capital market.

Manne (1961) finds that the optimal investment policy is *constant-cycle*, namely, it displays a stationarity property: successive investments are all of the same size and undertaken at equally spaced points of time. Although this research contribution identifies the main features of state-owned utility industries when these are facing a capacity expansion policy, they are exclusively restricted to the investment problem as it is faced by *public utilities*. Close in spirit to Manne (1961), we depart from his approach in two main respects.

First of all, we try to extend the analysis to a *demand function* which first linearly increases and then decreases over time. From a theoretical viewpoint, assuming that demand is a function of price and that this function fluctuates over time enriches the standard model as formulated by Manne (1961, 1967) in two directions. First, demand is no longer exogenously increasing over time, independently of price, but it depends explicitly on the price policy selected by the firm over time. Furthermore it also allows to consider the phenomenon of cycle, namely phases of boom and recession alternating over time, which is particularly relevant for the time being.

Moreover, we substitute to the traditional plant size problem a new version, in which *state-owned utilities are changed into profit-maximising entities*. As such, a private firm is allowed to use specific instruments which are not available to a public firm. Specifically, a privately owned firm can adopt, in parallel with its *investment* policy, a *price* policy in order to dampen (stimulate) demand over time when demand level results to be higher (lower) than installed capacity. While recognizing that utility services belong to the set of basic services and, as a such, their demand does not react so promptly to price changes, yet assuming a price sensitive demand allows to take into account how the investment policy is implemented by a profit-maximizing utility in a market economy.

Our aim is to study the following problem: *What is the optimal price policy, and*

the ensuing optimal size of investment, that a privatized utility selects through time if there are not regulatory constraints? How the resulting sequence of successive investments through time compares with the optimal sequence under state ownership? Which lessons can be drawn in terms of welfare?

Of course, the answer to these questions would be simple if the price selected by the monopolist would be kept constant over time. Indeed, in this case, the investment size would be fully determined by the length of the time-interval during which the capacity of the last investment is sufficient to face the demand level at that price. Yet, the problem is no longer as simple if we consider at the same time the possibility opened to the monopolist to manipulate the price over time. In that case, the monopolist can either change demand by increasing or decreasing the price trajectory or, on the contrary, benefit from full instantaneous monopoly profit by adapting simply the monopoly price to the demand pattern.

We prove that when a privatized utility is allowed to combine price and investment policies, it undertakes an investment size which is lower than the one recommended by a public monopoly. More precisely, we show that if the investment cost may not be recouped by installing further capacity, then at the optimal solution the privatized utility quotes a price dampening instantaneous demand at the level of the available capacity and no investment is undertaken. Alternatively, if the investment cost may well be recouped by further installation, then a positive investment is realized. Yet, even in this scenario, the profit maximizing policy consists in dampening the instantaneous demand for some times and installing a capacity which is lower than the one which would be installed with no price manipulation under public ownership. Finally, we show that such a type of policy displays a stationarity property, namely repeats identically from cycle to cycle.

3. The basic framework

Let us consider a monopolist facing a demand function $D(t, p(t))$, first increasing and then decreasing over time which is defined as follows:

$$D(t, p(t)) = \begin{cases} A + t - t_i - p & \text{for} \quad t \in [t_i, t_i'] \\ A + t_{i+1} - t - p & \text{for} \quad t \in [t_i', t_{i+1}], \end{cases}$$

where t denotes continuous time, p instantaneous price and t_i' some point in the interval of time $[t_i, t_{i+1}]$. For sake of simplicity, we assume that the monopolist defines the investment size x_{t_i} at fixed equally spaced points of time t_i, $i = 0, 1, 2, \ldots, +\infty$. Thus, in the interval $[t_i, t_{i+1}]$, the production capacity remains constant. So, at each t_i, the firm decides the capacity x_{t_i} to be installed and sets the price $p(t)$ for $t \in [t_i, t_{i+1}]$. Then, at time t_{i+1}, a new investment is undertaken and a new price schedule for this period is defined, and so on.[1]

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[1] These points can be interpreted on the basis of lifetime of the existing capacity. In other words, one can imagine these time points as being the interval of time after which the existing equipment ceases to be as good as before and thus investment can be reduced to a replacement or renewal decision. This is in line with the estimates of investment for basic services showing that a large part of expenditure relates to the maintenance and renewal of the existing production capacity.

At each price, in the period of time $[t_i, t']$, $t' = \frac{t_{i+1}+t_i}{2}$, demand expands through time as the intercept of the demand function grows proportionally to t, and then in the period $[t'_i, t_{i+1}]$ it decreases through time. It is interesting to notice that if we fix $t' = t_{i+1}$, the problem can be reduced to a traditional capacity expansion problem where a monopolist is required to define an optimal policy in terms of price regimes and investment size to meet a demand function which always grows linearly over time. We label the point of time t'_i as the *turning point*. Up to a change of units we set $t_i = i$, and thus $t' = \frac{1}{2} + i$. The interval $[i, i+1]$ between two dates at which a new investment is decided is called *cycle*, and the periods $[i, t']$ and $[t_i, i+1]$ of increasing demand and decreasing demand respectively, *phase*s of the cycle.

At each instant of time t, the capacity of the firm is bounded by the existing amount of equipment $x(t)$. While the existing capacity may exceed the current demand level $D(t, p(t))$, no under-capacity is admitted, so that $D(t, p(t)) \leq x(t)$, namely the basic service provided should always meet the existing demand. So, whatever the price policy which is adopted at each instant, the monopolist must invest in order to meet the resulting demand. The investment cost for new capacity x_i at the beginning of each cycle i is defined as

$$f(x) = ax_i.$$

This cost structure is assumed to hold forever. The time horizon is unbounded.

In the usual plant size problem, given an exogenous pattern of demand, the sequence of capacity investments would be automatically determined by the investment time points. Yet, when the monopolist can manipulate the price through time, this correspondence ceases to operate since it depends on the price policy selected. A *price policy* is a function $p(t)$ which specifies the price announced by the monopolist at each instant t. Given any price policy, we may associate to it a sequence of investment for new capacity undertaken at the beginning of each cycle $(x_0, x_1, \ldots, x_i, \ldots) = \mathbf{x}(p(t))$.

Formally the problem is to find $p(t)$ and, accordingly $\mathbf{x}(p(t)) = (x_0, x_1, \ldots, x_i, \ldots)$, so that the objective function $V(\mathbf{x}, p(t))$ given as

$$V(\mathbf{x}, p(t)) = \int_0^\infty p(t) D(t, p(t)) e^{-rt} dt - \sum_{i=0}^\infty ax_i e^{-ri}$$

is maximized, subject to the following capacity constraint

$$D(t, p(t)) \leq x(t),$$

where r denote the interest rate in the capital market, which is assumed to be constant over time. A policy is said to be *optimal* when it consists in an optimal price pattern through time and, as a consequence, an optimal sequence of investment in order to satisfy demand at each instant of time.

4. The optimal policy

First of all, notice that the optimal policy consists in defining an optimal investment sequence *and* an optimal price regime.

Of course, as far as the optimal investment sequence, it is defined in such a way that the marginal revenue stemming from a non-negative investment is equal to the marginal cost of installing this capacity.

As far as the optimal price regime, it is worth stressing that the cost function does not depend on the choice of $p(t)$. Then, a sufficient condition for the optimality of $p(t)$ is that it maximizes the integrand $p(t)D(t,p(t))$ at any point t, given the capacity constraint. Notice that, within any cycle $[i,i+1]$, the objective function $V(\mathbf{t},p(t))$ achieves its maximum for $p(t)$ given by

$$p(t) = \begin{cases} \max\left(\frac{A+t-i}{2}, A+t-i-x_i\right) & \text{for} \quad t \in [i,t_i'] \\ \max\left(A+i+1-t-x_i, \frac{A+i+1-t}{2}\right) & \text{for} \quad t \in [t_i',i+1] \end{cases}$$

for $i = [t]$ the integer part of t. This follows from the maximization problem

$$\max_t \ p(t)D(t,p(t))$$

$$\text{s.t. } D(t,p(t)) \leq x_i, i = [t].$$

Whatever the selected sequence of investment size, in each phase two price regimes may arise, depending on the productive capacity compared with the demand level.

Assume that during the phase of increasing demand, at some date t, where $i \leq t < t_i'$, the capacity constraint is not binding, namely, the demand level at that date t is lower than the current capacity or $D(t,p(t)) < x_i$. Then, at the optimal policy, $p(t)$ is set equal to the maximizing price regime $p_B^M(t) = (A+t-i)/2$, as the demand does not need to be dampened. Yet, the demand expands over time while the installed capacity remains fixed during the cycle i.

When the capacity constraint turns out to be binding, namely the demand level is just satisfied by the current capacity or $D(t,p(t)) = x_i$, then the firm chooses to contract the demand $D(t,p(t))$ within the limits imposed by the existing capacity by quoting the price regime $p_B^C(t) = A+t-i-x_i$. At the time t_i' when the phase of decreasing demand takes place, in spite of the decreasing pattern of demand function, the installed capacity is not yet sufficient to meet demand. So, the price regime $p_R^C(t) = A+(i+1)-t-x_i$ dampening instantaneous demand is used for some instant of time. Then, when the capacity is sufficient to meet the level of demand corresponding to the instantaneous monopoly price, this maximizing regime $p_R^M(t) = (A+i+1-t)/2$ is quoted. The two price patterns $p_B^M(t)$ and $p_B^C(t)$ quoted during the increasing demand phase, and $p_R^M(t)$ and $p_R^C(t)$ quoted during the decreasing demand phase are called *monopoly price regime* and *constrained price regime*, respectively. Of course, if the capacity is such that it satisfies the demand level even at time t_i', then the constrained regimes never apply.

Further, we denote by t_i^* (or t_i^{**}) the point of time when the monopoly price regime $p_B^M(t)$ becomes equal to the constrained price regime $p_B^C(t)$ during the increasing demand (or the constrained price regime $p_R^C(t)$ becomes equal to the monopoly price regime $p_R^M(t)$ during the decreasing demand) and we label this point as the *switching point* t_i^* (or *switching point* t_i^{**}). It is easy to verify that $t_i^* = 2x_i + i - A$ (or

$t_i^{**} = A + i + 1 - 2x_i$). Notice also that the value of the switching point t_i^{**} during the decreasing demand phase depends on the switching time t_i^*. Indeed, from easy computations we get:

$$t_i^{**} = 2i + 1 - t_i^* \tag{1}$$

It derives from (1) that the later the switching time t_i^*—namely the longer the time when the monopolist quotes the monopoly price regime $p_B^M(t)$ in the first phase—the earlier the switching time t_i^{**}—namely the shorter the period of time when the demand function is dampened by the constrained price regime $p_R^C(t)$ during the decreasing demand phase.

4.1 The optimal investment sequence

We start to identify here the optimal sequence of investments, then we move to define the optimal price regime in order to fully characterize the optimal policy.

First of all, notice that for an initial investment to be non-negative at the optimal solution in the cycle $[0,1]$, the marginal revenue stemming from a non-negative investment must be equal to the marginal cost of installing this capacity, namely:

$$\int_0^1 (A + t - i)e^{-rt}dt = a(1 - e^{-r})$$

or

$$\frac{1}{r^2}\left(1 + rA - \frac{r}{e^r - 1}\right) = a$$

Then, when the gain of installing a non-negative capacity is higher than the cost of investing

$$\frac{1}{r^2}\left(1 + rA - \frac{r}{e^r - 1}\right) > a,$$

then both the regimes can apply; whereas when the cost of investing is high with respect to the gain of installing a non-negative capacity

$$\frac{1}{r^2}\left(1 + rA - \frac{r}{e^r - 1}\right) \leq a,$$

the monopolist refrains from investing, namely $x^* = 0$.

Let us briefly summarize the above finding as follows:

Proposition 1. *When $\frac{1}{r^2}\left[1 + rA - \frac{r}{e^r - 1}\right] > a$ holds, the optimal investment policy consists in a positive investment, when the reverse holds, namely $\frac{1}{r^2}\left[1 + rA - \frac{r}{e^r - 1}\right] < a$, it consists in zero investment.*

4.2 The optimal price regime

Let us define now the optimal price regime which completes the global optimal policy as it is defined by this profit-maximizing firm. We first remark here that three price scenarios may arise within a cycle.

In Scenario A (see Figure 1), the switching point t_i^* is exactly equal to t_i', and the optimal price pattern coincides with the monopoly price regime $p_B^M(t)$ during the whole phase $[i, t_i']$. Then, as the existing capacity suffices to meet this peak at time t_i', during the decreasing demand phase the demand function is not dampened and the optimal price pattern coincides with the monopoly price regime $p_R^M(t)$ during the whole phase $[t_i', i+1]$.
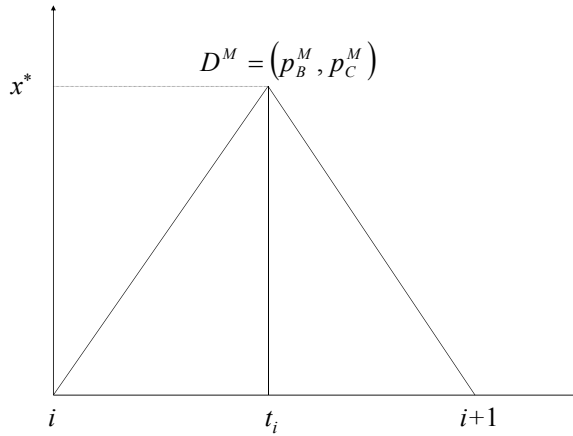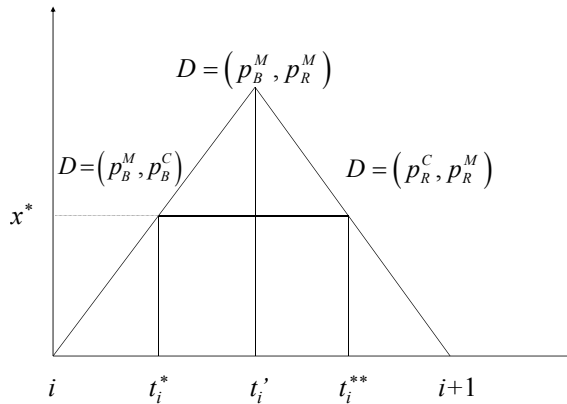

Figure 1. Demand function in Scenario A

Figure 2. Demand function in Scenario B

In Scenario B (see Figure 2), the switching point t_i^* lies between i and t_i'; then, the firm quotes the monopoly price regime between i and t_i^* when the installed capacity suffices to meet the demand level corresponding to the instantaneous monopoly price, whereas it quotes the constrained regime between t_i^* and t_i' in order to dampen the demand at the level of the existing capacity. Starting from t_i' the demand function decreases over time and, accordingly, the firm quotes the price regime $p_R^C(t) = A + i + 1 - t - x_i$ so as to contract the demand $D(t, p(t))$ within the limits imposed by the existing capacity. When the capacity constraint ceases to be binding, namely $D(t, p(t)) < x_i$, then firm switches to the monopoly price regime $p_R^M(t) = A + i + 1 - t/2$.

In Scenario C (see Figure 3), the switching point t_i^* lies before i; then the monopolist is forced to use the constrained price regime during the whole cycle in order to meet the capacity constraint.

$$D^C = \left(p_B^C, p_R^C \right)$$
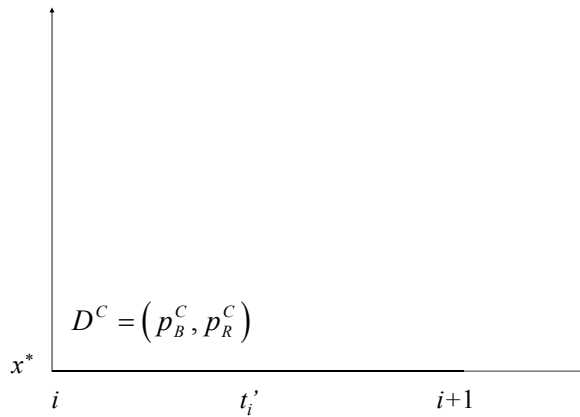
x^*

i t_i' $i+1$

Figure 3. Demand function in Scenario C

We prove that quoting the monopoly regime for the whole cycle is never profit-maximizing, namely that the switching point t_i^* can never be *exactly equal* to the point t_i', excluding thereby Scenario A.

Proposition 2. *During any phase $[i, t_i'[$, it is profit-maximizing to quote—either for a part or for the whole phase—a price higher than a monopoly tariff, in such a way to dampen the demand at the level corresponding to the available productive capacity.*

Proof. See Appendix.

We deduce from the above that only the two remaining scenarios can be observed at an optimal price policy. The optimal price pattern within the cycle must either consist of alternating in the phase of increasing demand the monopoly regime and after the switching point t_i^*, the constrained regime, and in the phase of decreasing demand the constrained regime and after the switching point t_i^{**}, the monopoly regime; or quoting always the instantaneous constrained price.

The first alternative corresponds to a situation where the capacity installed at time i is large enough to serve the monopoly demand for some period during the increasing demand, so that the switching point t_i^* is interior to this phase.

The second one holds when the investment at time i is so low that it is even not sufficient to meet the monopoly demand $D\left(i, p^M(i)\right)$ at that time.

Taking into account that the global of optimal policy depends both on the investment policy, and on the price policy since the investment must meet demand and demand depends on price policy, we can easily conclude that when the optimal capacity x_i^* installed at time i is positive, then firm alternates both the price regimes; otherwise, if no investment is undertaken, namely $x^* = 0$, then the constrained regime only arises.

Combining the results in Proposition 1 and 2, we can state the following:

Proposition 3. *When $\frac{1}{r^2}\left(1 + rA - \frac{r}{e^r - 1}\right) > a$ holds, the optimal policy consists in a positive investment and involves both the monopoly and constrained price regimes. When the reverse holds, namely $\frac{1}{r^2}\left(1 + rA - \frac{r}{e^r - 1}\right) < a$, the optimal policy consists in zero investment and the constrained price regime only applies.*

Notice also, that such type of policy repeats identically from a cycle to another, namely:

Proposition 4. *The optimal policy is stationary through all cycles.*

Proof. See Appendix.

5. Some welfare considerations

Now, let us briefly consider how the above problem would have been faced by a public utility in order to get some insights on the effects of a change in ownership on investment and prices.

To this aim, without loss of generality, consider the cycle $[i, i+1]$. First notice that if no price manipulation is consented, as no undercapacity is admitted, then the monopolist invests a time i in such a way as to meet a demand whose pattern is fully determined by a price corresponding to the perfect competitive equilibrium price. Indeed, in the case of public utilities with government operating the service, quite often a price equal to marginal cost and a lump-sum subsidy to keep the firm operating have been observed (see Ran Kim and Horn 1999 for details on this).

With a constant returns technology, this price is equal to the marginal investment cost a. Accordingly, the value of the demand function at price $p = a$ and at each instant t in the interval writes as:

$$D(t, p(t)) = \begin{cases} A + t - t_i - a & \text{for} \quad t \in [t_i, t_i'] \\ A + t_{i+1} - t - a & \text{for} \quad t \in [t_i', t_{i+1}] \end{cases}$$

Of course, *ceteris paribus*, at each instant of time, the higher any constant price applied during the cycle, the lower the corresponding demand level and thus the lower the peak that demand function reaches at time t_i'. That is to say, the closer the equilibrium price to a monopoly regime, the lower the demand level at any instant of time within the cycle, and the lower its peak at time t_i'. First, notice that the optimal increment

of capacity chosen by the privatized monopolist manipulating demand through price never exceeds the one resulting from the instantaneous monopoly price, as proved in Proposition 1. Furthermore, and, *a fortiori*, it cannot exceeds the increment of capacity needed to meet demand corresponding to the constant competitive price a. For example, in the cycle $[0,1]$, $t' = 1/2$, the investment x for meeting a demand function corresponding to the price a is equal to $A + 1/2 - a$; whereas the investment undertaken by a privatized utility is equal to $2A + 1/4$. In other words:

Proposition 5. *The optimal increment of capacity chosen by a privatized utility is necessarily smaller than the increment of capacity selected by a state-owned utility facing the level of demand corresponding to the competitive price.*

6. Conclusion

Our main finding, as just stated in the above proposition, is of course derived within a specific framework, where we only consider how a change in ownership affects the economic behaviour of a firm. Thus, we do not take into account here that the privatization plans are sometimes coupled to a weak legal environment and often biased by corruption in management (see for details Megginson and Netter 2001). Not even, we consider whether pace and methods of privatization can affect the rationale of planning investment adopted by the privatized entities and the ability of these entities to take advantage of technological progress. Moreover, we do not allow for a different behavior corresponding to different types of new private owners, either foreign or domestic.

Still, in spite of all these drawbacks, the framework as it is now allows to illustrate risks deriving from privatizing utilities when the institutional environment is not suited for a market economy. Indeed, our major conclusion implies that, without the intervention of public authorities, privatization of a state owned firm must necessarily lead to a contraction in the path of production investment as settled by a public utility. Thus, the above comparison can be viewed as being a means for analysing welfare effects induced by privatization reform when initiated in a lacking regulatory framework. It is worth noting that as our model considers the economic behaviour of a privatized utility as it develops over time, welfare losses are likely to emerge in each cycle, if no change in the institutional environment takes place.

Finally, our findings are in line with the view introduced by Stiglitz (1999) and then largely shared (Kennedy 1999; Nellis 1999; Wood 2004; Lieberman and Kopf 2007) that a firm's economic performance during transition from a planned-economy to a market structure is deeply affected not only by its public or private ownership but also, and even more, by the regulatory structure and economic environment where it operates. Ran Kim and Horn (1999, p. 6) when describing Stiglitz' work (1999) write: "By looking at the example of China vis-à-vis the former socialist economies, he [Stiglitz] concludes that effective competition and regulatory policies are important, rather than privatization itself. China had shown that an economy might achieve more effective growth by focusing first on competition, leaving privatization until later. In contrast, competition remains thwarted in many of the former socialist economies that pursued privatization first, demonstrating that without effective competition and reg-

ulatory policies, private rent-seeking can be every bit as powerful, and perhaps even more distortionary, than public rent-seeking. By looking at the example of China vis-à-vis the former socialist economies, concludes that effective competition and regulatory policies are important, rather than privatization itself."

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Appendix

Proof of Proposition 2.

First, notice that the above proposition is equivalent to say that during any phase $[i, t_i']$ the switching point t_i^* belongs either to the interior of the cycle, or it is strictly smaller than i. Assume that, for some i, x_i' would be the optimal installed capacity at date i and that $x_i' = D^M(t_i')$, where $D^M(t_i') = D(p_B^M(t_i'), t_i')$. Then, the monopolist can quote the monopoly price regimes $p_B^M(t)$ and $p_R^M(t)$ during the whole phases of increasing demand and decreasing demand, respectively. The present value of the discounted flow of revenues R_i during the cycle $[i, i+1]$ obtains as

$$R_{i,i+1} = \int_i^{t_i'} \left(\tfrac{A+t-i}{2}\right)^2 e^{-rt} dt + \int_{t_i'}^{i+1} \left(\tfrac{A+i+1-t}{2}\right)^2 e^{-rt} dt. \tag{2}$$

Assume now that the capacity drops by a small quantity ε so that $x_i' - \varepsilon < D^M(t_i')$ with $0 < \varepsilon < 1$. The monopolist gains the discounted cost saved by reducing the investment ε, namely $\varepsilon a(e^{-ri} - e^{-r(i+1)})$. Yet, the demand is not completely met. This induces to switch from the monopoly price regime $p_B^M(t)$ to the constrained regime $p_B^C(t)$ in the phase of increasing demand and to alternate the constrained price regime $p_R^C(t)$ and the monopoly regime $p_R^M(t)$ in the phase of decreasing demand. Thus, the present value of the discounted flow of revenues during the cycle i turns into:

$$R_i = \int_i^{t_i'-\delta} \left(\tfrac{A+t-i}{2}\right)^2 e^{-rt} dt + \int_{t_i'+\delta}^{i+1} \left(\tfrac{A+i+1-t}{2}\right)^2 e^{-rt} dt + \tag{3}$$

$$+ \int_{t_i'-\delta}^{t_i'} \left[\left(\tfrac{A+t_i'-\delta-i}{2}\right)^2 + \left(\tfrac{A+t_i'-\delta-i}{2}\right)(t-i-(t_i'-\delta-i)) \right] e^{-rt} dt +$$

$$+ \int_{t_i'}^{t_i'+\delta} \left(\tfrac{A+i+1}{2} - t - \tfrac{t_i'+\delta}{2}\right)\left(\tfrac{A+i+1}{2} - \tfrac{t_i'+\delta}{2}\right) e^{-rt} dt$$

where the third and fourth integrals denote the revenue stemming from using the constrained price regimes between $t_i' - \delta$ and t_i', t_i' and $t_i' + \delta$, respectively, and $\varepsilon = \delta/2$. Subtracting (3) from (2) yields the loss L resulting from alternating monopoly price regimes and constrained regimes in the cycle rather then using solely the monopoly price regimes in both the phases of the cycle:

$$L = \int_{t_i'-\delta}^{t_i'} \left[\left(\tfrac{A+t-i}{2}\right)^2 - \left(\tfrac{A+t_i'-\delta-i}{2}\right)^2 + \left(\tfrac{A+t_i'-\delta-i}{2}\right)(A+t-i-(A+t_i'-\delta-i)) \right] e^{-rt} dt$$

$$+ \int_{t_i'}^{t_i'+\delta} \left[\left(\tfrac{A+i+1-t}{2}\right)^2 - \left(\tfrac{A+i+1}{2} - t + \tfrac{t_i'+\delta}{2}\right)\left(\tfrac{A+i+1}{2} - \tfrac{t_i'+\delta}{2}\right) \right] e^{-rt} dt$$

This loss L is a function of third order in ε, as it is given by the integral of a function of the order of δ^2 over an interval of length δ, so its order is of magnitude δ^3. The gain $G = \varepsilon a \left(e^{-ri} - e^{-r(i+1)}\right)$ is of first order in ε. Accordingly, for ε small enough, the net loss should be negative, which is the desired contradiction. $\square$

Proof of Proposition 4.

Let us first remark the following, which will be used below. The optimal capacity investments $x_i's$ are the solution of

$$\max V(\mathbf{x}, p(t)) = \int_0^\infty p(t)D(t, p(t))e^{-rt}dt - \sum_{i=0}^\infty ax_ie^{-ri},$$

both in the case when the optimal price policy consists in alternating the monopoly price regime and the constrained regime, and in the case when the constrained regime applies during the whole cycle.

Further, notice that the switching point t_i^* exists, it is unique for each cycle $[i, i+1]$, and univocally entails the switching point t_i^{**}. Accordingly, if we prove that the optimal investment policy is constant size, the optimal price policy repeats identically from a cycle to the other.

Let us focus first on the case when both the monopoly and the constrained price regimes apply. Consider a specific cycle $[i, i+1]$ and $t_i^* \in [i, t_i']$. The first order condition with respect to x_i writes as

$$\int_{t_i^*}^{t_i'} (A+t-i-2x_i)e^{-rt}dt + \int_{t_i'}^{t_i^{**}} (A+i+1-t-2x_i)e^{-rt}dt = ae^{-ri}(1-e^{-r})$$

or

$$e^{-ri}\int_{t_i^*-i}^{t_i'-i} (s-(t_i^*-i))e^{-rs}ds + \int_{t_i'-i}^{t_i^{**}-i} (1-(t_i^*-i)-s)e^{-rs}ds = ae^{-ri}(1-e^{-r}), \quad (4)$$

where $s = A+t-i$. Taking into account that $t_i' = 1/2+i$ and $t_i^{**} = 2i+1-t_i^*$, (4) can be rewritten as

$$e^{-ri}\left(\int_{t_i^*-i}^{\frac{1}{2}} (s-(t_i^*-i))e^{-rs}ds + \int_{\frac{1}{2}}^{1-(t_i^*-i)} (1-(t_i^*-i)-s)e^{-rs}ds\right) = ae^{-ri}(1-e^{-r})$$

or

$$F(t_i^*-i) = a, \quad (5)$$

where $F(l) = \int_l^{1/2} \frac{(s-l)e^{-rs}ds}{(1-e^{-r})} + \int_{1/2}^{1-l} \frac{(1-s-l)e^{-rs}ds}{(1-e^{-r})}$ is a function that does not depend on i. As $t_i^* < i+1/2$ for any i, it is immediate to see that $t_i^* = i+\bar{l}$ where $\bar{l}$ is the unique solution to $F(l) = a$. Then, given the time i when the increment of capacity is installed, t_i^* is univocally determined by $\bar{l}$, which does not depend on i, for any i. Finally, as t_i^* identifies the level of available capacity x_i in any cycle $[i, i+1]$, the solution is stationary, as claimed.

Let us move now to the case when the marginal cost of undertaking a non-negative investment is not compensated by the revenue stemming from this investment. Thus, the monopolist refrains from investing, namely $x_i^* = 0$, and constrained regime only applies. As this condition does not depend on the cycle i, so that $x_i^* = x^* = 0$, this policy repeats identically from a cycle to another. □