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PARTIAL PRIVATIZATION OF STATE HOLDING CORPORATIONS

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Partial Privatization of State Holding Corporations[*]

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Abstract

We consider a state holding corporation with two plants that may produce complement or substitute goods and that compete with one or two private firms. We find that the government partially privatizes the two plants of the state holding corporation and is indifferent between selling them partially to a single investor or to different investors. However, in the former case the government retains a greater (lower) stake in the state corporation if goods are substitutes (complements).

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1. INTRODUCTION

One of the issues analyzed by the literature on mixed oligopoly is the decision by governments whether to privatize a single public firm (see, for example, De Fraja and Delbono 1989, 1990; Corneo and Jeanne 1994).[1] These papers have been extended to consider, among other factors, partial privatization of public firms (Matsumura, 1998; Lin and Matsumura, 2012), strategic privatization under international trade (Bárcena-Ruiz and Garzón 2005a, 2005b), sequential privatization of public firms (Matsumura and Shimizu 2010), privatization when the public firm is as efficient as private firms (Bárcena-Ruiz 2012), and privatization under an interdependence payoff structure (Matsumura and Okamura 2015).

The papers cited above usually assume that the public firm produces a single good at a single production plant. However, in practice governments own firms that produce various types of goods at various production plants, and they are mainly organized as state holding corporations (see Kumar 1992).[2] As far as we know, the theoretical literature on mixed oligopoly has hardly analyzed privatization of state holding corporations (henceforth referred to as state corporations). One exception is the paper by Bárcena-Ruiz and Garzón (2016), who consider a state corporation with two plants that produce differentiated goods. They study whether the government wants to privatize the state corporation, and in that case whether the two plants are sold to different private investors or to a single investor. They assume that if a plant of the state corporation is privatized it is fully sold to private investors. This has happened in many cases of privatization of public firms integrated into state corporations.[3] However, on other occasions state corporations partially privatize their firms. This issue has not been

1. The OECD (2005) points out that in the EU governments are the largest shareholders in many partially privatized firms. State control is also significant in Japan, China, Indonesia, Korea, Malaysia, Singapore, and Thailand. In many industries in these countries there is interaction between private and public firms, as in the markets for cars, ships, and steel manufactures (see De Fraja, 2009).
2. Holdings comprising domestic public firms have been set up by European governments such as, for example, the Sociedad Estatal de Participaciones Industriales -SEPI- in Spain (see www.sepi.es), the Istituto per la Ricostruzione Industriale -IRI- in Italy (see Cafferata, 2010), the Agence des Participations de l'État -APE- in France (www.economie.gouv.fr), and the State-owned Assets Supervision and Administration Commission of the State Council (SASAC) in China (http://www.sasac.gov.cn).
3. Examples of fully privatized Spanish public firms include: the telecommunications firm Telefónica, the shipbuilding firm Iza and the insurance company Musini (see www.sepi.es).

studied by the relevant literature, so in order to fill this gap this paper analyzes the decision whether to partially privatize state corporations.

Our paper relates to the literature on partial privatization that began with the seminal paper by Matsumura (1998). He considers a mixed duopoly where a public firm and a private firm compete and finds partial privatization in equilibrium under moderate conditions. This paper has been extended to analyze factors that affect partial privatization of public firms. Among other factors, the literature has considered partially foreign-owned private firms (Han and Ogawa, 2008), foreign investment in partially privatized firms (Lin and Matsumura, 2012), cross-ownership of firms (Jain and Pal, 2012; Chai and Karasawa-Ohtashiro, 2015), trade policies (Chao and Yu, 2006; Long and Stähler, 2009), product differentiation (Fujiwara, 2007; Lu and Poddar, 2007), free entry (Matsumura and Kanda, 2005; Wang and Chen, 2010), endogenous timing of decisions (Bárcena-Ruiz and Garzón, 2010), environmental problems (Kato, 2006; Ohori, 2006), and merger problems (Bárcena-Ruiz and Garzón, 2003; Mendez-Naya, 2008). However, this literature has not considered partial privatization of state corporations that produce more than one type of goods at more than one production plant.

State corporations are usually multiproduct, multiplant firms that produce different products, which may be substitutes or complements. Therefore, we consider an industry made up by a state corporation and a private sector. The state corporation owns two production plants each of which produces a differentiated good, and these goods may be substitutes or complements. The private sector comprises two private plants that produce differentiated goods. These plants may be owned by different investors (henceforth uniplant firms) or by a single investor (henceforth the multiplant firm).[4] The government may partially privatize the two plants of the state corporation, so it has two options: It may sell a percentage of the ownership of both plants to a single private investor, or it may sell a percentage of the ownership of each plant to a different private investor.

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4. Multiproduct firms are omnipresent in modern economies (Eckel and Neary, 2010). Literature on this issue has analyzed, for example, market structure (Shaked and Sutton, 1990), product choice and the determinants of product variety (Anderson and De Palma, 2006), the effect of firm heterogeneity on industry profitability and welfare (Symeonidis, 2009), international trade and productivity (Bernard et al., 2010), and environmental policies implemented by governments (Bárcena-Ruiz and Garzón, 2014).

We find evidence supporting the idea that the analysis conducted in the paper is important. Renault and Volkswagen are good examples of firms producing substitute goods. Renault produces two brands of cars, Dacia and Renault, and the French government owns 15% of the firm. Similarly, the Volkswagen Group produces several brands of car (such as Volkswagen, Audi, Seat, and Skoda) and the State of Lower Saxony owns at least 15% of the firm.[5] An example of public firms that produce complementary goods can be found in telecommunication firms, which usually have several business lines: Telephone, television and the Internet. In the European Union several governments have partially privatized their telecommunication firms, such as Deutsche Telekom in Germany and France Télécom in France (see www.fundinguniverse.com). The German government currently owns 31.7% of the shares in Deutsche Telekom and the French government owns 13.4% of the shares in Orange,[6] the brand under which France Télécom operates.[7]

We find in the paper that the government partially privatizes the two plants of the state corporation but is indifferent between selling them to a single private investor or to different private investors. When goods are complements, the government keeps a larger stake in the state corporation if its plants are sold to different private investors than if they are sold to a single private investor. Moreover, the government retains a larger stake if private firms are multiplant than if they are uniplant. If goods are substitutes the contrary result is obtained. Finally, if goods are independent in demand the government keeps the same stake in the state corporation in all cases. From this it can be concluded that the stake that the government retains in the state corporation depends on the type of goods produced by the state corporation and the private firms, and on whether private firms are uniplant or multiplant.

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5. See https://group.renault.com/en/finance-2/financial-information/key-figures/ (for Renault), and http://www.volkswagenag.com/content/vwcorp/info_center/en/publications/2015/03/Y_2014_e.bin.html /binarystorageitem/file/GB+2014_e.pdf (for Volkswagen).
6. See www.telekom.com/shareholder-structure (for Deutsche Telekom), and http://www.4-traders.com/ORANGE-SA-4649/company/ (for Orange).
7. Another example is China State Shipbuilding Corporation (CSSC), a state corporation that has many subsidiaries. In 2015 one of its core subsidiaries, Guangzhou Shipyard International Company (GSCI), whose activity mainly covers ship building, offshore marine construction and heavy machine manufacturing, sold 4.83 % of its shares to private firm Yangzhou Kejin Shipbuilding Co. Ltd. Now GSCI is known as Offshore & Marine Engineering Company (COMEC) and the Chinese government owns more than 60 percent of the shares in this company (http://comec.cssc.net.cn).

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 analyzes the privatization of the state corporation assuming uniplant private firms. Section 4 extends the analysis by considering a multiplant private firm. Section 5 compares the two cases, and Section 6 concludes.

2. THE MODEL

We consider an economy made up of a public sector and a private sector that produce differentiated goods, denoted by 1 and 2, which may be substitutes or complements. The public sector comprises a state holding corporation, denoted by firm A, whose objective function is social welfare if it is fully public. It owns two plants producing goods 1 and 2, denoted by $1A$ and $2A$ respectively. The private sector may comprise two uniplant private firms or a single multiplant firm with two plants. We denote the private uniplant firms and the plants of the private multiplant firm which produce good 1 and good 2 by $1B$ and $2B$ respectively. The objective function of a uniplant private firm is its own profit and the objective function of the multiplant private firm is the joint profits of its two plants.

On the consumption side, there is a continuum of consumers of the same type. The representative consumer maximizes $U(q_1, q_2) - p_1 q_1 - p_2 q_2$, where p_i is the price of good i, $q_i = q_{iA} + q_{iB}$ is the quantity of good i and, q_{ik} is the output produced by firm or plant ik, $i=1, 2$; $k=A, B$. The function $U(q_1, q_2)$ is assumed to be quadratic, strictly concave and symmetric in q_1 and q_2:

$$U(q_1, q_2) = (q_1+q_2) - ((q_1)^2 + 2bq_1q_2 + (q_2)^2)/2, \; -1 < b < 1.$$

The inverse demand functions are given by:

$$p_i = 1 - (q_{iA}+q_{iB}) - b(q_{jA}+q_{jB}), \; i \neq j; \; i,j=1,2; \; -1 < b < 1,$$

where goods are substitutes if $b>0$, complements if $b<0$ and independent in demand if $b=0$. Following De Fraja and Delbono (1989) and Bárcena-Ruiz and Garzón (2005a),

we assume that firms have identical technologies represented by the following quadratic cost function:

$$C(q_{ik}) = cq_{ik}^2/2, \; i = 1, 2; k = A, B.$$

Therefore, the profit function of plant or firm ik is:

$$\pi_{ik} = p_i \; q_{ik} - cq_{ik}^2/2, \; i{=}1, 2; k = A, B. \tag{1}$$

The profit of multiplant firm k is the joint profit of the two plants:

$$\pi_k = \pi_{1k} + \pi_{2k}, \; k = A, B. \tag{2}$$

The producer surplus is the sum of the profits of firms and is given by $PS = \pi_{1A} + \pi_{2A} + \pi_{1B} + \pi_{2B}$. The consumer surplus is given by:

$$CS = ((q_{1A}{+}q_{1B})^2 + 2b(q_{1A}{+}q_{1B})(q_{2A}{+}q_{2B}) + (q_{2A}{+}q_{2B})^2)/2.$$

The government aims to maximize the social welfare, i.e. the sum of the producer surplus and the consumer surplus:

$$W = CS + PS. \tag{3}$$

To increase social welfare the government can sell off part of the plants of the state corporation to private investors. In this case the government has two options: to sell to a single private investor or to different private investors. The state corporation is then jointly owned by the public and private sectors. We assume that the government owns β percent of the shares and the private investor owns the remaining $(1–\beta)$ percent, so the partially privatized firm maximizes the weighted average of social welfare and firm profits (see Matsumura, 1998). Therefore, if the government sells part of the two plants of the state corporation to the same investor it owns the same stake in the two plants and thus the objective function of the firm is given by:

$$V = \beta W + (1-\beta)(\pi_{1A} + \pi_{2A}), \ 0 \leq \beta \leq 1. \tag{4}$$

When the government sells part of each plant to a different private investor, the objective function of plant i is given by:

$$V_i = \beta_i W + (1-\beta_i) \ \pi_{iA}, \ 0 \leq \beta_i \leq 1, \ i=1, 2. \tag{5}$$

Clearly, if $\beta_i=1$ plant iA of the state corporation remains public, and if $\beta_i=0$ plant iA is fully privatized.

To analyze the government's decision on the optimal degree of partial privatization of the state corporation, we propose a two-stage game. In the first stage the government decides what percentage of the shares in the state corporation it will sell to private investors. In this case, the government has two options: sell off part of both plants to a single private investor, or sell part of each plant to a different investor. In the second stage the firms make production decisions simultaneously. We solve the game by backward induction to obtain a subgame perfect equilibrium. We consider two cases: in the first case private firms are uniplant, and in the second there is a single multiplant private firm.

Henceforth we assume that $c=1$ to simplify the presentation of results. It can be shown that results are robust to changes in this parameter.

3. UNIPLANT PRIVATE FIRMS

Denote the case where private firms are uniplant by superscript U. The government may partially privatize the two plants of the state corporation, selling shares in each plant to a different private investor (denoted by the superscript D) or selling shares in the state corporation to a single private investor (denoted by superscript S).

3.1. SINGLE PRIVATE INVESTOR

In this case the two plants of the state corporation are sold off in part to a single private investor. In the second stage of the game semipublic firm A chooses the output levels

q_{1A} and q_{2A} that maximize its objective function, given by expression (4). Private firm iB sets the output level q_{iB} that maximizes its profit, given by expression (1), $i =1, 2$. Solving these problems, we obtain the following first order conditions:

$$(1 - 3q_{Ai} - q_{Bi} - b(2q_{Aj} + q_{Bj}))(1 - \beta) + (1 - 2q_{Ai} - q_{Bi} - b(q_{Aj} + q_{Bj}))\beta = 0,$$

$$1 - q_{Ai} - 3q_{Bi} - b(q_{Aj} + q_{Bj}) = 0, i \neq j; i, j = 1, 2. \tag{6}$$

From (6) we obtain the following output of firms and social welfare as a function of β:

$$q_{iA} = \frac{2}{8+b^2(1-\beta)-3\beta+b(7-4\beta)}, \quad q_{iB} = \frac{2+b-\beta(1+b)}{8+b^2(1-\beta)-3\beta+b(7-4\beta)},$$

$$W = \frac{(40+44b+12b^2+b^3-2(1+b)(14+b(8+b))\beta+(1+b)^2(4+b)\beta^2)}{(8+b^2(1-\beta)-3\beta+b(7-4\beta))^2}, \quad i=1, 2. \tag{7}$$

In the first stage of the game the government chooses the optimal value of β that maximizes social welfare, given by expression (7). Solving this problem we obtain the following result.

Lemma 1. Under uniplant private firms, when the government sells part of the state corporation to a single private investor, in equilibrium:

$$\beta^{SU} = \frac{4+b}{5+b}, \quad q_{iA}^{SU} = \frac{5+b}{2(7+6b+b^2)}, \quad q_{iB}^{SU} = \frac{3+b}{2(7+6b+b^2)}, \quad \pi_{iA}^{SU} = \frac{(5+b)(7+3b)}{8(7+6b+b^2)^2}, \quad \pi_{iB}^{SU} = \frac{3(3+b)^2}{8(7+6b+b^2)^2},$$

$$CS^{SU} = \frac{(1+b)(4+b)^2}{(7+6b+b^2)^2}, \quad PS^{SU} = \frac{(31+20b+3b^2)}{2(7+6b+b^2)^2}, \quad W^{SU} = \frac{9+2b}{2(7+6b+b^2)}, \quad i = 1, 2.$$

It is easy to see that $0<\beta^{SU}<1$, so the government partially privatizes the state corporation. Consumer surplus decreases while producer surplus increases with the degree of privatization of the state corporation. These two effects balance for a value of β between 0 and 1, $\beta = \beta^{SU}$. We also find that the percentage of shares that remains public increases with b ($\partial \beta^{SU}/\partial b > 0$).

To explain why β^{SU} increases with b two effects must be taken into account. The first is the internalization effect: a multiplant firm internalizes how the output of one of its plants affects that of its other plant. When such a firm produces substitute goods ($b>0$) it

takes on board that its two plants compete with each other, which encourages it to reduce the output of its plants. Thus, with substitute goods multiplant firms produce less than uniplant firms. With complement goods ($b<0$) the opposite result is obtained since a multiplant firm takes on board that its two plants cooperate, so the output of one plant increases with that of the other plant. Thus, with complement goods multiplant firms produce more than uniplant firms. As the state corporation produces two goods, one in each plant, it internalizes how the output of one of its plants affects that of the other. The second effect is the objective function effect: the state corporation produces more than private firms since it takes consumer surplus into account. If the state corporation is semipublic, its production decreases with the stake owned by the private sector, $1-\beta$.

When $b<0$, goods become less complementary as b increases so the internalization effect becomes weaker. In this case the output of the two plants of the state corporation decreases with b. When $b>0$, goods become closer substitutes as b increases and thus the internalization effect becomes stronger. In that case the output of the two plants of the state corporation also decreases with b. Therefore, as b increases the output of the firms decreases due to the internalization effect, regardless of whether goods are substitutes or complements. Since the government wants to attain a certain output from firms it can achieve the desired result by choosing the right stake in the state corporation due to the objective function effect. The greater β is, the greater the weight of social welfare is in the objective function of the semipublic state corporation and, thus, the greater its output is. Therefore, the government retains a greater stake the greater the value of b ($\partial\beta^{SU}/\partial b > 0$) is, to increase the output of the plants of the state corporation.

Finally, $q_{iA}^{SU} > q_{iB}^{SU}$ and $\pi_{iA}^{SU} > \pi_{iB}^{SU}$ for all values of parameter b. This is because firm A is semipublic and therefore takes into account the consumer surplus, which increases with the output of the firms. As a result firm A produces more than private firms and obtains greater market share and profits.

3.2. DIFFERENT PRIVATE INVESTORS

In the second stage of the game, private firm iB sets the output level q_{iB} that maximizes its profit, given by expression (1), $i =1,\ 2$. In this case, part of each plant of the state

corporation is sold to a different private investor. Each semipublic firm chooses the output level q_{iA} that maximizes its objective function given by expression (5). Solving these problems, we obtain the following first order conditions:

$$(1 - 3q_{Ai} - q_{Bi} - b(2q_{Aj} + q_{Bj}))(1 - \beta_i) + (1 - 2q_{Ai} - q_{Bi} - b(q_{Aj} + q_{Bj}))\beta_i = 0,$$

$$1 - q_{Ai} - 3q_{Bi} - b(q_{Aj} + q_{Bj}) = 0, \ i \neq j; \ i,j = 1,2.$$

(8)

From (8) we obtain the following output of the firms and social welfare as a function of β_1 and β_2:

$$q_{iA} = \frac{-2(8 - b(4 - \beta_j) - 3\beta_j)}{b^2(4 - \beta_i)(4 - \beta_j) - (8 - 3\beta_i)(8 - 3\beta_j)}, \quad q_{iB} = \frac{-(2 - \beta_i)(8 - b(4 - \beta_j) - 3\beta_j)}{b^2(4 - \beta_i)(4 - \beta_j) - (8 - 3\beta_i)(8 - 3\beta_j)}, \ i \neq j; \ i,j = 1,2,$$

$$W = ((b^3(4 - \beta_1)^2(4 - \beta_2)^2 - 2b^2(\beta_1(48\beta_2 - 7\beta_2{}^2 - 96) + \beta_1{}^2(14 - 7\beta_2 + \beta_2{}^2) +$$

$$2(96 - 48\beta_2 + 7\beta_2{}^2)) + b(\beta_1{}^2(104\beta_2 - 15\beta_2{}^2 - 152) + 8\beta_1(132 - 90\beta_2 + 13\beta_2{}^2) -$$ (9)

$$8(192 - 132\beta_2 + 19\beta_2{}^2)) + 2(\beta_1(672\beta_2 - 111\beta_2{}^2 - 928) + \beta_1{}^2(154 - 111\beta_2 + 18\beta_2{}^2) +$$

$$2(640 - 464\beta_2 + 77\beta_2{}^2)))) / (b^2(4 - \beta_1)(4 - \beta_2) - (8 - 3\beta_1)(8 - 3\beta_2))^2.$$

In the first stage of the game the government chooses the optimal value of β_1 and β_2 that maximizes social welfare, given by expression (9). Solving this problem we obtain the following result.

Lemma 2. Under uniplant private firms, when the government sells part of each plant of the state corporation to a different private investor, in equilibrium:

$$\beta_i^{DU} = \frac{4}{5+b}, \quad q_{iA}^{DU} = \frac{5+b}{2(7 + 6b + b^2)}, \quad q_{iB}^{DU} = \frac{3+b}{2(7 + 6b + b^2)}, \quad \pi_{iA}^{DU} = \frac{(5+b)(7+3b)}{8(7 + 6b + b^2)^2}, \quad \pi_{iB}^{DU} = \frac{3(3+b)^2}{8(7 + 6b + b^2)^2},$$

$$CS^{DU} = \frac{(1+b)(4+b)^2}{(7 + 6b + b^2)^2}, \quad PS^{DU} = \frac{31 + 20b + 3b^2}{2(7 + 6b + b^2)^2}, \quad W^{DU} = \frac{9 + 2b}{2(7 + b(6+b))}, \ i = 1,2.$$

As in the case of a single investor it is obtained that the government partially privatizes the state corporation: $0 < \beta_i^{DU} < 1$. Given the symmetry of the model, the government retains the same stake in each plant of the state corporation. The percentage of shares that remains public, β_i^{DU}, decreases with b $(\partial \beta_i^{DU} / \partial b < 0)$. As the state corporation is partially privatized by selling the plants to different private investors,

there are two semipublic uniplant firms and there is no internalization effect. When goods are substitutes, as *b* increases goods become closer substitutes and market competition increases. When goods are complements the output of the firms is lower than when goods are substitutes, but goods become less complementary as *b* increases, so the output of the firms increases. As a result, as *b* increases, and the output of the firms increases whether goods are substitutes or complements. Thus, due to the objective function effect, the stake in the semipublic firms retained by the government becomes smaller the greater the value of *b* is. Finally, $q_{iA}^{DU} > q_{iB}^{DU}$ and $\pi_{iA}^{DU} > \pi_{iB}^{DU}$ for all values of parameter *b* since firm *iA* is semipublic and takes consumer surplus into account.

3.3. COMPARISON OF RESULTS

We first compare the degree of privatization of the two plants of the state corporation when they are sold to a single investor with that which results when they are sold to different investors. From Lemmas 1 and 2 the following is obtained.

Proposition 1. Under uniplant private firms, in equilibrium: $\beta^{SU} > \beta_i^{DU}$ if goods are substitutes (*b*>0), $\beta^{SU} < \beta_i^{DU}$ if goods are complements (*b*<0), and $\beta^{SU} = \beta_i^{DU}$ if goods are independent in demand (*b*=0).

Regardless of whether goods are substitutes or complements, the internalization effect is stronger if the plants of the state corporation are sold off in part to a single private investor than if they are sold to different private investors. This is because in the second case semipublic firms are uniplant so there is no internalization effect. Given a stake-holding in the state corporation by the government, when goods are substitutes production and market competition is lower if the two plants are sold in part to a single private investor. In this case, due to the objective function effect, the government retains a greater percentage of the shares in the state corporation ($\beta^{SU} > \beta_i^{DU}$) to increase production. However, when goods are complements production and market competition are greater if the two plants are sold off in part to a single private investor due to the

internalization effect. In that case, the objective function effect implies that the government retains a lower stake in the state corporation ($\beta^{SU} < \beta_i^{DU}$). Finally, if goods are independent in demand ($b=0$) there is no internalization effect so a multiplant firm produces the same output as uniproduct firms, which means that $\beta^{SU} = \beta_i^{DU}$.

By comparing the welfare levels shown in Lemmas 1 and 2 the following result is obtained.

Proposition 2. Under uniplant private firms, in equilibrium, $W^{SU} = W^{DU}$. This means that the government is indifferent between selling part of the two plants of the state corporation to a single investor and selling part of each plant to a different private investor.

When the government sells part of the state corporation the producer surplus increases at the expense of consumer surplus. Thus, the government partially privatizes the state corporation to balance these two effects. Proposition 1 shows that if goods are substitutes (complements), the government retains a greater (lower) stake in the state corporation when the plants are partially sold to a single private investor than when they are sold to different private investors. In this way, the government can achieve the same welfare in both cases. As a result, the firms produce the same output in both cases ($q_{iA}^{SU} = q_{iA}^{DU}$, $q_{iB}^{SU} = q_{iB}^{DU}$), so the consumer and producer surpluses and welfare are also the same ($CS^{SU} = CS^{DU}$, $PS^{SU} = PS^{DU}$, $W^{SU} = W^{DU}$). [8]

4. MULTIPLANT PRIVATE FIRMS

Up to now we have considered that the state corporation competes in the product market with uniplant private firms. However, in modern economies multiplant firms are omnipresent and state corporations may compete with multiplant private firms rather than with uniplant private firms. Thus, we now consider that the state corporation

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[8]. This is not possible when the government has to fully privatize the state corporation (as in Bárcena-Ruiz and Garzón, 2016), so welfare is not equal in both cases under full privatization.

competes in the product market with a multiplant private firm that owns two plants producing differentiated goods. We denote this case by superscript *M*.

We now compare the degree of privatization of the two plants of the state corporation when they are sold to a single investor and when they are sold to different investors. From Lemmas A1 and A2 (see Appendix) the following is obtained.

Proposition 3. Under a multiplant private firm, in equilibrium: $\beta^{SM} > \beta_i^{DM}$ if goods are substitutes ($b>0$), $\beta^{SM} < \beta_i^{DM}$ if goods are complements ($b<0$), and $\beta^{SM} = \beta_i^{DM}$ if goods are independent in demand ($b=0$).

The explanation of this result is similar to that given in Proposition 1 so we omit it. The main difference is that there is one multiplant private firm rather than two uniproduct private firms. Due to the internalization effect, a multiplant private firm produces less (more) with substitute (complement) goods than uniplant private firms.

By comparing the welfare levels shown in Lemmas A1 and A2 the following result is obtained.

Proposition 4. Under a multiplant private firm, in equilibrium: $W^{SM} = W^{DM}$.

The explanation of this result is similar to that given in Proposition 2 so we omit it.

5. COMPARISON OF RESULTS

By comparing Propositions 1 and 3 the following result is obtained.

Proposition 5. In equilibrium: if *b<0* we obtain that $\beta_i^{DM} > \beta_i^{DU} > \beta^{SM} > \beta^{SU}$, if *b>0* we obtain that $\beta^{SU} > \beta^{SM} > \beta_i^{DU} > \beta_i^{DM}$, and if *b=0* we obtain that $\beta^{SU} = \beta^{SM} = \beta_i^{DU} = \beta_i^{DM}$.[9]

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9. It can be shown that the main result obtained in this proposition holds that there if it is assumed that there are *n* uniplant or multiplant private firms competing in the product market. The state corporation is never fully privatized even when n is high, and the degree of privatization increases with n. This is a well known result in the relevant literature (see, for example, Fujiwara, 2007).

This proposition shows that when goods are complements ($b<0$), the government keeps a larger stake in the state corporation if its plants are sold to different private investors than if they are sold to a single private investor. Moreover, the government retains a larger stake if private firms are multiplant than if they are uniplant. If goods are substitutes ($b>0$) the contrary result is obtained. Finally, if goods are independent in demand ($b=0$) the government keeps the same stake in the state corporation in all cases. From this it can be concluded that the stake that the government retains in the state corporation depends on the type of goods produced by the firms and on whether private firm are uniplant or multiplant.

To explain the result obtained in Proposition 5, note that the internalization effect and the objective function effect depend on two factors: The first is whether the two plants of the state corporation are sold in part to a single private investor or to different investors. The second one is whether private firms are uniplant or multiplant. Both factors affect the internalization effect since only multiplant firms (either semipublic or private) take into account how the output of one plant affects that of the other. However, only the first factor affects the objective function effect since only a semipublic firm takes social welfare into account. Thus, the first factor is more important since it is relevant to both effects.

When goods are complements, the internalization effect means that, the two plants produce more if they are sold to a single private investor than if they are sold to different investors. Thus, as shown in Propositions 1 and 3, the objective function effect means that the government retains a lower stake in the state corporation in the former case. Moreover, compared with the case when there are two private uniplant firms, the private sector produces more when there is a multiplant firm because of the internalization effect. This may cause semipublic plants or firms to reduce output and market competition. In this case, to counterbalance the output reduction the government retains a larger stake in the state corporation due to the objective function effect. Thus, independently of whether the state corporation is sold to a single investor or to different investors, the government retains a greater percentage of the shares in the state corporation if private firms are multiplant than if they are uniplant. Therefore, if goods are complements it is obtained that $\beta_i^{DM} > \beta_i^{DU} > \beta^{SM} > \beta^{SU}$.

When goods are substitutes the internalization effect means that the two plants produce less if they are sold to a single private investor than if they are sold to different investors. Thus, as shown in Propositions 1 and 3, due to the objective function effect the government retains a lower stake in the state corporation in the latter case. Moreover, compared with the case when there are two private uniplant firms, the internalization effect means that the private sector produces less when there is a multiplant firm, which may encourage partially privatized plants to increase their output. In this case, the government has less incentive to increase output by retaining a higher stake in the state corporation due to the objective function effect. Thus, independently of who buys part of the state corporation, the government retains a lower percentage of the shares if private firms are multiplant than if they are uniplant. Therefore, if goods are substitutes it is obtained that $\beta^{SU} > \beta^{SM} > \beta_i^{DU} > \beta_i^{DM}$. Finally, if goods are independent in demand there is no internalization effect, so $\beta^{SU} = \beta^{SM} = \beta_i^{DU} = \beta_i^{DM}$.

6. CONCLUSIONS

The theoretical literature on mixed oligopoly has hardly analyzed the privatization of state corporations. One exception is the paper by Bárcena-Ruiz and Garzón (2016) who assume that if a plant of the state corporation is privatized it is fully sold to private investors. However, there is evidence showing that state corporations often partially privatize their firms. In this paper we analyze a government's decision on whether to partially privatize a state holding corporation with two plants that may produce complement or substitute goods. The state holding corporation competes with two private plants, which may belong to different firms or to a multiplant firm. To privatize the state holding corporation the government may sell off part of its two plants to a single private investor or to different private investors.

The result obtained in this paper helps to understand the different degrees to which state holding corporations have been privatized by governments in practice depending on whether the goods produced by firms are substitutes or complements. We find in the paper that the government partially privatizes the two plants of the state corporation but

is indifferent between selling them to a single private investor or to different private investors.

When goods are complements, the government keeps a larger stake in the state corporation if its plants are sold to different private investors than if they are sold to a single private investor. However, social welfare in equilibrium is the same in the two cases and thus the government is indifferent between them. Moreover, the government retains a larger stake if private firms are multiplant than if they are uniplant.

If goods are substitutes the contrary result is obtained. The government keeps a lower stake in the state corporation if its plants are sold to different private investors than if they are sold to a single private investor. Social welfare in equilibrium is the same in the two cases so the government is indifferent between them. Moreover, the government retains a lower stake if private firms are multiplant than if they are uniplant.

Finally, if goods are independent in demand the government keeps the same stake in the state corporation in all cases considered in this paper. From this it can be concluded that the stake that the government retains in the state corporation depends on the type of goods produced by the state corporation and the private firms, and on whether private firm are uniplant or multiplant.

APPENDIX: MULTIPLANT PRIVATE FIRM

i) Single private investor. In this case, the two plants of the state corporation are sold in part to a single private investor. In the second stage of the game semipublic firm A chooses the output levels q_{1A} and q_{2A} that maximize its objective function, given by expression (4). Private firm B sets the output levels q_{1B} and q_{2B} that maximize its profit, given by expression (2). Solving these problems, we obtain the following first order conditions:

$$(1 - 3q_{Ai} - q_{Bi} - b(2q_{Aj} + q_{Bj}))(1 - \beta) + (1 - 2q_{Ai} - q_{Bi} - b(q_{Aj} + q_{Bj}))\beta = 0,$$

$$1 - q_{Ai} - 3q_{Bi} - b(q_{Aj} + 2q_{Bj}) = 0, \, i \neq j; \, i, j = 1, 2.$$

From the above first order conditions we obtain the following output of the firms and social welfare as a function of β:

$$q_{iA} = \frac{2+b}{8+5b(2-\beta)-3\beta+b^2(3-2\beta)}, \quad q_{iB} = \frac{2+b-\beta(1+b)}{8+5b(2-\beta)-3\beta+b^2(3-2\beta)},$$

$$W = \frac{(2(2+b)^2(5+4b)-2(1+b)(2+b)(7+5b)\beta+(1+b)^2(4+3b)\beta^2)}{(8+5b(2-\beta)-3\beta+b^2(3-2\beta))^2}, \, i = 1, 2.$$

In the first stage of the game the government chooses the optimal value of β that maximizes social welfare. Solving this problem we obtain the following result.

Lemma A1. Under multiplant private firms, when the government partially sells the state corporation to a single private investor, in equilibrium:

$$\beta^{SM} = \frac{(2+b)^2}{5+5b+b^2}, \quad q_{iA}^{SM} = \frac{5+5b+b^2}{14+22b+10b^2+b^3}, \quad q_{iB}^{SM} = \frac{3+2b}{14+22b+10b^2+b^3},$$

$$\pi_{iA}^{SM} = \frac{(5+5b+b^2)(7+9b+3b^2)}{2(14+22b+10b^2+b^3)^2}, \quad \pi_{iB}^{SM} = \frac{(3+2b)^3}{2(14+22b+10b^2+b^3)^2}, \quad CS^{SM} = \frac{(1+b)(8+7b+b^2)^2}{(14+22b+10b^2+b^3)^2},$$

$$PS^{SM} = \frac{62+134b+103b^2+32b^3+3b^4}{(14+22b+10b^2+b^3)^2}, \quad W^{SM} = \frac{(9+8b+b^2)}{14+22b+10b^2+b^3}, \, i = 1, 2.$$

ii) Different private investors. In this case, each plant of the state corporation is sold in part to a different private investor. In the second stage of the game, private firm iB sets the output level q_{iB} that maximizes its profit, given by expression (1), $i = 1, 2$. Each semipublic firm chooses the output level q_{iA} that maximizes its objective function given by expression (5). Solving these problems, we obtain the following first order conditions:

$$(1 - 3q_{Ai} - q_{Bi} - b(q_{Aj} + q_{Bj}))(1 - \beta_i) + (1 - 2q_{Ai} - q_{Bi} - b(q_{Aj} - q_{Bj}))\beta_i = 0,$$

$$1 - q_{Ai} - 3q_{Bi} - b(q_{Aj} + 2q_{Bj}) = 0, i \neq j; i, j = 1, 2.$$

From the above first order conditions we obtain the following output of the firms and social welfare as a function of β_1 and β_2:

$$q_{iA} = \frac{(2+b)(8+b^2-3\beta_j-b(7-2\beta_j))}{b^4+b^2(\beta_i(11-4\beta_j)-11(3-\beta_j))+(8-3\beta_i)(8-3\beta_j)},$$

$$q_{iB} = \frac{(b^2(2-\beta_j)+(8-3\beta_j)(2-\beta_i)+b(\beta_j(5-2\beta_i)+6\beta_i-14))}{b^4+b^2(\beta_i(11-4\beta_j)-11(3-\beta_j))+(8-3\beta_i)(8-3\beta_j)}, i \neq j; i, j = 1, 2,$$

$$W = (b^7 - 2b^6 + b^5(\beta_1(22-9\beta_2)+22\beta_2-59) + b^4(92+2\beta_1{}^2(1-\beta_2) -$$
$$41\beta_2 + 2\beta_2{}^2 + \beta_1(26\beta_2 - 2\beta_2{}^2 - 41)) + b^3(1020 - 673\beta_2 + 101\beta_2{}^2 +$$
$$\beta_1(454\beta_2 - 71\beta_2{}^2 - 673) + \beta_1{}^2(101 - 71\beta_2 + 12\beta_2{}^2)) +$$
$$2\left(\beta_1(672\beta_2 - 111\beta_2{}^2 - 928) + \beta_1{}^2(154 - 111\beta_2 + 18\beta_2{}^2) + 2(640 - 464\beta_2 + 77\beta_2{}^2)\right) +$$
$$b^2(1078\beta_2 - 173\beta_2{}^2 - 1560 + \beta_1{}^2(125\beta_2 - 20\beta_2{}^2 - 173) + \beta_1(1078 - 770\beta_2 + 125\beta_2{}^2)) +$$
$$b(\beta_1{}^2(127\beta_2 - 21\beta_2{}^2 - 180) - 4(416 - 290\beta_2 + 45\beta_2{}^2) + \beta_1(1160 - 804\beta_2 + 127\beta_2{}^2))))/$$
$$(b^4 + b^2(\beta_1(11 - 4\beta_2) - 11(3 - \beta_2)) + (8 - 3\beta_1)(8 - 3\beta_2))^2.$$

In the first stage of the game the government chooses the optimal value of β_1 and β_2 that maximizes social welfare. Solving this problem we obtain the following result.

Lemma A2. Under a multiplant private firm, when the government sells each plant of the state corporation to a different private investor, in equilibrium:

$$\beta_i^{DM} = \frac{4+3b}{5+5b+b^2}, \quad q_{iA}^{DM} = \frac{5+5b+b^2}{14+22b+10b^2+b^3}, \quad q_{iB}^{DM} = \frac{3+2b}{14+22b+10b^2+b^3},$$

$$\pi_{iA}^{DM} = \frac{(5+5b+b^2)(7+9b+3b^2)}{2(14+22b+10b^2+b^3)^2}, \quad \pi_{iB}^{DM} = \frac{(3+2b)^3}{2(14+22b+10b^2+b^3)^2}, \quad CS^{DM} = \frac{(1+b)(8+7b+b^2)^2}{(14+22b+10b^2+b^3)^2},$$

$$PS^{DM} = \frac{62+134b+103b^2+32b^3+3b^4}{(14+22b+10b^2+b^3)^2}, \quad W^{DM} = \frac{9+b(8+b)}{14+b(22+b(10+b))}, i = 1, 2.$$

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