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Is partial privatization of universities a solution for higher education?

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Abstract

This paper accounts simply for the link between higher education and the productive economy through educated workers. We study a model of vertical successive monopolies where students/workers acquire qualification from a University then “sell” skilled labor to a monopoly which itself sells its final product to consumers, linking through quality the education sector to the labor and output markets. We determine the optimal share the State should keep in the University to compensate for the market imperfections, while taking into account the inefficiencies of public management. The resulting partially privatized University fixes the tuition fees so as to maximize a weighted sum of profits and social welfare. We derive the optimal public share under the hypothesis that the State may subsidize the tuition fees/University losses, then under the constraint that the University should make a nonnegative profit. We prove that in both cases, the State should keep a substantial share (higher under the first hypothesis) in the University, unless public management is too inefficient in which case the University’s management should be completely private.

1 INTRODUCTION

Over the last few decades, a substantial expansion of private higher education has been recorded all over the world. Data from the 2010 PROPHE's statistics indicate that private higher education holds 33.1% of total higher education enrollment.¹ More specifically, Asia leads with 36%, US follows with 29.4%, and Europe registers the lowest percentage with only 16%. The expansion of private higher education has been seen as a necessity to cope with “more students and less money” (Thornton, 2012, p. 13), that is, the overwhelming increase of the demand for higher education and the incapacity or the unwillingness of public higher education to absorb such a demand. The general idea that the public management is “wasteful, inefficient and unproductive” (Walker, 1984, p. 30) is behind the observed waves of privatization of the public sector in general and higher education institutions in particular, along with an increasing competition for the use of declining public resources.

Concerning the higher education sector in particular, several papers compared universities' efficiency in a cross-country perspective (Agasisti & Johnes, 2009; Agasisti & Pérez-Esparrels, 2010; Herberholz & Wigger, 2018; Lehmann et al., 2018). But to the best of our knowledge only Agasisti and Ricca (2016) and Bayraktar et al. (2013) establish a comparison between public and private universities' efficiency within the same country, the former in Italy and the latter in Turkey. They conclude to the superior efficiency of private universities relative to their public counterparts.

More recently, the reverse trend has also been observed (Kwieck, 2017; Levy, 2013). According to Kwieck (2017, p. 260), “in post-communist Europe, [...] the dynamics have clearly been changing toward more publicness and less privateness in the last decade,” which has been called by the author “deprivatization” of higher education.

Privatization and deprivatization have to be understood in dynamic terms, in terms of less or more implication of the State in the sector and of “increased [or decreased] reliance on market mechanisms to govern higher education” (McLendon & Mokher, 2009, pp. 25–26). In fact, we are speaking in both cases of a degree in privatization and a tendency to go in one way or in the opposite one, thus to increase or decrease, in other words, to choose the degree of privatization. Indeed, according to Levy (2013), universities can partly privatize, like other public enterprises, as a way to improve their management. In this paper, we aim at determining the optimal share the State should keep in a University to alleviate market inefficiencies (which are different from the inefficiencies already identified in the literature), taking into account the inefficiency of public management and explicitly relating the quality of education to the quality of the final output, thus considering the effect of higher education on the downstream firm through the educated workers, in a successive monopolies model.

Education, as an important part of human capital, is a global public good. Indeed education and higher education have been quite extensively shown to have positive effects in terms of productivity, economic growth, health, civic participation, and nonmarket benefits (marriage, fertility, etc.; For a survey, see Farrell et al., 2006). Because of the existence of strong spillover effects the provision by the private sector would not be optimal. In the same frame of mind, “the privatization agenda inevitably raises the questions of equitable access, intergenerational social mobility, and the individualistic nature of modern societies” (Kwieck, 2017, p. 261). The present paper ignores the public good character of education and focuses on the link between higher education and the real economy through educated workers. But this alone accounts

¹<http://www.albany.edu/dept/eaps/prophe/>

simply at the same time for the two roles identified by Farrell et al. (2006, p. 9), “the accumulation of human capital (that is, educated and trained men and women) on the one hand, and the accumulation and application of knowledge to the production process, on the other,” as highly educated workers are at the same time one of the outputs of higher education and “the primary source of application of global academic knowledge to the domestic economy.” (Farrell et al., 2006, p. 13). And we will show that this alone may question the provision of education by a private owner. While “many academic leaders assert that a proper higher education is supposed to be removed, or at least substantially insulated, from commercialization and market forces,” (Johnstone, 2003, p. 356) partial privatization may be a pragmatic solution to improve the management of education institutions, ease the pressure on public resources and stick more closely to the market needs without losing sight of general interest.

At this stage, it seems important to define more precisely the terms we will be using throughout the paper. Privatization of a public university does not necessarily mean the transfer of its legal ownership to a private owner. This has almost never been observed, contrasting with other public enterprises such as airlines or water and electricity suppliers (Levy, 2013). We mean rather, as Levy (2013, p. 36) put it, that “the public universities in question seek to improve their management such that they are more like their private counterparts.” Being like a private university would mean seeking more efficiency until the university’s resources are devoted to “the most profitable income-generating activity open to it” (Williams, 1996, p. 52). In short, a partially privatized public university heeds more attention to its profit. This may occur for several reasons and may take different forms (Levy, 2013). First, as in East Asia, governments reduce the financial budget of public higher education, compelling indirectly public universities to seek other sources to finance their activities. Second, as in Romania, public universities are subject to an entrepreneurial partnership with foreign universities, which encourages labeled public universities to improve management and administration activities hence improving efficiency. The third model of partial privatization adopted in post communist Russia allows students who cannot access the restrictive public quota (free or low tuition fees) to enter the same universities while paying for their enrollment. Public universities are encouraged or even constrained to give more room to diverse members of the society in governance boards, among which the potential employers, that is, the firms, which participate increasingly in strategic decisions (Godonoga, 2017) introducing their ways of seeing things, in a way their philosophy and their practices. On the other side, a private university may be made “more public,” in the sense that it may be compelled to take into account the general interest, even if it remains legally entirely privately owned. Indeed States may directly or indirectly influence the private provision of higher education through regulatory mechanisms or general standards and procedures (Godonoga, 2017). What matters is not the legal owner of the university, but rather how the decisions are taken, who participates in the decisions, thus the firm’s objective function to be maximized. Hence legally private universities may be partly public in that they are forced to integrate at least partially criteria linked to general interest and legally public universities may be partially private in that they integrate profit maximization into their management procedures. In this paper, a partially privatized university simply maximizes a weighted sum of social welfare and profit.² At the extremes we have purely public universities and purely private ones. Each time we will refer to the State’s or public share (or management or ownership) in the university, we will mean the weight of the social welfare in the objective function maximized by the university.

²Other ways exist to model Public–Private Partnerships, for instance in Iossa and Martimort (2015) and Attanasi et al. (2020), or in Canta (2021) on health care issues. We ignore the complementarity that may exist between public and private services as assumed by Hickey et al. (2021).

When we consider the effect of higher education in this model, with a monopoly in the education sector and a monopoly in the product one, there are inefficiencies due to the market power of each monopoly. Moreover the resulting vertical supply chain implies a “double marginalization” effect, another type of market inefficiency now familiar in Industrial Organization.³ The question in the present paper is to what extent the public presence in the management of the university may compensate for these market inefficiencies, while taking into account the own inefficiency of public management.

Another question to be emphasized regarding higher education is labor market, insofar as today’s students are tomorrow’s workers. Several authors (De Fraja, 2001; Oliveira, 2006; Romero & Del Rey, 2004) highlight the link between education and labor market only by considering wages in the function of students’ utility. But they do not consider wages as endogenous variables. In our model we consider that salaries are endogenously determined through the equilibrium between supply and demand on the labor market. We moreover emphasize the link between education’s quality and the quality of commercialized goods through workers’ quality. This is in line with the findings of the OECD Survey of Adult Skills “that educational attainment is positively related to skill proficiency.” (Sarrico, 2017, p. 17). To the best of our knowledge, we are the first to model explicitly the link between education and the final product market this way. And rather than supposing directly that employees’ wages/utilities or firms’ profits are increasing with qualification, as in existing literature, we suppose more basically that a better qualification results in a better product (a better educated employee will produce a handbag of better quality). We then prove under this hypothesis, that equilibrium net salaries, employees’ utilities and the firm’s profit are increasing with education quality.

Specifically, we consider a model of successive monopolies in which one University “sells” qualification to students/workers who “sell” skilled labor to a manufacturer which finally sells its product to consumers. Workers are differentiated by their cost of learning/working which is itself increasing in the skill level. On the product market, there is a vertical preference for quality. The product’s quality is assumed to increase with the qualification of workers. We allow private and public sectors to hold shares in the University. The unit cost at the University is assumed to be increasing in the proportion of shares held by the State. In the first step of the game, the State fixes the proportion of shares it holds in the University. In the second step, the University chooses tuition fees to maximize a sum of social welfare and University profits weighted respectively by the public and private shares in the University. In the third step, the firm fixes its price so as to maximize its profit. The wage balances demand and supply on the labor market.

The results on the equilibrium degree of privatization turn out to depend discontinuously on the “State’s inefficiency parameter” which measures how much the unit cost increases with the proportion of public ownership of University shares. When the State’s inefficiency parameter is below a critical level, it is optimal to have a partially privatized University where the State keeps a very large majority of University’s shares⁴ and the appeal to the private sector is very limited. Above the threshold, full privatization emerges.

However in most cases, under partial privatization, the partially privatized University would make losses. This equilibrium is sustainable through the State’s commitment to cover the potential University’s losses, that is, to subsidize tuition fees. It is thus optimal for the State

³This successive monopolies structure may be interpreted as a case of complementary monopolies where one of the firms play first. On complementary monopolies, see for instance the pioneering works of Cournot (1960) and Sonnenschein (1968) and a more recent and general characterization in Amir and Gama (2013).

⁴More than 80%.

to publicly subsidize the partially private University to reduce market inefficiencies which are different from the inefficiencies already identified in the literature (underinvestment in higher education because of individual budget constraints and family background⁵). This provides an additional theoretical basis for what we observe about the policies of countries, including the most liberal ones, in terms of granting scholarships to students and more generally of subsidizing universities.

Nevertheless implementing this policy may not be always politically feasible. States may be suspected to enable the existence of inefficient universities that “choose to make losses.” We then solve the model when one introduces the constraint that the University should not make losses after privatization. Under this constraint, we also prove that, when the State is not too inefficient, it keeps a large share⁶ in the University. It is only for large enough values of the State's inefficiency parameter that both cases converge to full privatization. Naturally the commitment case is closer to the social optimum and the losses in terms of social welfare due to the impossibility to subsidize the University decrease as the State's inefficiency parameter increases and becomes null when the State becomes too inefficient.

In both cases, that is, whether or not the State can subsidize the partially private University, the State has to play a crucial role to regulate the market through a substantial presence in the education sector. This is so whereas we take into account public inefficiencies, unless the State is too inefficient in which case it has better leave the education sector to completely private management.

1.1 Related literature

Most authors who deal with vertical successive monopolies under linear wholesale prices show that the laissez-faire equilibrium is not socially optimal (Lerner, 1933; Machlup & Tabor, 1960; MacKenzie, 1951; Stigler, 1951; Zeuthen, 1933). Indeed, cumulative mark-ups from one producer to another might increase considerably the price charged to consumers and reduce quantities. One way to overcome double marginalization is public regulation through State's ownership. For example, an upstream public firm chooses its price at its marginal cost (as if the buyer produces itself the upstream product) or a downstream public firm sells its product at its marginal value (as if the firm produces itself the upstream product). In both situations, market regulation absorbs the cumulative markups effect (Stigler, 1951). However, using a spatial model, Heywood and Pal (2004) rule out the problem of double marginalization by assuming that the demand for the final product is completely inelastic. The authors show that, due to the strategic interaction between upstream and downstream firms, public regulation may well increase downstream firms' profits and decrease welfare with respect to a model with no public intervention. Hence, the issue of public regulation in the context of successive monopolies is still controversial and remains of interest.

Furthermore, most articles which study State regulation and privatization in vertically differentiated markets, introduce general models of competition between public and private firms (Grilo, 1994; Nishijima, 2008). Rare are authors who study these issues in a specified market, for example health (Barbot & Brandao, 2005) or education (Romero & Del Rey, 2004).

⁵In this respect, see Fernández (1998), Keane and Wolpin (2001), Cameron and Taber (2004), Brown et al. (2012) and Park (2019) among numerous others.

⁶This share is equal to $2/3$ which is lower than the public share kept in the commitment case.

More specifically, Romero and Del Rey (2004) focused only on competition between private and public universities and did not deal with mixed ownership. Otherwise, to the best of our knowledge, Ishibashi and Kaneko (2008) are the only authors to have analyzed the possibility of partial privatization within the context of vertical differentiation. The authors showed that within a mixed duopoly, under price and quality competition, partial privatization holds at equilibrium. However, they did not deal with the education issue. Hence, partial privatization of education (or higher education) in relation with the productive sector remains under-explored in the literature.

Public institutions are generally considered as less efficient than private ones, and privatization is usually adopted to offset State's inefficiency. Indeed, Tuckman (1984) argues that public ownership generates additional costs due to inefficient production's management, poor production's capacities or conflict of interests between the State and the managers. To the best of our knowledge, only Oliveira (2006) highlights this point by considering a positive parameter which captures the degree of State's inefficiency in the cost function of public universities. However, the author supposes the same level of cost inefficiency for either public universities or partially public universities. In the present paper, we consider that the degree of State's inefficiency is weighted by the share held by the State in the university, which is more realistic in our opinion.

Finally, we position our paper relative to the literature addressing the labor market in theoretical models of education economics. De Fraja (2001) and Oliveira (2006) consider future compensation or lifetime earnings for a student/worker as a function of his/her ability and the average ability of students attending the same university (or the quality of the university as in Romero and Del Rey (2004)), but do not take into consideration interactions between demand and supply on the labor market. In his pioneering work, Becker (1975) assumes that the training or education, be it on-the-job training assumed by firms or through schooling, raises the firm's revenue, without indicating the mechanism. Hatsor (2014) relates directly the quantity produced by the firm to the level of education achieved, thus perceiving productivity in quantitative terms. The quality to which Hatsor refers is the quality of teaching, not of the product. Hatsor and Zilcha (2020) suppose that attending a university augments the basic skills (or the earning potential) by some factor and that production is carried out by competitive firms with no differentiation.

In this paper, we consider a monopoly with market power that may choose the quality of its product. Wages are determined endogenously through labor market clearing. The supply of labor is given by the number of students/workers having accepted to study and work and the demand for labor equals the demand for the final output in the market. Without supposing that a better education increases the earnings a priori, we prove that it holds at equilibrium. Actually we prove that the net salary, the utility of workers/students and the firm's profit are increasing with the education quality. It thus seems that the hypotheses made in previous literature about the effect of education on productivity in a broad sense may result from our more basic hypothesis on the link between the quality of the product and the education quality.

That the product's quality increases with the qualification of workers may be related to the abundant literature on the effect of R&D on productivity, such as Griliches (1979, 1998), Jaffe et al. (1993), Jaffe and Trajtenberg (1996), Mohnen (1996), Blomstrom and Kokko (1998), and Cincera and van Pottelsberghe (2001). In a way, we confirm the pioneering idea of Griliches that the technical change identified as the engine of growth by the earlier works of Abramovitz (1956) and Solow (1957) is an endogenous result of the economic activity (Farrell et al., 2006). Indeed the number of the students/workers educated by the University and their qualification,

which both may account for productivity, are endogenously determined in our model. Our hypothesis on the link between the qualification of the workers and the product's quality can also be related to the conclusions of the OECD Survey of Adult Skills (Farrell et al., 2006). Indeed the Survey finds that the adults who have tertiary education attainment have a higher proficiency in information processing skills, probably resulting in higher products' quality, than those who have not attained upper secondary education.

The remainder of the paper is organized as follows. Section 2 introduces the model and characterizes the social optimum. Section 3 studies the equilibrium of the model in the case where the State commits to cover the possible losses of the partially private University. Section 4 characterizes the equilibrium of the model in the no-commitment case where the State has not the possibility to cover the University's losses. Section 5 concludes. All proofs are given in Appendix A.

2 THE MODEL

We consider one University which supplies higher education.⁷ It provides qualification e to students at tuition fees t . Graduate students “sell” skilled labor to one private firm perceiving a unit salary ω . The firm offers its final product at price p . The quality q of the product which is supplied is an increasing function of the qualification e of the workers. For the sake of simplicity we assume $q = e$. The market's structure is depicted in Figure 1.

The workers. It is natural to suppose that the qualification of a worker increasingly conditions the produced quality of the final output. For simplicity sake, we suppose that the product's quality equals the qualification, hence allowing to denote in the same manner both variables. Denote by e the worker's qualification/effort and at the same time the product's quality. As in De Fraja (1999), the utility of a worker/student is given by:

$$U_\alpha = \omega - t - \alpha e,$$

where α characterizes the sensitiveness of each student/worker to qualification and is uniformly distributed over $[0, \bar{\alpha}]$ with a density normalized to one. Indeed, a higher qualification and product's quality needs more effort and time, thus is (all things being equal) not desirable from the workers' viewpoint. Parameter $\bar{\alpha}$ is assumed to be sufficiently high so that it is never constraining. A type α -worker goes to the University to acquire a qualification and to work if this provides him/her a larger utility than staying at home.⁸

The consumers. There is a continuum of consumers uniformly distributed on $[0, \bar{\theta}]$ with a density normalized to 1, supposing that $\bar{\theta} > 1$. The utility of a consumer buying one unit of product of quality $q = e$ at price p is given, as in Mussa and Rosen (1978), by:

$$V(\theta) = \begin{cases} \theta e - p & \text{if he/she buys one unit of product,} \\ 0 & \text{if he/she buys nothing.} \end{cases}$$

⁷We ignore in this model the role of universities in terms of production of R&D as in Stenbacka and Tombak (2020) or equivalently that the produced R&D is translated into quality of education.

⁸An alternative interpretation is that workers with no qualification produce a numeraire good under constant returns to scale.

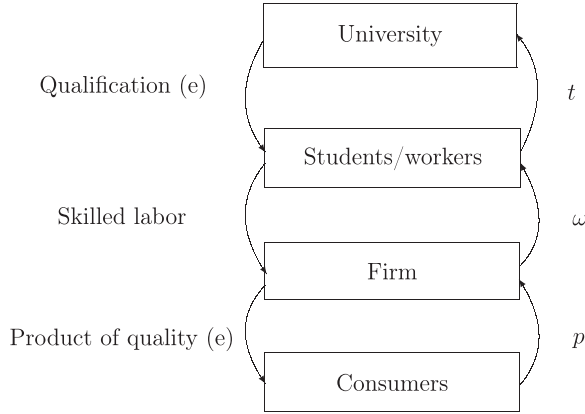


FIGURE 1 The market structure

Each consumer is assumed to buy one unit of output if it procures him/her a positive utility. Otherwise, he/she buys nothing.

We assume that one unit of output requires one unit of labor. Thus, the demand for labor equals the total product demand. Quality q may be chosen in $[0, \bar{q}]$, \bar{q} being the maximal quality possible.

We suppose that the population of consumers is different from the population of workers. This amounts to assume that the considered sector is negligible w.r.t. the rest of the economy, so that the quantity consumed by the workers in the firm is negligible.

The University. We denote by $\beta \in [0, 1]$ the share held by the State in the University. The extreme values $\beta = 0$ and $\beta = 1$ correspond respectively to a fully privatized and a public University.

Assuming that public universities are less efficient than private ones, we introduce a parameter k which captures their degree of inefficiency in the University's cost function.⁹ However, as partially public universities are less inefficient than fully public ones, we consider that the degree of State's inefficiency is weighted by the percentage of shares held by the State in the University. We thus implicitly assume that the managerial effort of private shareholders reduces costs (which is one of the reasons for privatization). Hence the higher is the degree of privatization, the more important is the managerial effort, the lower are the costs. Formally, the unit education cost is assumed to be given by:

$$c(e) = (\beta k + (1 - \beta))e,$$

where parameter k measures the degree of cost inefficiency of public management. We suppose $k \geq 1$, so that a purely public university is less efficient than its private counterpart. Indeed, the cost is equal to ke when $\beta = 1$ (purely public University), while this cost is equal to e when $\beta = 0$ (purely private University). The case $k = 1$ corresponds to a fully efficient State.

The University maximizes a sum of the social welfare (SW) and the profit of the University (Π^U) weighted respectively by the public and private shares in the University:

$$G = \beta SW + (1 - \beta)\Pi^U.$$

⁹There is an abundant literature to explain the tendency of public management to inefficiency, for instance, Mueller (1989), Niskanen (1971), and Wilson (1989). More references may be found in Drazen (2000).

The social welfare is given by:

$$SW = \pi^U + \pi^F + SC + SL,$$

where SC and SL stand respectively for the consumers' and workers' surpluses and Π^U and Π^F stand respectively, for the University and firm's profits.

Define $\kappa = \frac{k-1}{\bar{\theta}-1}$.

The game. Decisions take place in a three-step game:

- The State chooses the quality of education (which equals the product's quality) e in $[0, \bar{q}]$, then its share in the University $\beta \in [0, 1]$ so as to maximize the social welfare SW .
- The University determines the tuition fees t so as to maximize the weighted sum G .
- The firm chooses p so as to maximize its profit Π^F .

Wages adjust balancing the demand and supply on the labor market.

The fact that the education quality be decided by the State may seem a natural hypothesis in some cases, as the State imposes in some countries the specifications to be met by universities, be they private or public. In the terms used by Godonoga (2017), our approach may be qualified as a “supply-push” one. Other alternatives are available. Remaining in the “supply-push” approach, the University may be supposed to be the one which decides the education quality. But it would be a “demand-pull” model to suppose that the quality is decided by the firm.¹⁰

We distinguish two cases: first, the commitment case where the State commits to cover the University's deficit when such a deficit appears, allowing the University to make losses at equilibrium (Section 3); second, the no-commitment case where we assume that the State does not cover the potential deficit of the University, solving the first step of the game corresponding to the choice of the State in terms of shares β and education quality e , under a constraint of nonnegativity of the University's profit (Section 4). In our analysis, we compare our results with a benchmark, the social optimum case defined and calculated just below.

In all the considered cases, wages adjust so as to balance supply and demand on the labor market. Worker α decides to acquire qualification at the University and work at the firm¹¹ when $U_\alpha \geq 0$, equivalent to $\alpha \leq \frac{\omega-t}{e}$. Thus, given the hypothesis on the density of workers, labor supply is $\frac{\omega-t}{e}$. On the demand side, Consumer θ purchases the product if $V(\theta) \geq 0$, equivalent to $\theta \geq \frac{p}{e}$. Hence, the demand for the product is $Q = \bar{\theta} - \frac{p}{e}$.

The equilibrium wage is such that:

$$\omega - t = \bar{\theta}e - p.$$

In all the considered cases (social optimum, commitment and no-commitment cases), given e , p , t and the parameters, the labor market clearing wage is given by the expression:

$$\omega = \bar{\theta}e - p + t. \quad (1)$$

¹⁰With our specification of the model, the results remain the same if we suppose alternatively that the University or the firm choose the quality of education. This is discussed further in the conclusion. Details of calculations are provided in Footnotes 14 and 16 with different timings for the choice of e .

¹¹Only qualified workers are employable. An agent's decision to work or not to work depends on the *net salary* (wage minus higher education cost) a worker is going to earn.

2.1 The social optimum

At the social optimum, the State fixes simultaneously the output price p , e the quality (of education and product), the tuition fees t and the share it holds in the University (β), the wage adjusting on the labor market. We prove that at the optimum, the salary ω and the tuition fees t are undetermined, under the condition that the difference between them must be constant, and the State chooses the price p so as to cancel the aggregate profit ($\Pi^U + \Pi^F = 0$). As long as the difference between the salary and the tuition fees satisfies the required condition, the exact values of ω and t have no impact on the optimal level of the product's quantity (then employment), profits and the social welfare. We summarize in Result 1 the outcome at the social optimum.

Result 1 (The social optimum). *At the social optimum, the share held by the State in the University, quality of education, tuition fees, price, salary and quantity are given by:*

$$\beta^{opt} = 0, \quad e^{opt} = \bar{q}, \quad \omega^{opt} - t^{opt} = \frac{\bar{q}(\bar{\theta} - 1)}{2}, \quad p^{opt} = \frac{\bar{q}(\bar{\theta} + 1)}{2}, \quad Q^{opt} = \frac{\bar{\theta} - 1}{2}.$$

Profits and social welfare are as follows:

$$\Pi^{Uopt} + \Pi^{Fopt} = 0, \quad SW^{opt} = \frac{\bar{q}(\bar{\theta} - 1)^2}{4}.$$

At the social optimum, the State privatizes completely the University! But this is so because it has the possibility to choose all the variables: the tuition fees, the product's price and the education quality, so as to maximize the social welfare, thus while internalizing all the externalities. In this case, it has no interest in keeping a share in the University, as it knows that education will be more costly when $\beta > 0$.

Only the difference $\omega - t$ is specified at the social optimum, not the precise values of ω and t which may vary along this linear relationship. Indeed the salary, the tuition fees and the price are linked by the labor market clearing relation. The quantity of the output being equal to the quantity of labor produced by the University, the sum of the profits (University and firm) depends only on the price. In the social surplus ω and t persist only in the workers' surplus which depends on the difference $\omega - t$, and not on each one of them.

3 EQUILIBRIUM IN THE COMMITMENT CASE

In this section, we characterize the equilibrium for the commitment case solving the game by backward-induction.

Inserting the labor-clearing wage given in Equation (1) into the firm's profit yields:

$$\Pi^F = (p - \omega) \left(\bar{\theta} - \frac{p}{e} \right) = (2p - \bar{\theta}e - t) \left(\bar{\theta} - \frac{p}{e} \right). \quad (2)$$

The firm's profit is then obtained as a function of e , p , and t , then maximized w.r.t price p , providing the price, the wage ω and the output quantity Q as a function of e , t , and β .

The University's profit is given by: $\Pi^U = (t - C(e))Q$.

The social welfare is given by: $SW = \pi^U + \pi^F + SC + SL$, where SC and SL stand, respectively, for the consumers' and workers' surpluses. The partially privatized University maximizes $G = \beta SW + (1 - \beta)\pi^U$.

Inserting the obtained expressions of p , ω and Q in π^U and SW , we obtain the expression of G as a function of t , e and β . Maximizing G w.r.t the tuition fees t , we obtain the equilibrium of the second step provided in Lemma 1, that is, the value of t , the tuition fees as a function of β and e .

Lemma 1. *For a given value of the State share in the University (β), and a given education quality e , at the equilibrium of the second step, the University fixes the tuition fees as follows:*

$$t(\beta, e) = \frac{e(\bar{\theta}(2 - 3\beta) + 2(k\beta + (1 - \beta)))}{4 - 3\beta}. \quad (3)$$

The output price, the salary, and the output quantity are thus given by:

$$p = \frac{e(1 - \beta + k\beta + \bar{\theta}(7 - 6\beta))}{2(4 - 3\beta)}; \quad \omega = \frac{e(\bar{\theta}(5 - 6\beta) + 3(\beta k + (1 - \beta)))}{2(4 - 3\beta)}; \quad Q = \frac{(\bar{\theta} - (\beta k + (1 - \beta)))}{2(4 - 3\beta)} \text{ for } \beta < \frac{\bar{\theta} - 1}{k - 1} = \frac{1}{\kappa}$$

and 0 otherwise.

Note that this may imply that the University gives grants to students, namely that we may have $t < 0$. This is the case, that is, $t(\beta, e) < 0$ iff

$$\bar{\theta}(2 - 3\beta) + 2(\beta k + (1 - \beta)) = \beta(\bar{\theta}(2\kappa - 3) - 2\kappa) + 2(1 + \bar{\theta}) < 0,$$

which can hold only when $\bar{\theta}(2\kappa - 3) - 2\kappa < 0$. Thus,

- if $\bar{\theta}(2\kappa - 3) - 2\kappa \geq 0$ which is equivalent to ($\kappa > 3/2$ and $\bar{\theta} \geq \frac{2\kappa}{2\kappa - 3}$), then $t > 0$. The students never receive grants independently of the share of the State in the University.
- if $\bar{\theta}(2\kappa - 3) - 2\kappa < 0$ which is equivalent to ($\kappa \leq 3/2$ or ($\kappa > 3/2$ and $\bar{\theta} < \frac{2\kappa}{2\kappa - 3}$)), then the students are given grants ($t < 0$) for

$$\beta > \frac{2(1 + \bar{\theta})}{2\kappa - \bar{\theta}(2\kappa - 3)}.$$

On the other hand, the University may fix a level of tuition below its marginal cost, hence making losses and needing public subsidies. This is the case when $t(\beta, e) < C(e)$, which is equivalent to

$$3(k - 1)\beta^2 + \beta(-2(k - 1) - 3(\bar{\theta} - 1)) + 2(\bar{\theta} - 1) < 0.$$

The previous inequality rewritten using κ then simplified by $(\bar{\theta} - 1)$, is equivalent to: $3\kappa\beta^2 - (3 + 2\kappa)\beta + 2 < 0$. This second-order polynomial has two roots: $2/3$ and $\frac{1}{\kappa}$. The polynomial is negative between the two roots but the ranking of the roots is different depending on whether $\kappa > 3/2$ or $\kappa < 3/2$.

- When $\kappa > 3/2$, $\frac{1}{\kappa} < 2/3$, the polynomial is negative when $\beta \in [\frac{1}{\kappa}, 2/3]$.
- When $\kappa < 3/2$, $\frac{1}{\kappa} > 2/3$, the polynomial is negative when $\beta \in [2/3, \max(\frac{1}{\kappa}, 1)]$.

The choice of the State at equilibrium in terms of education quality and public share is given in Proposition 1.

Proposition 1 (The commitment case). *At the subgame perfect equilibrium, the State chooses $e^* = \bar{q}$ and its share β^* in the University as follows (recalling that $\kappa = \frac{k-1}{\theta-1}$ and denoting $\kappa_0 \equiv \frac{3}{28}(9 - 4\sqrt{2}) \simeq 0.358194$):*

- (i) If $\kappa = 0$ then $\beta^* = 1$, that is, the University is completely public;
- (ii) if $0 < \kappa < \kappa_0$, then privatization is partial with $\beta^* = \hat{\beta}(\kappa) = \frac{1}{6\kappa} (12\kappa - 3 + \sqrt{9 - 36\kappa + 32\kappa^2})$;
- (iii) if $\kappa \geq \kappa_0$, then we have full privatization, that is, $\beta^* = 0$.

As depicted in Figure 2 the State's share in the University at equilibrium (β^*) depends discontinuously on the State's inefficiency parameter (κ). Note that when the University is partially privatized, β^* is decreasing for values of $\kappa \in [0, \kappa_0[$ tending towards $\beta_0 = \beta(\kappa_0) \simeq 0.818$. Hence, under partial privatization the State holds always a large majority in the University with more than 80% of shares.

Mathematically, the discontinuity of the optimal value of β^* results from the fact that SW , the function to be maximized, may be double-peaked, with a local maximum at 0 and another one at $\hat{\beta}(\kappa)$. The global maximum is the one among the two local maxima with the highest value of SW . The comparison between both depends on κ . The optimal value β^* jumps down from $\hat{\beta}(\kappa)$ to zero, when κ goes beyond some threshold.

It is interesting to notice that, as $\hat{\beta}(\kappa) > 2/3$ for all $\kappa < \kappa_0 (< 3/2)$, a partially privatized University always makes losses at equilibrium and is then (partially) funded by the State. On the other hand, a partially privatized University provides grants to its students iff $\kappa \in \left[0, \frac{3}{14}(3 - \sqrt{2})\right)$, that is, if the public management is not too inefficient, noting that $\frac{3}{14}(3 - \sqrt{2}) < \kappa_0 \equiv \frac{3}{28}(9 - 4\sqrt{2})$.

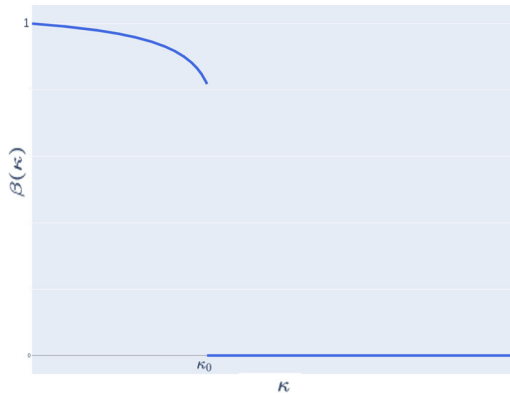


FIGURE 2 The State's share in the University, β^* , at equilibrium in the commitment case

Finally, the expression of $\beta^* = \hat{\beta}(\kappa)$ in case (ii) is not mathematically defined at $\kappa = 0$, but converges to 1, the optimal value obtained for $\kappa = 0$, as κ tends to zero, whence the continuity at $\kappa = 0$ of β^* .

Corollary 1 characterizes the equilibrium outcome in terms of relevant variables: price, tuition fees, salary, exchanged quantity of the product, profits and social welfare.

Corollary 1. *At the subgame perfect equilibrium the prices, salary, quantity, profits and social welfare are given, for each case identified in Proposition 1, as follows:*

(i) *When $\kappa = 0$ (at equilibrium, $\beta^* = 1$: fully public University):*

$$\begin{aligned} p &= \frac{1}{2}(\bar{\theta} + 1)\bar{q}, & t &= (2 - \bar{\theta})\bar{q}, & \omega &= \frac{1}{2}(3 - \bar{\theta})\bar{q}, \\ Q &= \frac{1}{2}(\bar{\theta} - 1). \\ \Pi^U &= -\frac{1}{2}(\bar{\theta} - 1)^2\bar{q}, & \Pi^F &= \frac{1}{2}(\bar{\theta} - 1)^2\bar{q}, & SW^C &= \frac{1}{4}(\bar{\theta} - 1)^2\bar{q}. \end{aligned}$$

(ii) *When $0 < \kappa < \kappa_0$ (at equilibrium $0 < \beta^* < 1$: partially private University):*

$$\begin{aligned} p &= \frac{\bar{q}(1 + \hat{\beta}(\kappa)\kappa(\bar{\theta} - 1) + \bar{\theta}(7 - 6\hat{\beta}(\kappa)))}{2(4 - 3\hat{\beta}(\kappa))}, \\ t &= \frac{\bar{q}(\bar{\theta}(2 - 3\hat{\beta}(\kappa)) + 2\hat{\beta}(\kappa)\kappa(\bar{\theta} - 1) + 2)}{(4 - 3\hat{\beta}(\kappa))}, \\ \omega &= \frac{\bar{q}(\bar{\theta}(5 - 6\hat{\beta}(\kappa)) + 3\hat{\beta}(\kappa)\kappa(\bar{\theta} - 1) + 3)}{2(4 - 3\hat{\beta}(\kappa))}, \\ Q &= \frac{\bar{\theta} - \kappa\hat{\beta}(\kappa)(\bar{\theta} - 1) - 1}{2(4 - 3\hat{\beta}(\kappa))}. \\ \Pi^U &= \frac{\bar{q}(\bar{\theta} - 1)^2(2 - 3\hat{\beta}(\kappa))(1 - \kappa\hat{\beta}(\kappa))^2}{2(4 - 3\hat{\beta}(\kappa))^2}, \\ \Pi^F &= \frac{\bar{q}(\bar{\theta} - 1)^2(1 - \kappa\hat{\beta}(\kappa))^2}{2(4 - 3\hat{\beta}(\kappa))^2}, \\ SW^C &= \frac{\bar{q}(\bar{\theta} - 1)^2(1 - \kappa\hat{\beta}(\kappa))^2(7 - 6\hat{\beta}(\kappa))}{4(4 - 3\hat{\beta}(\kappa))^2}. \end{aligned}$$

(iii) *When $\kappa \geq \kappa_0$ (at equilibrium, $\beta^* = 0$: fully private University):*

$$\begin{aligned} p &= \frac{\bar{q}(7\bar{\theta} + 1)}{8}, & t &= \frac{\bar{q}(\bar{\theta} + 1)}{2}, & \omega &= \frac{\bar{q}(5\bar{\theta} + 3)}{8}. \\ \Pi^U &= \frac{1}{16}(\bar{\theta} - 1)^2\bar{q}, & \Pi^F &= \frac{1}{32}(\bar{\theta} - 1)^2\bar{q}, & SW^C &= \frac{7}{64}(\bar{\theta} - 1)^2\bar{q}. \end{aligned}$$

Figure 3a,b provide the social welfare and the University's profit at equilibrium for all values of κ . It has been obtained numerically for $\kappa \in]0, \kappa_0]$.

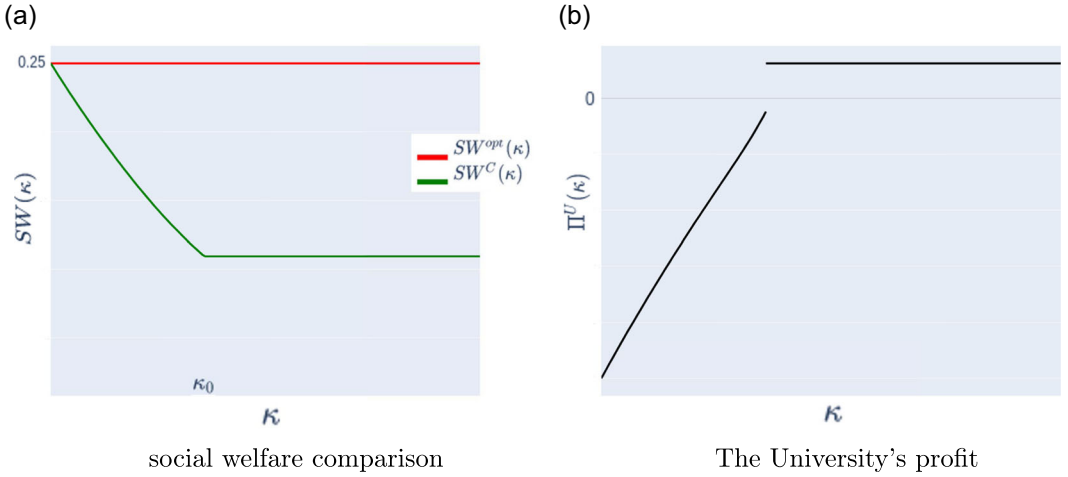


FIGURE 3 (a) Social welfare and (b) University's profit at equilibrium in the commitment case

When the State is fully efficient (Case (i), $\kappa = 0$) the University is fully State managed and tuition fees (t) may be positive or negative, meaning that students may receive grants (when $\bar{\theta} > 2$). Note however that in this case the fees are always fixed below the University's marginal cost ($t = (2 - \bar{\theta})\bar{q} < C(\bar{q}) = \bar{q}$, as $\bar{\theta} > 1$). This underpricing policy is adopted to eliminate the market's inefficiencies due to the firm's pricing above its marginal cost ($p > \omega$). Indeed, a decrease in tuition fees generates a decrease in equilibrium wages ($\frac{\partial \omega}{\partial t} > 0$), which reduces the double marginalization effect. Moreover, the tuition fees are fixed at a level so as to cancel the aggregate profit ($\Pi^F + \Pi^U = 0$), as if the firm produced at a price equal to the *social* marginal cost. Such a mechanism ensures the same level of welfare as the socially optimal one. Hence, as in Stigler (1951) we conclude that in the full efficiency case one way to overcome double marginalization is public regulation through State ownership of the upstream firm.

Note that the firm and the University may be State subsidized, insofar as we assume that a negative level of tuition fees corresponds to giving grants to students ($t < 0$ for $\bar{\theta} > 2$) and a negative level of salaries ($\omega < 0$ when $\bar{\theta} > 3$) implies that the State has to finance the firm to enhance employment.

When partial privatization holds at equilibrium (Case (ii)), the level of welfare is always under the optimum's level as illustrated in Figure 3a. An increase in the degree of privatization increases tuition fees increasing the double marginalization effect and the market's inefficiency, thus decreasing social welfare.

Note that partial privatization appears at equilibrium even if the University makes losses as obtained in Figure 3b. This should be explained by the fact that partial privatization has two contradictory effects. On the one hand, a decrease in β decreases cost inefficiency due to State ownership ($c(e) = (\beta k + 1 - \beta)e$), thus reducing losses. On the other hand, it increases the output price, which increases the market's inefficiency (double marginalization). To absorb the market's inefficiencies, the social planner tolerates losses even if the University is partially privatized. Our results are similar to those of Gohsh et al. (2013) who consider a model of competition between a public domestic firm and a foreign private one and prove that even if partial privatization emerges at equilibrium, the public firm's price is below marginal cost due to the adverse price effect of privatization: an increase in privatization level decreases domestic firm's losses and increases the foreign price.

Naturally, for high values of the State's inefficiency (Case (iii)), the University is fully privatized. Since there is no State ownership, the University imposes a high level of tuition fees, which increases cumulative markups. In this situation which corresponds to successive private monopolies, both the University and the firm make profits.

It may appear surprising not to have a discontinuity of SW^C , while β^* is discontinuous. Mathematically this happens because, as explained earlier, the function to be maximized (SW), is double-peaked with 0 and another positive value of β as local maxima. The optimal value is equal to the latter for $\kappa < \kappa_0$ and shifts down to 0 when $\kappa > \kappa_0$. At $\kappa = \kappa_0$, the values of SW at the two local maxima are precisely equal, meaning that the optimal value of SW , which is SW^C is continuous.

In Cases (i) and (ii) where the public share in the University is positive, the University makes a negative profit. And for privatization to be feasible, the private sector must have some incentive to buy shares in the University. This is why we need the assumption that the State be able to commit to cover *ex post* the University deficit when such a deficit appears. When this is not possible, we have to take into account a constraint of nonnegativity of the University's profit. This is the object of the following section.

4 EQUILIBRIUM IN THE NO-COMMITMENT CASE

In this section, we assume that the State does not commit to cover the losses the partially privatized University may make. A constraint of nonnegativity is introduced on the University's profit. Proposition 2 provides the equilibrium in this case.

Proposition 2 *The no-commitment case. Under the constraint of nonnegativity of the University's profit, at the subgame perfect equilibrium, the State chooses the higher education quality $e^{**} = \bar{q}$ and its share β^{**} as follows (denoting by $\kappa_1 = \frac{6 - \sqrt{21}}{4}$):*

- (iv) $\beta^{**} = \frac{2}{3}$, if $0 \leq \kappa < \kappa_1$ (i.e., partial privatization),
- (v) $\beta^{**} = 0$ if $\kappa \geq \kappa_1$ (i.e., full privatization).

Figure 4 depicts graphically β^* obtained in the commitment case and β^{**} in the no-commitment one. In the no-commitment case the University switches from partial privatization to full privatization at $\kappa = \kappa_1 \simeq 0.3543$. In the commitment case (Proposition 1) the University switches to full privatization at $\kappa_0 \simeq 0.3582 > \kappa_1$. Hence, the no-commitment and commitment solutions respectively, β^{**} and β^* meet from $\kappa = \kappa_0$. In other words, from the value of $\kappa = \kappa_0$ the constraint on the University's profit is no longer active, and the State chooses anyway to privatize completely. As the values of κ_0 and κ_1 are very close, we represent in Figure 4b a zoom in on the figure on the interval $[\kappa_1, \kappa_0]$, with a change of scale on the β -axis, so that we see more precisely and relevantly what happens.

As the State does not commit to cover the University's losses, partial privatization is chosen for low values of the State's inefficiency parameter, but with a lower value of the State's share in the University to overcome the State's inefficiency. As the University is not allowed to make

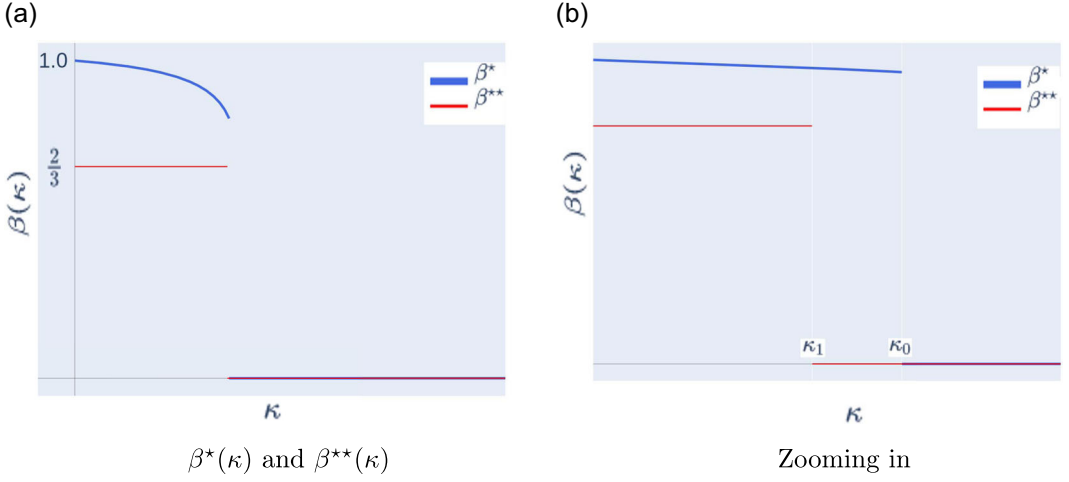


FIGURE 4 The State's share at equilibrium in the commitment (β^*) and no-commitment (β^{**}) cases. (a) $\beta^*(\kappa)$ and $\beta^{**}(\kappa)$. (b) Zooming in

losses, the State chooses partial privatization even in the full efficiency case where it is as efficient as a private owner.¹²

In Corollary 2, we provide the equilibrium outcome when the University is partially privatized. The equilibrium outcome for Case (v) is the same as in Case (iii) given in Corollary 1.

Corollary 2. For $\kappa < \kappa_1$ (Case (iv)), at equilibrium in the no commitment case, the University is partially privatized and the output price, the tuition fees, the salary, quantity, profits and social welfare of equilibrium are given as follows:

$$\begin{aligned}
 p &= \frac{\bar{q}}{12}(9\bar{\theta} + 2\kappa(\bar{\theta} - 1) + 3), & t &= \frac{\bar{q}}{3}(2(\bar{\theta} - 1)\kappa + 3), \\
 \omega &= \frac{\bar{q}}{4}(\bar{\theta} + 3 + 2\kappa(\bar{\theta} - 1)), \\
 Q &= \frac{(\bar{\theta} - 1)}{12}(3 - 2\kappa), & \Pi^U &= 0, & \Pi^F &= \frac{(\bar{\theta} - 1)^2\bar{q}}{72}(3 - 2\kappa)^2, \\
 SW^{NC} &= \frac{(\bar{\theta} - 1)^2\bar{q}}{48}(3 - 2\kappa)^2.
 \end{aligned}$$

In the partial privatization case, tuition fees equal the University's marginal cost resulting in zero University's profit. Here, under the assumption of nonnegativity of the University's profit, the State absorbs as far as possible the market inefficiencies due to double marginalization and chooses to hold two-thirds of the University (a majority of shares) even when the State is fully efficient.

Comparing graphically (Figure 5a,b below), the levels of social welfare achieved in the commitment and no-commitment cases with its optimal level (social optimum), it is not surprising that:

¹²That means that the scarcity of public funds is another reason for privatization, besides the assumed inefficiency of public management.

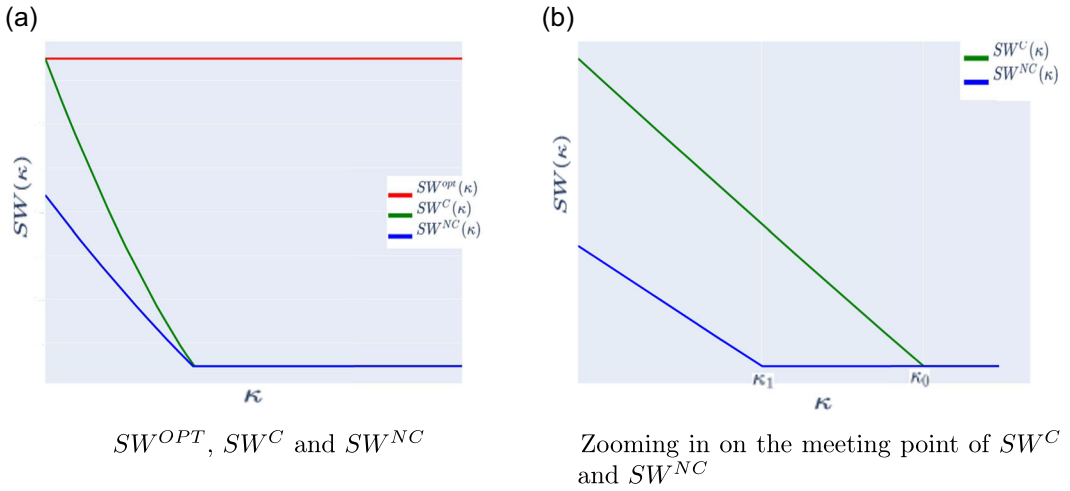


FIGURE 5 Comparison of social welfare at equilibrium in the commitment, no-commitment, and optimum cases. (a) SW^{OPT} , SW^C , and SW^{NC} . (b) Zooming in on the meeting point of SW^C and SW^{NC}

- both cases lead to suboptimal situations, except for the unrealistic full efficiency case under commitment,
- the commitment case is socially better than the no-commitment one.

Although partial privatization is never adopted under the social optimum (Result 1), it is adopted under the two regimes (commitment and no-commitment), with different values of the State's share. The social optimum is a completely centralized solution giving absolute power to the social planner to choose all the variables of interest. The only constraint is the balance of supply and demand on the labor market. Under the commitment and no-commitment regimes, the firm chooses its price and the University chooses the tuition fees, the State choosing its share and the higher education quality while anticipating the choices of the University and the firm. These regimes are doubtlessly more representative of the real world, the no-commitment case corresponding a priori to more liberal governments. Hence, as the State cannot reasonably be supposed to be able to directly manage the economy and the universities, partial privatization may appear to be a possible pragmatic solution to overcome partly the inefficiencies of public management without losing sight of the general interest.

The social optimum being impossible to achieve, the commitment case appears as a second best solution when feasible. The no-commitment regime is a kind of “third best” solution which comes in the last position, as it forbids optimal values of the State's share because of the impossibility to finance the University's losses/tuition fees. This simple model provides a way to measure the losses in terms of social welfare (equal to the difference $SW^C - SW^{NC}$) due to the impossibility for the State to commit to cover the losses of the University (subsidize the tuition fees). The social welfare losses are decreasing with the inefficiency of the State. When the State is particularly inefficient, the two solutions converge and full privatization holds equally under both regimes. The losses in terms of social welfare are however important when the State is particularly efficient, that is, for low values of the State's inefficiency parameter. This may be so while we take into account only the effect of the University on the real economy through

education and the labor market, which is clearly a small part of the externalities of higher education.

Note interestingly that, when the optimal public share in the University is positive (i.e., for low values of κ , so that the State is not too inefficient) under both regimes, this public optimal share does not vary much with the State's inefficiency parameter, remaining at a high level. When the State's inefficiency threshold is crossed, the optimal public share discontinuously shifts down to zero, that is, to completely private management. One can say that there is no room for "mild privatization" or for half measures. At equilibrium, under each regime studied, one must have either a "very publicly" managed University with a substantial presence of the State or a completely private University with no public intervention at all.

Finally, it is easy to see that the utility of each worker is increasing with the quality (which is also the qualification). This is so, while we did not suppose it a priori and even if a higher quality requires a higher effort perceived negatively by the worker. In fact this is so (the student/worker perceives negatively effort/quality) at a given wage and a given tuition fees. But the firm and the University must take this into account to attract students and workers. To do so, they must set a wage/tuition fees such that the utility is nonnegative for a sufficient number of workers. The potential worker will decide to work only if $U = \omega - t - \alpha e \geq 0$. But ω and t are linear w.r.t. e , implying that the utility of each worker is linear w.r.t. e with a positive coefficient. The net salary ($\omega - t$) is also a linear function of e with a positive coefficient, thus is increasing with e . It is even easier to see that the firm's profit is also increasing with the quality, which induces the firm to choose the maximal quality if it were up to it to make this choice, whether this choice is made after or before the choice of tuition fees (See Footnotes 13 and 15). Hence we show that the equilibrium net salary, utility of the workers and the firm's profit are increasing with the quality of education, which corresponds to the assumptions made by the previous papers (Becker, 1975; Hatsor, 2014; Hatsor & Zilcha, 2020).

5 CONCLUSION

We analyzed a model of vertical successive monopolies where one initially public University sells "qualification" to students/workers who "sell" skilled labor to one producing firm which itself "sells" a final product to consumers. We suppose that State ownership generates additional costs. In the first step of the game, the State determines the quality of higher education and the proportion of shares it decides to hold in the University and the proportion which will be held by the private sector. At the second step, the University chooses the level of tuition fees. At the third step, the firm chooses its price. Salaries adjust balancing supply and demand on the labor market.

We prove that, when the State commits to cover the University's losses (thus to subsidize the tuition fees), partial privatization holds at equilibrium for low levels of State's inefficiency, otherwise the University is fully privatized. Moreover, under the constraint that the University should not make losses (the no-commitment case), the results are only slightly different: the private sector owns one-third of the University for small values of the State's inefficiency parameter while full privatization holds for large values. In the two cases the State holds a large majority in the University.

Comparing the two cases with the optimum, we prove that the commitment case is closer to the optimum, thus appearing to be a second best.

Our analysis may be extended in several directions. In the first place, we did not introduce formally as is often done, a shadow cost λ of public funds. Such a shadow cost reflects the fact that “distortionary taxation inflicts disutility $1 + \lambda$ on taxpayers to levy 1 for the State.” (Laffont & Tirole, 1993, p. 55). However, what we called the “commitment case” simply corresponds to the case where the shadow cost $\lambda = 0$ while our “no-commitment case” corresponds to an infinite value of λ . Since similar qualitative results are obtained in these two extreme cases, it can safely be conjectured that they would also hold for intermediate values of the shadow cost.

In our model, we suppose that the higher education quality is determined by the State. This is a natural assumption as the sector of higher education is generally regulated by the State which imposes a set of specifications on universities, even in the most liberal countries. But this is not the only possible assumption. The potential employer, that is, the firm, may be the one which decides the quality of higher education, according to its needs, especially in periods of high unemployment. In this case and with our hypotheses, in particular supposing no costs for the firm other than the wages, the firm will also choose the maximal quality. However this may not hold if it is reasonably supposed that the firm bears other costs. This quality may also be decided by the University itself arguing that the University is in touch with the employers more than the State and that it would be safer for the employment of graduates to let the University decide the quality of higher education. Finally, this quality may be decided through a negotiation between the State and the employer. The University, through the employer representation in the governance boards, may as a matter of fact, allow cooperation between the State and the industry on the questions related to higher education, where both parties may negotiate over the contents of courses and higher education programs.

We can extend our model to the oligopoly case, either in the higher education sector, interestingly between a public university and a private one, or on the output market with at least two firms serving the same market. The framework of endogenous timing may then be considered in our model between a private and a public university, as in Amir and De Feo (2014). In their paper, the simultaneous play never emerges in a subgame perfect equilibrium, which has important consequences in terms of welfare, as it is shown that the welfare is always higher under a sequential game. The consideration of the endogenous timing in our model with an education sector and a productive one may thus a priori have important consequences on our conclusions on privatization.

One may consider the higher education sector within a general equilibrium model as in Kahloul et al. (2017), since each individual may be at the same time a consumer, a student/worker and a shareholder (of the productive firm or of the University). Finally, the consequences in terms of development, in particular poverty, of the existence and privatization of a university be it public or private, may be evaluated as in Kahloul et al. (2019).

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APPENDIX A

Proof of Result 1. At optimum, the State maximizes social welfare in terms of t , β and p .

$$\begin{aligned} SW &= SC(t, p, \beta) + SL(t, p, \beta) + \Pi^U(t, p, \beta) + \Pi^F(t, p, \beta) \\ &= \frac{(\bar{\theta}e - p)^2}{2e} + \frac{(\omega - t)^2}{2e} + (t - C(e))\left(\bar{\theta} - \frac{p}{e}\right) + (p - \omega)\left(\bar{\theta} - \frac{p}{e}\right) \end{aligned}$$

Substituting the labor market equilibrium wage ω given in Equation (1), we obtain:

$$SW = \frac{(\bar{\theta}e - p)(p - C(e))}{e} \quad (A1)$$

The FOC respectively w.r.t p , β and t gives $p = \frac{1}{2}e(\bar{\theta} + C(e))$, $\beta = 0$, however, t is undetermined.

Then we obtain $p^{opt} = \frac{1}{2}e(\bar{\theta} + 1)$ and $\beta^{opt} = 0$. Thus from the labor market equilibrium wage relationship (1), we obtain $\omega^{opt} - t^{opt} = \frac{1}{2}e(\bar{\theta} - 1)$, yielding

$\Pi^{Uopt} + \Pi^{Fopt} = 0$ and $SW^{opt} = \frac{1}{4}e(\bar{\theta} - 1)^2$. Maximizing SW w.r.t. e yields $e = \bar{q}$, whence all the results. \square

Proof of Lemma 1. We solve by backward induction. At the third step of the game, the firm maximizes its profit with respect to p . Inserting the expression of ω obtained in Equation (1) into the firm's profit:

$$\Pi^F = (p - (\bar{\theta}e - p + t))\left(\bar{\theta} - \frac{p}{e}\right) = (2p - \bar{\theta}e - t)\left(\bar{\theta} - \frac{p}{e}\right). \quad (A2)$$

The FOC w.r.t p gives¹³ $p = \frac{3\bar{\theta}e + t}{4}$. Substituting this value for p in (1), we obtain $\omega = \frac{\bar{\theta}e + 3t}{4}$. Integrating the value of p in the equilibrium output Q sold to consumers, we obtain¹⁴

$$Q(t) = \begin{cases} \frac{\bar{\theta}e - t}{4e} & \text{if } t < \bar{\theta}e \\ 0 & \text{otherwise} \end{cases} \quad (A3)$$

At the second step of the game, we determine the level of tuition fees set by the University.

Using the expression of $Q(t)$ given by Equation (A3), the social welfare, given by Equation (A1), may be rewritten as a function of Q as follows:

$$SW(Q) = Q(e\bar{\theta} - Q) - C(e). \quad (A4)$$

Tuition fees are determined so as to maximize:

$$G = \beta Q(t)(e\bar{\theta} - Q(t)) - C(e) + (1 - \beta)(t - C(e))Q(t).$$

The FOC w.r.t t gives $t = \frac{e\bar{\theta}(2 - 3\beta) + 2C(e)}{(4 - 3\beta)}$. Substituting this value for t in the equilibrium of the third step of the game for the price and salary we obtain respectively, $p = \frac{e\bar{\theta}(7 - 6\beta) + C(e)}{2(4 - 3\beta)}$ and $\omega = \frac{e\bar{\theta}(5 - 6\beta) + 3C(e)}{2(4 - 3\beta)}$.

We integrate the equilibrium value of t in (A3).

The sign of $Q(t)$ is the same as $(e\bar{\theta} - C(e)) = e(\bar{\theta} - \beta\kappa + \beta - 1) = (\bar{\theta} - 1)(1 - \beta\kappa)$. Then $Q = 0$ if $\beta > \frac{1}{\kappa}$ and all surpluses are equal to zero. Otherwise, $Q = \frac{(\bar{\theta} - 1)(1 - \beta\kappa)}{2(4 - 3\beta)}$ and all surpluses are positive.¹⁵ \square

¹³Substituting the obtained value of p into the firm's profit, we obtain $\pi^F = \frac{(e\bar{\theta} - t)^2}{8e}$ which is increasing in e . This implies that the firm would choose $e = \bar{q}$ if it were up to it to make that choice before its price.

¹⁴This is so because the equation giving the output as a function of the firm's price $Q = \bar{\theta} - \frac{p}{e}$ is valid only when the output quantity is nonnegative, that is, when the price is not too high ($p < \bar{\theta}e$). Otherwise the quantity is null.

¹⁵Substituting the value of t obtained into the expression of G , we obtain $G = (1/2)e(\bar{\theta} - 1)(1 - \beta\kappa)$ which is increasing with e whenever $\beta < \frac{1}{\kappa}$ and that the University would choose $e = \bar{q}$ if it were up to it to make that choice before the tuition fees. If it were up to the firm to choose e before the University fixes the tuition fees, it would also choose $e = \bar{q}$, as the firm's profit with the obtained value of t is given by $\pi^F = e(\bar{\theta} - 1)^2 \frac{1 - \beta\kappa}{2(4 - 3\beta)^2}$ which is increasing in e .

Proof of Proposition 1. Substituting the value for $Q = \frac{(\bar{\theta}-1)(1-\beta\kappa)}{2(4-3\beta)}$ into Equation (A4) one obtains SW as a function of β for $\beta \leq \frac{1}{\kappa}$,

$$SW = e(\bar{\theta} - 1)^2 \frac{(7 - 6\beta)(1 - \kappa\beta)^2}{4(4 - 3\beta)^2}. \quad (\text{A5})$$

As SW is zero for all $\beta > \frac{1}{\kappa}$ and $SW(0) = \frac{7e(\bar{\theta}-1)^2}{64} > 0$, it follows that SW is never maximum for values of $\beta > \frac{1}{\kappa}$. Determining the maxima of function SW with respect to β over the interval $[0, 1]$ is equivalent to determining the maxima with respect to β , over the interval $[0, \min\{1, \frac{1}{\kappa}\}]$, of function

$$H(\beta) = \frac{(7 - 6\beta)(1 - \kappa\beta)^2}{4(4 - 3\beta)^2}$$

It is easy to compute

$$H'(\beta) = \frac{(1 - \kappa\beta)}{2(4 - 3\beta)} (-9\kappa\beta^2 - 9(1 - 4\kappa)\beta + 9 - 28\kappa).$$

$H'(\beta)$ is of the same sign as the second term in the right-hand side, which is a second-order polynomial denoted by $f(\beta) = -9\kappa\beta^2 - 9(1 - 4\kappa)\beta + 9 - 28\kappa$, except when $\kappa = 0$.

For $\kappa = 0$, $H(\beta) = \frac{7-6\beta}{4(4-3\beta)^2}$, then $H'(\beta) = \frac{9(\beta-1)}{2(3\beta-4)} > 0$ for all values of $\beta \in [0, 1]$. Hence, H is increasing w.r.t β and $\beta^* = 1$.

For $\kappa > 0$, according to the sign of the determinant of the second-order polynomial, one obtains:

- For all values of $\kappa \in [\frac{3}{8}, \frac{3}{4}]$, the determinant is negative, hence $H'(\beta) < 0$ always and H is decreasing w.r.t β , hence $\beta^* = 0$.
- For all values of $\kappa \in]0, \frac{3}{8}[\cup] \frac{3}{4}, +\infty[$, f has two roots and only the largest one $\hat{\beta}$ may correspond to a local maximum of function H , as the sign of f is positive before and negative after.

$$\hat{\beta}(\kappa) = \frac{1}{6\kappa} \left(12\kappa - 3 + \sqrt{9 - 36\kappa + 32\kappa^2} \right).$$

More precisely, given the negative sign of the coefficient of the second-order term (-9κ), there are three potential local maxima: $\beta = 0$, $\beta = \hat{\beta}$ and $\beta = \min(1, \frac{1}{\kappa})$. Moreover $\beta = \min(1, \frac{1}{\kappa})$ is a local maximum only when $\hat{\beta}(\kappa) > \min(1, \frac{1}{\kappa})$.

- For $\kappa \in]0, \frac{3}{8}[$, we are going to prove that $\hat{\beta}(\kappa) \in [0, 1]$. Since $\frac{\partial \hat{\beta}(\kappa)}{\partial \kappa} = \frac{-4\kappa^2}{2\sqrt{9-36\kappa+32\kappa^2}(-6\kappa+3+\sqrt{9-36\kappa+32\kappa^2})} < 0$, $\lim_{\kappa \rightarrow 0} \hat{\beta}(\kappa) = 1$ and $\lim_{\kappa \rightarrow \frac{3}{8}} \hat{\beta}(\kappa) = \frac{2}{3}$, then $0 < \hat{\beta}(\kappa) < 1$. Thus only $\beta = 0$ and $\hat{\beta}(\kappa)$ are potentially local maxima of H . We then

need to compare $H(\hat{\beta}(\kappa))$ with $H(0)$. It turns out that $H(\hat{\beta}(\kappa)) \geq H(0)$ if $\kappa \leq \frac{3}{28}(9 - 4\sqrt{2}) \simeq 0.3581954$, and $\beta^* = \hat{\beta}(\kappa)$. Otherwise, $H(\hat{\beta}(\kappa)) < H(0)$ and $\beta^* = 0$.

- For $\kappa \in \left] \frac{3}{4}, +\infty \right[$:
- If $\kappa \in \left] \frac{3}{4}, 1 \right[$, since $\hat{\beta}(\kappa) - 1 = \frac{6\kappa - 3 + \sqrt{9 - 36\kappa + 32\kappa^2}}{6\kappa} > 0$ and $f(1) < 0$ for $\kappa < 1$, then the roots of the polynomial are necessarily both larger than $\beta = 1$. Thus $f(\beta) < 0$ for all values of $\beta \in [0, 1]$, hence H is decreasing w.r.t β and $\beta^* = 0$.
- If $\kappa \in [1, +\infty[$, we have to maximize¹⁶ $H(\beta)$ on $[0, \frac{1}{\kappa}]$. $\hat{\beta}(\kappa) - \frac{1}{\kappa} = \frac{12\kappa - 9 + \sqrt{9 - 36\kappa + 32\kappa^2}}{6\kappa} > 0$ over this interval and we can easily prove that¹⁷ $f(\frac{1}{\kappa}) < 0$. Then both roots of f are larger than $\frac{1}{\kappa}$, implying that $f(\beta) < 0$ for all values of $\beta \in [0, \frac{1}{\kappa}]$. Hence H reaches its maximal value for $\beta^* = 0$. From the expression of SW given in (A5), SW is increasing w.r.t e . Hence maximizing SW w.r.t e gives $e^* = \bar{q}$. \square

Proof of Corollary 1. We substitute the equilibrium value β^* in the expressions of the tuition fees, price, salary and quantity at the equilibrium of the second step given in Lemma 1. We then obtain profits and surpluses using Equations (2), (3) and (A4). \square

Proof of Proposition 2. We solve the first step of the game under the constraint that the University does not make losses. According to the results of Section 3, $\hat{\beta}(\kappa) > \frac{2}{3}$ for all values of $\kappa \in]0, \frac{3}{28}(9 - 4\sqrt{2})[$. Partial privatization with $\beta = \hat{\beta}(\kappa)$ is never feasible on this interval. Recalling the variations of SW from the proof of Proposition 1, only $\beta = 0$ and $\beta = \frac{2}{3}$ are potential maxima of SW . We then need to compare $SW(0)$ and $SW(\frac{2}{3})$. It turns out that¹⁸ $SW(\frac{2}{3}) > SW(0)$ if $0 \leq \kappa \leq \kappa_1 = \frac{6 - \sqrt{21}}{4}$ and $\beta^{**} = \frac{2}{3}$. When $\kappa_1 < \kappa < \kappa_0$, $SW(\frac{2}{3}) < SW(0)$, and $\beta^{**} = 0$. For $\kappa \geq \kappa_0$, the solution in the commitment case ($\beta^* = 0$) ensures a nonnegative University's profit. Thus $\beta^{**} = 0$. From Equation (A5), SW is increasing w.r.t e . Hence maximizing SW w.r.t e gives $e^{**} = \bar{q}$. \square

Proof of Corollary 2. We substitute the equilibrium values of $\beta^{**} = \frac{2}{3}$ and $e^{**} = \bar{q}$ in the expressions of price, tuition fees, salary, quantity, given as a function of β at the equilibrium of the second step in Lemma 1. We then obtain profits and surpluses using Equations (2), (3) and (A4). \square

¹⁶Here $\min(1, \frac{1}{\kappa})$ shifts to $\frac{1}{\kappa}$.

¹⁷The sign of this expression is the same as $-28\kappa^2 + 27\kappa - 9$ which is a second-order polynomial with a negative determinant.

¹⁸The sign of $SW(0) - SW(\frac{2}{3})$ is the same as $(-15 + 48\kappa - 16\kappa^2)$.