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Research Article

Rent Extraction through Alternative Forms of Competition in the Provision of Paternalistic Goods

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We compare the properties in terms of rent extraction of spatial competition and monopoly franchises using Dutch first price auctions, two of the most widely used tools to regulate public service provision. In a framework where the regulator can imperfectly observe costs, but the latter are not necessarily private information to each competitor, spatial competition is more effective in extracting rent if providers are very different in their productivity and if they can observe the costs of their competitors. When they are quite similar and have limited information on the competitors' characteristics, the use of a monopoly franchise through an auction mechanism should be preferred. In the latter environment, a multiple object auction allows more rent to be extracted from the provider.

1. Introduction

Service provision in the public sector has experienced a substantial change through the introduction of forms of competition among providers. For essential facilities (such as energy, gas, and water), competition for and in the market, along with some forms of price regulation, is envisaged. For other local services, competition for the market and price regulation is often used.[1] Production costs often become private information to the provider, a problem which the literature has long recognised [1], and for which specific solutions have been proposed [2–7]. In the recent past, policy makers have extended these reforms to the provision of health, social care, education, and other local services. Forms of competition such as spatial competition and monopoly franchises [8–13] have been implemented, but none of them has proved to be optimal.

For education, the empirical evidence shows that competition does not have an impact on the cost of providing the service, but it might improve school performances [14–17]; for hospital care and nursing homes the evidence is fairly mixed [18–23]; in all these sectors cream skimming practices might arise [24]. We argue that performances depend on the specific characteristics of each service, which calls for a more accurate investigation of providers' responses to alternative regulatory instruments in this very particular context. Services are in fact usually produced on demand (and the latter is not very elastic because they are often perceived as a primary need); they cannot be stocked or transported; and their quality is difficult to verify.[2] The supply of these services is often associated with the notion of soft paternalism [25]; in other words Government thinks that individuals should use them irrespective of their ability to pay. For this reason, the price usually covers only a fraction of the cost, hence the provider has to be subsidised. The technology of production, although universally available, may require fixed, sunk investments, which restrict the number of firms that can acquire it. Another important characteristic is related to workers' motivation. The literature assumes that workers in sectors such as health, education, social care, and public protection are devoted, because they receive utility from their salary and the output they produce. This positive externality always reduces the cost and/or enhances the quality level of the service in vertically integrated systems. In a separated structure, the advantages of employing devoted workers may simply become part of the rent to the provider (see e.g. [26–29]). This risk may be partly reduced by the choice of an appropriate competition framework. In this paper we compare the rent that can be extracted using spatial competition and monopoly franchise in an environment where the service to be produced is a paternalistic good. We assume that production costs can be imperfectly observed by the regulator, but they are not always private information to each provider. This assumption is justified by the nature of the provider's rent, which depends both on personal abilities and workers' characteristics, which are common to a specific service.

We show that the market information structure is a key factor for a successful regulatory choice. If providers have perfect information on their competitors, the two regulatory instruments can be ranked according to the value of specific parameters; in fact if the two competitors are "sufficiently" different in their degree of efficiency, spatial competition should be preferred because it allows more rent to be extracted. The case of incomplete information is more complex because the outcome of the game depends on the beliefs each player has about the efficiency of its competitor. Although a precise decision scheme for the regulator cannot be designed, it is still possible to offer general rules on how the choice should be made. For example, it turns out that monopoly franchises should be preferred if the productivity levels of the providers are thought to be homogeneous. Both single and multiple service competition are considered. In this respect we show that for monopoly franchises, a multiple object auction allows more rent to be extracted from the provider.

The paper will be organised as follows. In Section 2 we describe the model. In Sections 3 and 4 we present the analysis for one and N services, respectively. In Section 5 we compare the performances of spatial competition and monopoly franchise. Conclusions are then drawn in Section 6.

2. The Model

In this paper we model the provision of services that have the nature of paternalistic goods in an environment with specific characteristics. There is no uncertainty about the cost of producing services, the technology is available to all the competitors, who may differ in their level of productivity. The investment in the technology is high and sunk, hence only a restricted number of firms are willing to enter the market. Users pay a limited fraction of the cost to produce the service. The regulator has to subsidise the provider, in an environment where it can imperfectly observe costs. Workers are devoted, that is, they receive utility from the salary and from the output they produce.

The Environment. In a community consisting of a mass of individuals, normalised to one for simplicity, N different services can be produced by two multiproduct firms (A and B), located at the extremes of a line of length one. They both use specific, separated technologies and each firm may produce all N services.

Quality can be observed by the service users, but it cannot be verified before a court. This is a problem common to the production of services, where quality cannot be measured by the outcome of the service supplied.[3] In health care, for example, the quality and the appropriateness of the treatment cannot be measured by the health gain of each single patient; in education the achievements of the students are not a precise indicator of the quality of the service supplied. A minimum verifiable level of quality, set to zero for simplicity, can be contracted for; any improvement over this level can only be obtained using indirect incentives to the provider.

The unit cost incurred by a firm to produce a specific service can be written as

$$C_{ij} = k_i + q_i - \alpha_{ij}, \quad i = 1, \ldots N, \; j = A, B, \tag{1}$$

where $k_i > \alpha_{ij}$ is a fixed cost which captures technology aspects and minimum quality requirements, q_i is the cost incurred to increase quality beyond the minimum verifiable level, and $\alpha_{ij} = \beta_{ij} + d_{ij}$. The term β_{ij} is a productivity parameter that captures reduction in costs due to the ability of the specific provider; d_{ij} reflects the devoted aspect of the workforce.[4] The two terms have a completely different nature. β_{ij} depends on specific characteristics of the provider and it may represent the higher degree in efficiency of a privatised organisation. In contrast, d_{ij} represents a cost reduction arising from an intrinsic characteristic of the workers which the regulation process assigns to the provider, but which is in fact a common good. α_{ij} can alternatively be private information to the provider or it can be observed (often imperfectly) by its competitor. The rationale for this assumption is as follows: the efficiency parameter may well be private information to each provider while the devoted characteristic of the workforce is an element that may be more common among a group of firms employing the same workforce.

The quantity of each service is set outside the model and it is not contracted for; to simplify the exposition we assume that each community member is using a unit of these services. The regulator sets a payment t_i for each unit produced.

The reimbursement t_i is higher than the price p_i charged to the consumer (the user charge), hence a subsidy g_i must be foreseen, that is

$$t_i = p_i + g_i. \tag{2}$$

The initial share between price and subsidy is determined outside the model.

Consumer's Choice. Service users are assumed to be uniformly distributed on a unit line with providers A and B located at the extremes (0 and 1). Users are indexed by their position on the line, so that x represents the consumer located at point x from the origin. We model consumers' utility U as the sum of two terms: a positive amount U_0 derived from the service fruition and a variable part that depends on its quality and on the cost they have to incur to use it. In formulas

$$U(x) = U_0 + \varphi q_j - c_x \quad j = A, B, \tag{3}$$

where q_j is the quality of the service offered by competitor j which can be observed directly or through experts' advice. The term c_x reflects several aspects related to costs: it can be partly determined by a user charge and by other private costs (transport for example). If each consumer incurs the same marginal distance cost m, (3) can be written as

$$U(x) = U_0 + \begin{Bmatrix} \varphi q_A - p_A - mx & A \text{ is chosen,} \\ \varphi q_B - p_B - m(1-x) & B \text{ is chosen} \end{Bmatrix}. \quad (4)$$

Here φq_A is the monetary equivalent gain derived from using the service of quality q_A from provider A, p_A is the user charge, while mx and $m(1-x)$ are travel costs. We assume that the fixed quantity U_0 is high enough, so that the consumer is always choosing to access the service from some provider, for example, the service is essential.

The role of consumers' choice in the model is determined by the regulator. If the market is regulated through a monopoly franchise, service users have to accept the appointed provider, while in the spatial competition model they are free to choose their preferred provider, on the basis of their net utility.

The Provider. The provider maximises the surplus, that is, the difference between total reimbursement, and production cost. Given the absence of uncertainty, it participates in the production process only if the surplus is nonnegative:

$$\sum_{i=1}^{N} D_{ij}\left(t_i - C_{ij}\right) \geq 0, \quad j = A, B, \quad (5)$$

where C_{ij} has been defined in (1), t_i is the reimbursement and D_{ij} is the number of units of service i delivered by provider j. In this model we have not explicitly modelled the effort of the management as in the more traditional regulatory models. This choice is justified by the assumption of absence of uncertainty on the production side. In this context the effort made by the provider becomes its private information and can be included in the parameter β_{ij}.

The Regulator. In our model the regulator chooses the form of regulation that allows the maximum rent to be extracted from the provider, independently of whether this rent improves the quality of the service produced or reduces the observed production cost. In actual fact the regulator will have to define through its welfare function a trade-off between quality and cost of the service. In this paper, we have preferred to abstract from these problems and compare some forms of competition on their relative ability to extract rent, since this allows us to consider multiple scenarios depending on the information available to players. Welfare considerations are very important from a regulation point of view and will be discussed in future works.

The Rules of the Game. The regulator has to choose the best instrument out of spatial competition models and monopoly franchises (using forms of Dutch first price auctions). In the first case both price and quality competition are feasible, since quality can be observed by the service user. The regulator has then to decide whether competitors can set the price charged to the consumer (the user charge) or if competition should be on the quality of the service. If the regulator allows price competition between suppliers, a maximum user charge p will be defined so that $p_j = p - r_j$ where r_j is the reduction in the user charge that provider j offers to its clients. In the case of paternalistic goods, p_j is usually zero (i.e., the service might be free at the point of use) or very low, and in this case competition can be made only on quality. As regards quality standards, given that they cannot be verified before a court, the regulator sets a minimum verifiable level, which we assume equal to zero. Competitors may then increase it to q_j in order to get a larger market share.

The auction can on the other hand be implemented only in terms of reduction in the benchmark reimbursement t^*, given that quality beyond a minimum verifiable level cannot be negotiated. The game arising between the providers is symmetric, hence a pure strategy Nash equilibrium exists [30]. The two competitors may however have imperfect information on their opponent's type. In this paper we consider both complete and incomplete information scenarios. In the latter case our approach implements a Bayesian Nash solution.

The regulator can observe consumer preferences, but has imperfect information about production costs. We will come back to this point later, by specifying which parameters are assumed to be known by the regulator.

In what follows we analyse the rent extraction potential of these regulatory instruments, under the above settings.

2.1. Benchmark Reimbursement. In the absence of competition, the regulator should contract with each provider separately through an agency model. Given that quality beyond a minimum requirement cannot be verified, q_i will be set to zero. For a generic service i the unit cost observed by the regulator is equal to $C_i = k_i$, while the true cost for provider j is $C_{ij} = k_i - \alpha_{ij}$. Here $\alpha_{ij} = \beta_{ij} + d_{ij}$ represents the combined effect on cost of the devoted aspect of the workforce (d_{ij}) and the productivity parameter (β_{ij}) and can be interpreted as the rent of the provider. For a generic service i, the regulator has to find the minimum reimbursement t_i that is compatible with the participation constraint of the agent. Given that the cost function is linear, the problem can be written in terms of the provision of a single unit as

$$\min\ t_i, \quad \text{s.t.} \begin{cases} C_i = k_i \\ t_i - C_i \geq 0, \end{cases} \quad (6)$$

so that the optimal reimbursement is set to

$$t_i^* = k_i. \quad (7)$$

From what the regulator observes on costs, this is the minimum reimbursement that satisfies the participation constraint. The true cost is however equal to $k_i - \alpha_{ij}$; this means that the provider enjoys a rent equal to α_{ij}, which derives from the inability of the regulator to observe its utility and cost function. This result is in line with the traditional literature on incentive compatible mechanisms, which shows that when information is private and the provider faces no uncertainty, an agency model is not efficient [31]. The presence of devoted workers may mitigate the result, but only in specific contexts where their utility is defined in terms of quality and quantity of output produced.[5] For this reason, in our setting where the number of services to be produced is fixed, other regulatory instruments have to be used and the agency model can be used as benchmark.

3. Single Service Regulation

In this section we assume that the regulation is made on each service separately, by comparing the rent extraction properties of a competition model à la Hotelling and Dutch first price auction mechanisms. A word on notation: since we are considering just one service the subscript i will be dropped throughout the section.

3.1. Spatial Competition. The reimbursement set in the previous section allows the provider to receive a unit rent equal to α_j. If the regulator makes suppliers compete for users, the rent will be partly returned to the community in the form of price reduction and/or quality enhancement, according to the specific rules set by the regulator. Given the nature of paternalistic good, the service is supplied free of charge (or for a very low user charge), but the consumer has to bear private costs to use the service. In this case the regulator will choose to make providers compete on quality [9, 12, 13, 16].[6]

In what follows we examine the choice of provider A as regards the use of its rent for competing with B when the user charge is set by the regulator and competition is only made on quality. Since the two players behave symmetrically, we show the best strategy only for competitor A.

From (4) we can derive the location $\overline{x}$ of consumers that are indifferent in the choice between A and B:

$$\overline{x} = \frac{\varphi(q_A - q_B)}{2m} + \frac{1}{2}. \tag{8}$$

The demand function for A can be obtained by multiplying $\overline{x}$ by the density which, given the unit length of the line, is equal to 1. The provider uses a part α_A^* of its rent to increase quality increase to level q_A. By linearity $q_A = \alpha_A^*$ and the demand function is[7]

$$D_A = \left[\frac{\varphi(\alpha_A^* - \alpha_B^*)}{2m} + \frac{1}{2}\right]. \tag{9}$$

The optimal revelation α_A^* can be obtained through the following maximisation:

$$\max\left[(t^* + \alpha_A - k - \alpha_A^*)D_A\right]. \tag{10}$$

Given that $t^* = k$, we can rewrite it as

$$\max_{\alpha_A^* \in [0,\alpha_A]} \left[D_A(\alpha_A - \alpha_A^*)\right]. \tag{11}$$

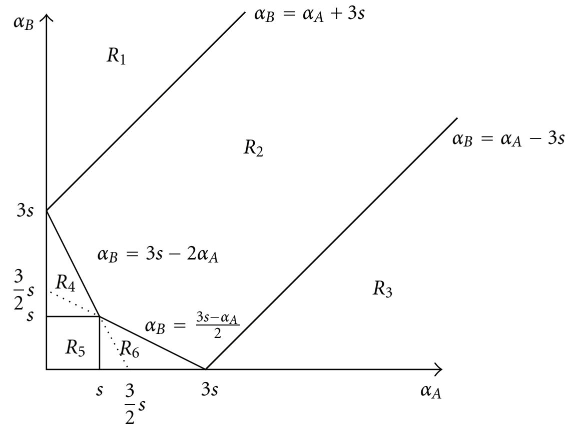

Figure 1: Regions for the distribution of the optimal points in the case of perfect information.

Thus, the objective function of provider A depends on the strategy chosen by B through the term D_A, which is a function of α_B^* and thus depends upon α_B. The solution of the game is thus also influenced by the players' relative information. A general maximisation process is presented in Appendix A. In the following sections we show how to interpret the results in different scenarios.

3.1.1. Complete Information. Each provider can observe the α_j of its competitor. This assumption can be justified on several grounds: "personal" knowledge of the competitor, given the number of firms on the market, and rent that predominantly depends on the devoted characteristics of the staff. Letus then assume that α_B is known to A and vice versa for B. Let $s = m/\varphi$ be the "position rent" of the competitors. The optimal revelations for both quality and price competition are derived in (12) through (A.15) in Appendix A:

$$\begin{gathered}
(\alpha_A, \alpha_B) \in R_1 : \alpha_A^* = \alpha_A, \quad \alpha_B^* = \frac{1}{2}(\alpha_B + \alpha_A - s), \\
(\alpha_A, \alpha_B) \in R_2 : \alpha_A^* = \frac{1}{3}(2\alpha_A + \alpha_B) - s, \\
\alpha_B^* = \frac{1}{3}(2\alpha_B + \alpha_A) - s, \\
(\alpha_A, \alpha_B) \in R_3 : \alpha_A^* = \frac{1}{2}(\alpha_A + \alpha_B - s), \quad \alpha_B^* = \alpha_B, \\
(\alpha_A, \alpha_B) \in R_4 : \alpha_A^* = 0, \quad \alpha_B^* = \frac{1}{2}(\alpha_B - s), \\
(\alpha_A, \alpha_B) \in R_5 : \alpha_A^* = 0, \quad \alpha_B^* = 0, \\
(\alpha_A, \alpha_B) \in R_6 : \alpha_A^* = \frac{1}{2}(\alpha_A - s), \quad \alpha_B^* = 0,
\end{gathered} \tag{12}$$

where regions R_1–R_6 are defined in (A.14) and presented in Figure 1.

If $\alpha_A, \alpha_B \leq s$, no rent is passed on to the consumer: in this case high transportation costs or a low evaluation of quality

Table 1: Revelation for player A in the independent types case.

	$0 \le E(\alpha_B) \le s$	$s \le E(\alpha_B) \le 3s$	$E(\alpha_B) \ge 3s$
α_A	$[0, s]$	$\left[0, \frac{3}{2}s - \frac{E(\alpha_B)}{2}\right]$	$[0, E(\alpha_B)) - 3s]$
α_A^*	0	0	α_A
α_A	$[s, 3s - 2E(\alpha_B)]$	$\left[\frac{3}{2}s - \frac{E(\alpha_B)}{2}, E(\alpha_B) + 3s\right]$	$[E(\alpha_B) - 3s, E(\alpha_B) + 3s]$
α_A^*	$\frac{1}{2}(\alpha_A - s)$	$\frac{1}{3}(2\alpha_A + E(\alpha_B)) - s$	$\frac{1}{3}(2\alpha_A + E(\alpha_B)) - s$
α_A	$[3s - 2E(\alpha_B), E(\alpha_B) + 3s]$	$[E(\alpha_B) + 3s, +\infty)$	$[E(\alpha_B) + 3s, +\infty)$
α_A^*	$\frac{1}{3}(2\alpha_A + E(\alpha_B)) - s$	$\frac{1}{2}(\alpha_A + E(\alpha_B) - s)$	$\frac{1}{2}(\alpha_A + E(\alpha_B) - s)$
α_A	$[E(\alpha_B) + 3s, +\infty)$		
α_A^*	$\frac{1}{2}(\alpha_A + E(\alpha_B) - s)$		

enhancement prevent competition between providers. In this case the providers are in fact local monopolists and have no incentive to use their rent to increase their demand.

After this threshold, the equilibrium depends on the relative size of α_A and α_B. In general if $\alpha_B > \alpha_A$, competitor A has to give away all his rent only if $\alpha_A \le \alpha_B - 3s$. Note also that α_A^* is increasing with α_A, no matter how player A is ranked with respect to its competitor.

An interesting solution in this context is represented by the case where one of the two providers is not devoted/efficient. If for example $\alpha_B = 0$ and $\alpha_A > s$, that is, if α_A is not too small, the solution can be written as $\alpha_A = (1/2)(\alpha_A - m/\varphi)$, thus the rent passed on to the consumer is half of the total rent, net of the position rent s.

3.1.2. Imperfect Information. We assume that player J models $\alpha_K, J \ne K, J, K = A, B$, as a random variable distributed in the range $[0, k]$. Each player will use the available information and its beliefs to derive a probability distribution for the random variable representing the rent of its competitor. The optimal strategy in the general case can then be derived from (A.15) in Appendix A by making the substitution $\tilde{\alpha}_B = E(\alpha_B)$. Hereafter we present two specific cases of imperfect information.

Fully Correlated Types. Each provider assumes it has the same α_j as its competitor. This may be a reasonable assumption in a market where β plays a marginal role (or it does not depend on personal characteristics of the management[8]), while d is quite important and has a low variance among workers in the same sector.

In this case when A observes α_A it also sets its evaluation $\tilde{\alpha}_B$ of α_B at $\tilde{\alpha}_B = \alpha_A$. Since competition is made on quality, the information rent passed on to the service user as an increased quality q_A^* from (A.15) will be equal to

$$\alpha_A = \max\left\{0, \alpha_A - \frac{m}{\varphi}\right\} = q_A^*. \tag{13}$$

Independent Types. Another reasonable assumption is that the two providers are quite different in their productivity hence they think that the observation of their own α_j does not allow anything to be inferred on the value of α_k for the competitor. In this case their guess of α_k will be uniformly distributed in the interval $[0, k]$.[9] In our model, by linearity, the revelation α_A^* will depend on the expected value $E(\alpha_B)$ of α_B, which in this case is $b/2$. From (A.15) revelations will depend on the relative size of b and the parameter $s = m/\varphi$. The detailed strategy for player A is given in Table 1. The shape of the reaction function of A depends on the three parameters $E(\alpha_B), \alpha_A$, and s. This of course determines how much rent A is willing to give up to compete with B for service users. To show their influence on the final result, we can use both Table 1 and Figure 2. First of all, A evaluates $E(\alpha_B)$ and, according to its value, it will move along one of the three columns of Table 1, whose graphical representation is given in Figure 2, each column corresponding to a different graph. If, for example, $E(\alpha_B) \le s$, the reaction function of A is depicted in Figure 2(a). For $\alpha_A \le s$, no rent is passed on, because A acts as a local monopolist. From this point onwards there is a positive relationship between α_A and α_A^*, whose steepness increases with $E(\alpha_B)$.

The relationship between α_A^* and $E(\alpha_B)$ is linear and can be obtained using (12) and Figure 1. In R_2 the slope is 1/3, while in R_3 it amounts to 1/2. In all other cases α_A^* does not depend on the value of $E(\alpha_B)$. For fixed α_A we can

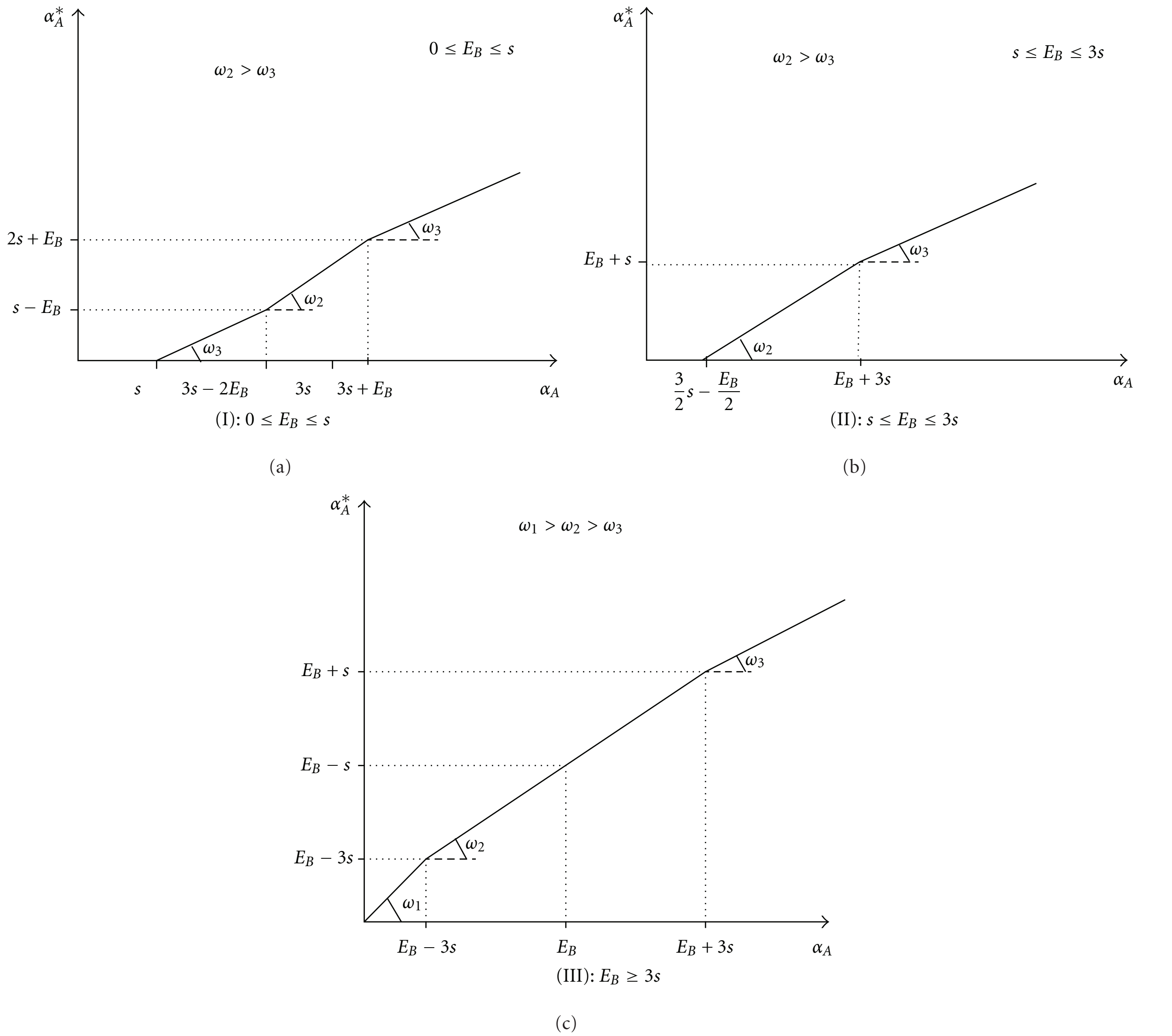

Figure 2: Optimal revelation α_A^* - imperfect information, independent types.

then conclude that α_A^* is a nondecreasing piece-wise linear function of $E(\alpha_B)$, but the slope of the slanted segments of the graph decreases as $E(\alpha_B)$ increases.

3.2. Monopoly Franchise through a Dutch First Price Auction. As an alternative to competition in the market, it is possible for the regulator to introduce a form of competition for the market. These instruments have been extensively studied by the literature on franchising [32, 33], but their application in the context of paternalistic goods provision is rather different because the provider does not usually pay a franchise fee[10] and the price is zero or highly subsidised.

In this section we present a Dutch first price auction that can be used to make the providers reveal their private information. Since quality cannot be verified, the auction can only be done on t.[11] Given the nature of the private information held by the provider, the benchmark solution (7) represents the maximum bid price.

Each provider has to make a bid for t and can use its private information α_j to lower it by declaring some $t(\alpha_j^*) = k - \alpha_j^*$ with $\alpha_j^* < \alpha_j$ and will win the auction by making the lowest bid. Since the service demand is fixed, the bidding strategy for provider A will be to choose α_A^* in order to maximise the function as follows:

$$[t(\alpha_A^*) + \alpha_A - k]\mathbb{P}(\alpha_A^* \geq \alpha_B^*), \quad (14)$$

where $\mathbb{P}(\alpha_A^* \geq \alpha_B^*)$ is the probability of winning the auction. As for the Hotelling model, the choice of α_A^* depends on the information the provider has on its competitor.

Once t has been determined, the regulator will define the share to be subsidised (g) and the part that the consumer has to pay as user charge (p).

3.2.1. Complete Information. If the provider can observe the parameter of its competitor, the solution will be to offer just a little more in terms of α_j^*, provided this is compatible with its parameters. In other words, the strategy of competitor A will be

$$\alpha_A^* = \min\{\epsilon + \alpha_B^*, \alpha_A\}, \quad \epsilon > 0. \tag{15}$$

Letus now examine two extreme cases. If $\alpha_A = \alpha_B$, both providers use all the rent to compete for the market and in the end they will share it. If one of the two, for example B, has no information rent, $\alpha_B^* = 0$ and thus $\alpha_A^* \simeq 0$.

Incomplete Information. Letus see how provider A behaves when the parameter for its competitor cannot be observed. In this case, α_B can be modelled as a random variable, distributed in the range $[0, b]$ with density f. As in the previous case, we explore both the case of independent and fully correlated types.

Fully Correlated Types. In this case, A thinks that its competitor has its same rent α. The information on α_A is fully informative on α_B and it will declare $\alpha_A^* = \alpha_A$. If their guess is exact, that is, $\alpha_A = \alpha_B$, they will end up sharing the market equally; if one of the two competitors has a higher rent, it will win the auction and become sole provider.

Independent Types. In this case, the information on α_A is not informative on α_B. The optimisation will be carried out as in [34, Section 2.3 page 16] and the equilibrium bid can be written as

$$\alpha_A^* = \alpha_A - \int_0^{\alpha_A} \frac{\mathbb{P}(\alpha_B \le \alpha)}{\mathbb{P}(\alpha_B \le \alpha_A)} d\alpha. \tag{16}$$

Note that if $\alpha_A \ge b$, that is, if A is convinced of being more efficient than B, the formula simplifies to

$$\int_0^b \mathbb{P}(\alpha_B \ge \alpha) d\alpha = E(\alpha_B), \tag{17}$$

that is, A will declare the mean value of the random variable α_B.

The solution in general depends on the density function f. Under the assumption of a uniform distribution, the above formula gives

$$\alpha_A^* = \alpha_A - \frac{b}{\alpha_A} \int_0^{\alpha_A} \frac{\alpha}{b} d\alpha = \frac{\alpha_A}{2}. \tag{18}$$

In this case, the auction allows half of the provider's rent to be obtained in the form of cost reduction.

4. Regulation of the Provision of N Services

In this section we propose an extension to the model and assume that the two providers can compete on more than one service, that is, they are multiservice producers. We assume that the production processes are separated so that there are no economies of scale or scope related to producing more goods at the same time.

4.1. Spatial Competition. For quality and price competition, the solution is still represented by (12). In this case, in fact, given that the production is separate and the consumers of both services might not be the same, the conditions for competition are set on each service separately as shown in Appendix C.

4.2. Monopoly Franchise. For the auction, even in the presence of separate production processes, competition is stronger than in the previous case when providers have no prior information on the productivity parameters of their competitors, independently of their relative competitive advantage. For the complete information case, it is possible to extract more rent only if the two providers are better at producing some services and worse at producing others. This is because by auctioning N services at the same time, the prize for winning the auction increases. This is a very interesting result which, as will be shown in this section, does not depend on which production each supplier is more efficient at producing.

4.2.1. Auction for N Goods, Complete Information. Given that the price of production is linear in the competitive advantage of each provider, the auction can be implemented on the average price for producing the N services, that is, the provider that declares the minimum average cost wins the auction. As before, we examine the behaviour of agent A. The cost for a generic service i produced by supplier A can be written as $k_i - \alpha_{iA}^*$ and the average price can be written as

$$\frac{\sum_{i=1}^N k_i}{N} - \frac{\sum_{i=1}^N \alpha_{iA}^*}{N}. \tag{19}$$

If the provider can observe its competitor's parameter, the solution will be to offer just a little more in terms of $\sum_{i=1}^N \alpha_{ij}^*$, provided this is compatible with its parameters. In other words, the strategy of competitor A will be

$$\sum_{i=1}^N \alpha_{iA}^* = \min\left\{\sum_{i=1}^N \alpha_{iB}^* + \epsilon, \sum_{i=1}^N \alpha_{iA}\right\}, \quad \epsilon > 0. \tag{20}$$

In terms of total rent extraction, this is equivalent to doing N separate auctions only if the condition $\alpha_{iA} \ge \alpha_{iB}$ or its converse holds for any i, that is, one of the players is more productive than its opponent in all the auctioned services. If the players' productivity parameters vary for different services, the rent extracted will be higher because providers can "spread" their competitive advantage across services.[12]

4.2.2. Auction for N Goods, Incomplete Information. Letus now turn to the case where each competitor J models the unknown α_{iK}, $K \ne J$ as a random variable distributed according to a distribution function f_{iK} in the support interval $[0, k_i]$ for all $i = 1, \ldots, N$. As in the previous sections, we will examine the fully correlated and the independent types and we will describe the behaviour of competitor A.

Fully Correlated Types. In this case, A thinks that its competitor has its same rent α_{iA}. The information on α_{iA} is fully informative on α_{iB} and it will declare $\sum_{i=1}^{N} \alpha_{iA}^* = \sum_{i=1}^{N} \alpha_{iA}$. If their guess is exact, they will end up sharing the market equally; if one of the two competitors has a higher rent, it will win the auction and become sole provider.

Independent Types. As in the single service case, independent type players model their opponent's productivity as a uniformly distributed random variable, that is, in this case $f_{iB} = 1/b_i$ for any i. Provider A wins if B declares a lower sum that is, if

$$\sum_{i=1}^{N} \alpha_{iB}^* \leq \sum_{i=1}^{N} \alpha_{iA}^*. \tag{21}$$

By linearity, the expected payoff of player A is

$$\left[\sum_{i=1}^{N} (\alpha_{iA} - \alpha_{iA}^*)\right] \mathbb{P}\left(\sum_{i=1}^{N} \alpha_{iB}^* \leq \sum_{i=1}^{N} \alpha_{iA}^*\right), \tag{22}$$

where the second term represents the probability for player A of winning the auction. Let now $z_A^* = \sum_{i=1}^{N} \alpha_{iA}^*$, $z_A = \sum_{i=1}^{N} \alpha_{iA}$, and Z_B be the random variable $Z_B = \sum_{i=1}^{N} \alpha_{Bi}$. If players A and B behave symmetrically, their optimal revelation will have the same form as a function of the total information rent. Therefore the problem can be formulated as a single goods auction in z and the solution is found as in [34]. The optimal revelation for player A solves the functional equation

$$z_A^*(z_A) := \arg\max_{z \in [0, z_A]} \left[(z_A - z)\mathbb{P}\left(Z_B \leq (z_A^*)^{-1}(z)\right)\right], \tag{23}$$

therefore

$$z_A^* = z_A - \frac{1}{\mathbb{P}(Z_B \leq z_A)} \int_0^{z_A} \mathbb{P}(Z_B \leq z)dz. \tag{24}$$

Since $Z_B = \sum_{i=1}^{N} \alpha_{iB}$ we have

$$\mathbb{P}(Z_B \leq z) = \int_K \frac{1}{b_1} \cdots \frac{1}{b_N} dx_1 \cdots dx_N = \int_0^z f_\Sigma(x)dx, \tag{25}$$

where the set K is given by $K = \{(x_1, \ldots, x_N) : \sum_{i=1}^{N} x_i \leq z, x_i \geq 0\}$ and f_Σ is the density function of the random variable Z_B. By standard probability theory f_Σ is the convolution product $f_1 * f_2 * \cdots f_N$ of the distribution functions f_i, which can be obtained by induction using the formula $(h * g)(x) = \int h(x-y)g(y)\,dy$. Since here the random variables are uniformly distributed, it is possible to derive an analytical formula for f_Σ. This allows us to compare the total rent extraction of the multiple service auction with the sum of what would be obtained by performing N different auctions. All mathematical details are presented in Appendix D. For $N = 2$ the density f_Σ can be easily computed and the optimisation can be carried out analytically as shown in Appendix D.1. Renumbering the services so that $b_1 \geq b_2$ we have

$$z_A^* = \begin{cases} \dfrac{2}{3} z_A & z_A \in [0, b_2] \\ \dfrac{1}{3} \dfrac{3z_A^2 - b_2^2}{2z_A - b_2} & z_A \in [b_2, b_1] \\ \dfrac{1}{3} \dfrac{3(b_1 + b_2)z_A^2 - 2z_A^3 - b_2^3 - b_1^3}{2b_1 b_2 - (b_1 + b_2 - z_A)^2} & z_A \in [b_1, b_1 + b_2]. \end{cases} \tag{26}$$

The optimal declaration of the productivity parameter in (26) is always greater than $z_A/2$. Since the optimal α_A^* for a single-goods auction is one half of the devoted characteristic α_A, the optimal value exceeds the sum of what is obtained by two different auctions. It is in fact possible to extend this result to the general case $N > 2$, showing that more rent can be extracted by bundling strategies, compared to performing separate auctions for different services. This result does not depend on the distribution of the abilities of the two providers; the only condition is that both have access to the technology.

5. Comparing the Results

The two models proposed are quite different: in the first case there is competition on the market, that is, both providers are allowed to supply the service and have to compete for clients in terms of quality. For the monopoly franchise, competition is for the market, that is, the competitors make their offer and the winner will be the sole provider of the service. Although the two frameworks are quite different, we have shown in the previous section that they can be compared in terms of α^*, the rent each provider is willing to give up in the competition process. This parameter is quite important in this context since it determines the amount of rent the regulator can extract from providers.

The regulator does not observe true production costs. Its information set is the one described for independent types, that is, it knows that the productivity parameter of each competitor may vary within a closed range and it knows the probability distribution of the values. Given that the degree of knowledge each provider has of its competitor depends on public information (the importance of the devoted workers characteristics, the influence that personal abilities of each provider may have on cost containment given the technology of production), we assume that the regulator can access this information.

The comparison is made along two lines:

(i) spatial competition versus monopoly franchise;

(ii) bundling versus competition over each single service separately.

5.1. Spatial Competition versus Monopoly Franchise. In this case the choice depends on the information set, on the degree of local monopoly the two firms can enjoy, and on the evaluation consumers have of the quality of the service

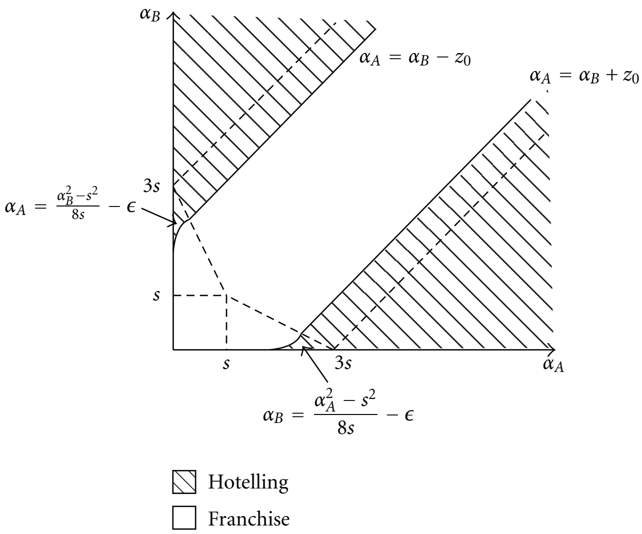

Figure 3: Total rent extraction comparison for the complete information case. Here $z_0 = 9s(-(1/2) + (1/6)\sqrt{(17s + 8\varepsilon)/s})$, as derived in (B.2) in Appendix B. Since $\varepsilon \simeq 0$, one has $z_0 \simeq 1.685s$.

produced. As in the previous section it is then necessary to distinguish between complete and incomplete information.

Complete Information. In this case both competitors know the value of the rent α_k of the opponent and set their best reply α_j^* accordingly. For this case it is possible to determine the best choice for any given couple (α_A, α_B). An analytic comparison between the total rent that can be extracted in both cases is reported in Appendix B. The outcome is summarised in Figure 3, where the corresponding splitting of the (α_A, α_B) plane is drawn. The choice between the two instruments depends on the difference $\alpha_A - \alpha_B$. If the values of the two rents are "sufficiently close" ($|\alpha_A - \alpha_B| \leq (3/2)s$), the monopoly franchise should be preferred. As pointed out in the previous section, competition in the Hotelling framework works only if the rent is higher than the local monopoly power. On the other hand, the Dutch auction, in a context where the two competitors have complete information, should be preferred only if the two rents are quite similar. The lower right and upper left borders of the white region in Figure 3 (referring to a monopoly franchise best choice) are in fact curved, due to the quadratic dependence of the total rent extraction in the Hotelling game on the quantity $\alpha_A - \alpha_B$. However the general rules for choosing between the two models do not change.

Incomplete Information. The comparison between the two models in this case is more complicated because it depends on the priors of each competitor on the likely value of the rent of the opponent.

For the fully correlated types, monopoly franchise is always a superior instrument. In this case the two opponents think they have the same information rent, therefore this case corresponds to a point on the bisector in Figure 3.

For independent types, it is not possible to define a general rule: the choice depends on the values of a, b, and s. In general, spatial competition should be preferred if the providers are very different in their rents, provided that the latter are not too small. In this case, in fact, only the use of spatial competition enables the regulator to get back part of the rent. If $|a - b|$ is fairly small, monopoly franchise should be preferred. In this case, in fact, the position rent of the Hotelling game disappears and possibly all the provider's rent is passed on to the consumers. In general, travel costs and a low evaluation of the quality of the service increase the monopoly rent, as expected. Other things being equal, spatial competition is more effective the lower the value of s.

5.2. Bundling versus Competition over Each Single Service Separately. The rent providers pass on to consumers in the spatial competition does not depend on the number of services they compete for. Each market is separate in this case. For monopoly franchises, there might be gains from bundling. If information is complete, this depends on the distribution of abilities among providers. If one of the two is better than the other in the provision of all the services bundled, there is no gain from bundling. For imperfect information and fully correlated types there is no gain in bundling from the regulator's point of view since the rent extracted is exactly the same.

For the independent types, a monopoly franchise allows more rent to be extracted and it should be used when possible. However, in the actual implementation of this auction, the regulator should avoid the winner stipulating a subcontract with the other provider for the supply of the services it is not able to produce efficiently. This policy would be ex-post efficient from a welfare point of view, but if such contracts are possible the two bidders would collude and the auction would not allow the regulator to extract rent from the providers.

6. Conclusions

In this paper we have examined the comparative advantages of regulation through spatial competition and monopoly franchises (through a Dutch first price auction) in a market where privatisation leads providers to acquire private information on their cost function and a rent through the employment of devoted workers. This framework is particularly suitable to examine the provision of paternalistic goods. For most of these services quality is not verifiable, price is heavily subsidised, and the number of competitors in the market is usually quite limited.

Our analysis shows that there is no a superior instrument for rent extraction: spatial competition is more powerful whenever the difference in the productivity level is (or the providers think it is) fairly large, provided the rent is not too small compared with the position rent s.

The position rent itself depends on the evaluation of the service quality and on travelling costs. A smaller s can be expected in the provision of services related to primary needs such as health and (partly) education; for other services where the marginal evaluation of quality is lower we can probably expect a higher monopoly power if a model of spatial competition is used.

Multiple factors should be taken into account in the choice: they relate to the information each competitor has on his opponent and on how likely it is that they make mistakes.

As per the choice between single auction and bundling, the N-service model may perform better than the single service and in any case its performance is never worse. It may therefore seem that it should always be preferred to single service regulation. In actual fact, this may well not be the case for two main reasons: bundling may add administrative costs which have not been considered in this model; it increases the incentive towards opportunistic behaviour which may lead to a regulatory failure.

Information plays a fundamental role in this model and the regulator should be acquainted with the technology of production, the market and the potential competitors, if it wishes to use the most effective regulatory instrument. This may represent a strict limit to bundling when the services are quite different from one another.

The analysis presented in this paper is preliminary: for its final choice, the regulator should also take into account the different effects of these regulatory instruments. The gains deriving from spatial competition are shared among service users, and the regulator can choose between price and quality competition. Monopoly franchises produce a reduction in the reimbursement t, which can be either used for lowering the user charge (benefit shared among users) or in the subsidy (benefit usually shared among taxpayers). The two groups may coincide or not; in any case the benefit itself may be distributed differently. A reduction in the user charge will favour the poorest (those with a higher marginal utility of income); if the tax system is progressive the tax reduction will be proportionally higher for the rich. For multiple auctions, if the provider is allowed to reduce user charges at its own discretion, cross subsidy may arise, thus producing important redistribution effects [35, 36]. Finally the choice of the regulatory instrument may affect the level of intrinsic motivation of the workforce, something that we have assumed to be set outside our model.

Although these aspects are very important, we believe that the effects of privatisation on the cost side have not yet received full attention and it is on these aspects that we have developed our paper. The analysis presented here can therefore be considered preliminary to a proper welfare analysis with regulation-dependent intrinsic motivation, which we plan to develop in subsequent works.

Appendix

A. Solution of the Hotelling Game

If $\alpha_A > 0$ the competing provider A should perform the following optimisation:

$$\max_{\alpha\in[0,\alpha_A]} V_A(\alpha), \qquad V_A(\alpha) = (\alpha_A - \alpha)D_A(\alpha),$$
$$D_A = \frac{\varphi}{2m}(\alpha - \alpha_B^*) + \frac{1}{2}. \tag{A.1}$$

Since players behave symmetrically, the optimal revelation α_B^* solves an analogous optimisation problem, which depends on α_B. However, the true value of this parameter could be private information to B. Following a Bayesian approach, we can model this parameter as a random variable distributed on the interval $[0, b]$. In fact, even the case of complete information about the competitor falls into this general setting, since it is sufficient to model the probability measure on $[0, b]$ with a Dirac delta centred at the observed value α_B. The optimisation is then carried out on the expected value of the payoff for player A. Linearity implies in fact that this is equivalent to substituting the (possibly unknown) value of α_B with its average. Here we substitute it with a new parameter $\tilde{\alpha}_B$, representing the evaluation relative to A of the unknown α_B. Consistently, we will use the notation $\tilde{\alpha}_B^*$ to denote the expected (from A) revelation of player B.

The first derivative of the new objective function is

$$V_A'(\alpha) = -\frac{\varphi}{2m}(2\alpha - \tilde{\alpha}_B^* - \alpha_A) - \frac{1}{2} \tag{A.2}$$

while $V_A''(\alpha) = -(\varphi/m)$, thus V_A is strictly concave. Note however that

$$V_A'(0) = \frac{\varphi}{2m}(\tilde{\alpha}_B^* + \alpha_A) - \frac{1}{2} \tag{A.3}$$

can be negative. In this case V_A will be decreasing on the interval $[0, \alpha_A]$, with maximum point $\alpha_A^* = 0$ and the same can be said, mutatis mutandis, for $\tilde{\alpha}_B^*$. For the present, let us set aside cases where at least one of these values is zero. From (A.2) we search for optimal couples $(\alpha_A^*, \tilde{\alpha}_B^*)$ satisfying

$$\alpha_A^* = \min\left\{\frac{1}{2}\left(\alpha_A + \tilde{\alpha}_B^* - \frac{m}{\varphi}\right), \alpha_A\right\},$$
$$\tilde{\alpha}_B^* = \min\left\{\frac{1}{2}\left(\tilde{\alpha}_B + \alpha_A^* - \frac{m}{\varphi}\right), \tilde{\alpha}_B\right\}. \tag{A.4}$$

Recalling that for any couple of real numbers x and y we have $\min\{x, y\} = (1/2)[x + y - |x - y|]$, setting for simplicity $s = m/\varphi$, the above equations can be rewritten as

$$\alpha_A^* = \frac{1}{4}[\tilde{\alpha}_B^* + 3\alpha_A - s - |\tilde{\alpha}_B^* - \alpha_A - s|] \tag{A.5}$$

$$\tilde{\alpha}_B^* = \frac{1}{4}[\alpha_A^* + 3\tilde{\alpha}_B - s - |\alpha_A^* - \tilde{\alpha}_B - s|] \tag{A.6}$$

and substituting the second equation in the first one

$$\alpha_A^* = \frac{1}{16}[\alpha_A^* + 12\alpha_A + 3\tilde{\alpha}_B - 5s - |\alpha_A^* - \tilde{\alpha}_B - s| - |\alpha_A^* - 4\alpha_A + 3\tilde{\alpha}_B - 5s - |\alpha_A^* - \tilde{\alpha}_B - s||]. \tag{A.7}$$

Now we have to examine different cases: firstly let us search for a solution α_A^* satisfying $\alpha_A^* - \tilde{\alpha}_B - s \geq 0$. Under this assumption, (A.7) yields

$$\alpha_A^* = \frac{1}{4}[3\alpha_A + \tilde{\alpha}_B - s - |\tilde{\alpha}_B - \alpha_A - s|]$$
$$= \frac{1}{2}\min\{\alpha_A + \tilde{\alpha}_B - s, 2\alpha_A\}. \tag{A.8}$$

By standard algebraic tools, since $s > 0$, it can be shown that the above solution satisfies the constraint $\alpha_A^* - \tilde{\alpha}_B - s \geq 0$ only if $\alpha_A \geq \tilde{\alpha}_B + 3s$. Moreover, this inequality implies $\alpha_A + \tilde{\alpha}_B - s \leq 2\alpha_A$, so that in this case $\alpha_A^* = (1/2)(\alpha_A + \tilde{\alpha}_B - s)$. Also, note that here $\alpha_A^* \geq \tilde{\alpha}_B + s > 0$. Substituting back in (A.6) we get $\tilde{\alpha}_B^* = \tilde{\alpha}_B \geq 0$, so that our couple of optimal values is always admissible in this case.

Now let us examine the existence of solutions of (A.7) satisfying $\alpha_A^* - \tilde{\alpha}_B - s < 0$. From (A.7) we obtain

$$\begin{aligned}\alpha_A^* &= \frac{1}{8}\left[\alpha_A^* + \tilde{\alpha}_B + 6\alpha_A - 3s - \left|\alpha_A^* - 2\alpha_A + \tilde{\alpha}_B - 3s\right|\right] \\ &= \frac{1}{4}\min\{\alpha_A^* + 2\alpha_A + \tilde{\alpha}_B - 3s, 4\alpha_A\}.\end{aligned} \tag{A.9}$$

Solving the equation $\alpha_A^* = (1/4)(\alpha_A^* + 2\alpha_A + \tilde{\alpha}_B - 3s)$ we find $\alpha_A^* = (1/3)(2\alpha_A + \tilde{\alpha}_B) - s$, which is admissible if and only if

$$\begin{aligned}&\frac{1}{3}(2\alpha_A + \tilde{\alpha}_B) - s + 2\alpha_A + \tilde{\alpha}_B - 3s \leq 4\alpha_A \Longleftrightarrow \alpha_A \geq \tilde{\alpha}_B - 3s \\ &\frac{1}{3}(2\alpha_A + \tilde{\alpha}_B) - s - \tilde{\alpha}_B - s < 0 \Longleftrightarrow \alpha_A < \tilde{\alpha}_B + 3s \\ &\frac{1}{3}(2\alpha_A + \tilde{\alpha}_B) - s > 0 \Longleftrightarrow \alpha_A > \frac{3s - \tilde{\alpha}_B}{2}.\end{aligned} \tag{A.10}$$

From (A.6) we find the corresponding $\tilde{\alpha}_B^* = (1/3)(2\tilde{\alpha}_B + \alpha_A) - s$. Note that this is in fact the "symmetric" case for the optimal values, thus also the constraint $\tilde{\alpha}_B \geq (3s - \alpha_A)/2$ has to be imposed to validate the optimal couple in this case.

Reciprocally, $\alpha_A^* = \alpha_A$ is a solution if and only if

$$\begin{aligned}&\alpha_A + 2\alpha_A + \tilde{\alpha}_B - 3s > 4\alpha_A \Longleftrightarrow \alpha_A < \tilde{\alpha}_B - 3s \\ &\alpha_A - \tilde{\alpha}_B - m < 0 \Longleftrightarrow \alpha_A < \tilde{\alpha}_B - s.\end{aligned} \tag{A.11}$$

Up to now we have considered only cases where both maximum points can be obtained from (A.5) and (A.6). By the above analysis, this covers the union of regions R_1, R_2, and R_3 in Figure 1 on a plane $(\alpha_A, \tilde{\alpha}_B)$, that is, it is valid outside the set

$$\begin{aligned}&\{(\alpha_A, \tilde{\alpha}_B) : \alpha_A \in [0, s],\ \tilde{\alpha}_B \in [0, 3s - 2\alpha_A]\} \\ &\cup \left\{(\alpha_A, \tilde{\alpha}_B) : \alpha_A \in [s, 3s],\ \tilde{\alpha}_B \in \left[0, \frac{3s - \alpha_A}{2}\right]\right\}.\end{aligned} \tag{A.12}$$

For these values of $(\alpha_A, \tilde{\alpha}_B)$ the optimal revelations have to be found supposing that at least one of them is zero. Supposing $\tilde{\alpha}_B^* = 0$, a solution of the form

$$\alpha_A^* = \min\left\{\frac{1}{2}(\alpha_A - s), \alpha_A\right\} = \frac{1}{2}(\alpha_A - s) \tag{A.13}$$

exists only if $\alpha_A > s$ (observe that this condition also implies $V_A'(0) > 0$) and, from (A.3), if $\tilde{V}_B'(0) < 0$, that is if and only if $\tilde{\alpha}_B < (3s - \alpha_A)/2$, otherwise we will have $\alpha_A^* = 0$. Lastly, note that both α_A^* and $\tilde{\alpha}_B^*$ are zero if and only if $\alpha_A \leq s$ and $\tilde{\alpha}_B \leq s$.

Collecting all the above results, if we split the first quadrant into the following regions (see Figure 1):

$$\begin{aligned}R_1 &= \{(x, y) : y \geq 3s, x \in [0, y - 3s]\} \\ R_2 &= \Big\{(x, y) :\ x \in [0, 3s], \\ &\quad y \in \left[\max\left\{3s - 2x, \frac{3s - x}{2}\right\}, x + 3s\right]\Big\} \\ &\quad \cup \{(x, y) :\ x \geq 3s, y \in [x - 3s, x + 3s]\} \\ R_3 &= \{(x, y) : x \geq 3s, y \in [0, x - 3s]\} \\ R_4 &= \{(x, y) : x \in [0, s], y \in [s, 3s - 2x]\} \\ R_5 &= \{(x, y) : x, y \in [0, s]\} \\ R_6 &= \left\{(x, y) : x \in [s, 3s], y \in \left[0, \frac{3s - x}{2}\right]\right\},\end{aligned} \tag{A.14}$$

we have

$$\begin{aligned}&(\alpha_A, \tilde{\alpha}_B) \in R_1 :\ \alpha_A^* = \alpha_A, \quad \tilde{\alpha}_B^* = \frac{1}{2}(\tilde{\alpha}_B + \alpha_A - s,) \\ &(\alpha_A, \tilde{\alpha}_B) \in R_2 :\ \alpha_A^* = \frac{1}{3}(2\alpha_A + \tilde{\alpha}_B) - s, \\ &\qquad \tilde{\alpha}_B^* = \frac{1}{3}(2\tilde{\alpha}_B + \alpha_A) - s, \\ &(\alpha_A, \tilde{\alpha}_B) \in R_3 :\ \alpha_A^* = \frac{1}{2}(\alpha_A + \tilde{\alpha}_B - s), \quad \tilde{\alpha}_B^* = \tilde{\alpha}_B, \\ &(\alpha_A, \tilde{\alpha}_B) \in R_4 :\ \alpha_A^* = 0, \quad \tilde{\alpha}_B^* = \frac{1}{2}(\tilde{\alpha}_B - s), \\ &(\alpha_A, \tilde{\alpha}_B) \in R_5 :\ \alpha_A^* = 0, \quad \tilde{\alpha}_B^* = 0, \\ &(\alpha_A, \tilde{\alpha}_B) \in R_6 :\ \alpha_A^* = \frac{1}{2}(\alpha_A - s), \quad \tilde{\alpha}_B^* = 0.\end{aligned} \tag{A.15}$$

An analogous table can be drawn for the choice of α_B^* by switching the indices A and B everywhere in the above equations.

B. Rent Extraction Comparison in the Complete Information Case

Letus examine in detail the case of complete information between providers and compare the total rent extraction for the two competition schemes. By symmetry it is sufficient to analyse the case where $\alpha_A \geq \alpha_B$. For the Hotelling game optimal revelations are given in (A.15), while from the results in Section 3.2.1, the revelation for the monopoly franchise case is given by $\min \alpha_B + \varepsilon, \alpha_A$, with $\varepsilon > 0$ small. Thus, if $\alpha_A = \alpha_B$, while for competition in the market we have either $\alpha_A^* = \alpha_B^* = 0$ or $\alpha_A^* = \alpha_B^* = \alpha_A - s$, the Dutch first price auction allows for all the rent to be extracted and thus performs better.

Let us now assume that $\alpha_A > \alpha_B$, so that for competition for the market the total extracted rent will equal $R_M = \alpha_B + \varepsilon$.

For spatial competition several cases have to be taken into account, since the total rent extracted in this case will be

$$R_H = \alpha_A^* D_A + \alpha_B^* D_B = \frac{1}{2s}(\alpha_A^* - \alpha_B^*)^2 + \frac{1}{2}(\alpha_A^* + \alpha_B^*). \quad \text{(B.1)}$$

From (A.14) and (A.15), recalling the graphical representation in Figure 1, we can distinguish four cases. We name them according to the corresponding region in the portion of quadrant under the bisector.

R_5 Since here $\alpha_A^* = \alpha_B^* = 0$ for spatial competition, we have $R_M > R_H$.

R_6 From (B.1) and (A.15) we have $R_H = (1/8s)(\alpha_A^2 - s^2)$, so that $R_M > R_H$ if $\alpha_B > ((\alpha_A^2 - s^2)/8s) - \varepsilon$.

R_2 In this case we obtain $R_H = (1/18s)(\alpha_A - \alpha_B)^2 + (1/2)(\alpha_A + \alpha_B) - s$ and thus setting $z = \alpha_A - \alpha_B$ it holds $R_H \leq R_M$ if and only if $g(z) \leq 0$, where $g(z) = (1/18s)z^2 + (1/2)z - (s + \varepsilon)$. Recalling that we are examining the part of region R_2 in Figure 1 lying under the bisector, we have to consider the behaviour of g for $z \in [0, 3s]$. Here g is increasing, with $g(0)g(3s) < 0$ if $s > \varepsilon$, which is the case since ε should be chosen as small as possible. Thus there exist $z_0 \in (0, 3s)$ such that $g < 0$ in $(0, z_0)$ and $g > 0$ in $(z_0, 3s)$. This point is given by the formula

$$z_0 = 9s\left(-\frac{1}{2} + \frac{1}{6}\sqrt{\frac{17s + 8\varepsilon}{s}}\right). \quad \text{(B.2)}$$

For $\varepsilon \simeq 0$ we obtain $z_0 \simeq 1.685s$. This means that in the part of region R_2 above the line $\alpha_A = \alpha_B + z_0$ we will have $R_M \geq R_H$, the reverse inequality being true elsewhere.

R_3 Here we have $R_H = (1/18s)[(\alpha_A - \alpha_B)^2 - s^2] + \alpha_B$ and since here $\alpha_A - \alpha_B \geq 3s$, we have $R_H \geq \alpha_B + s$, so that since $\varepsilon < s$ we get $R_M \geq R_H$.

The graphical description of these results is depicted in Figure 3.

C. Hotelling with More Than One Good

Provider j maximises the following utility function:

$$\max\left(\sum_{i=1}^{N}\left[t_i + \alpha_{ij} - k_i\right]D_{ij}\right). \quad \text{(C.1)}$$

Given that the rules for cost reimbursement have already been defined, we can rewrite the following expression as

$$\max\left(\sum_{i=1}^{N}\left(\alpha_{ij} - \alpha_{ij}^*\right)D_{ij}\right). \quad \text{(C.2)}$$

Since the demand functions are separate in each service i and all summands are nonnegative, each of them can be optimised separately, so that the F O C can be written as

$$-D_{ij} + \left(\alpha_{ij} - \alpha_{ij}^*\right)\frac{\varphi_i}{2m_i} = 0, \quad k \neq j \quad \text{(C.3)}$$

and the analysis carried out in Appendix A above is valid for any optimal α_{ij}^*.

D. N-Services Auctions in the Uniformly Distributed Case

Assume that players A and B are competing over N different services, $N \geq 2$. Letus examine the game strategy for player A: since the auction is done on the average price, by (24), through integration by parts we can write

$$z_A^* = \frac{1}{\mathbb{P}(Z_B \leq z_A)}\int_0^{z_A} z f(z)dz, \quad \text{(D.1)}$$

where f is the density of the random variable $Z_B = \sum_{i=1}^N \alpha_{iB}$. Suppose that each unknown function α_{iB} can be modelled as a uniformly distributed random variable on the interval $[0, b_i]$, with $b_1 \geq b_2 \geq \cdots \geq b_N$. Then their sum is distributed in $[0, \sum_{i=1}^N b_i]$ with density $f = f_1 * \ldots * f_N$. In this case it is possible to derive an analytic formula for the density f as follows: [37, 38]

$$\begin{aligned} f(s) = {} & \frac{1}{(N-1)!\prod_{i=1}^N a_i} \\ & \times \Bigg[s^{N-1}\varepsilon(s) - \sum_{j_1=1}^{N}\left(s - b_{j_1}\right)^{N-1}\varepsilon\left(s - b_{j_1}\right) \\ & + \sum_{1\leq j_1<j_2\leq N}\left(s - a_{j_1} - a_{j_2}\right)^{N-1}\varepsilon\left(s - b_{j_1} - b_{j_2}\right) \\ & + \cdots + (-1)^N\left(s - \sum_{i=1}^N b_i\right)^{N-1}\varepsilon\left(s - \sum_{i=1}^N b_i\right)\Bigg] \end{aligned} \quad \text{(D.2)}$$

and the distribution function $F(s) = \mathbb{P}(Z_B \leq s)$

$$\begin{aligned} F(s) = {} & \frac{1}{N!\prod_{i=1}^N b_i} \\ & \times \Bigg[s^{N}\varepsilon(s) - \sum_{j_1=1}^{N}\left(s - b_{j_1}\right)^{N}\varepsilon\left(s - b_{j_1}\right) \\ & + \sum_{1\leq j_1<j_2\leq N}\left(s - b_{j_1} - b_{j_2}\right)^{N}\varepsilon\left(s - b_{j_1} - b_{j_2}\right) \\ & + \cdots + (-1)^N\left(s - \sum_{i=1}^N b_i\right)^{N}\varepsilon\left(s - \sum_{i=1}^N b_i\right)\Bigg], \end{aligned} \quad \text{(D.3)}$$

with $\varepsilon(x) = 1$ for $x \geq 0$ and zero otherwise.

Since the optimal strategy for player A in any one-service auction is to declare half of his competitive advantage α_{iA}, performing N different auctions would lead A to declare half of $z_A = \sum_{i=1}^N \alpha_{iA}$.

Let us then analyse the behaviour of

$$z_A^*(z_A) - \frac{z_A}{2}. \quad \text{(D.4)}$$

Whenever this function is positive, performing a single auction for N different services would allow more rent to be extracted than setting up N one-service auctions. Therefore, we are interested in the sign of the function

$$h(z_A) = 2\int_0^{z_A} z f(z)\, dz - z_A F(z_A), \quad z_A \in \left[0, \sum_{i=1}^{N} b_i\right]. \tag{D.5}$$

We have: $h(0) = h(\sum_{i=1}^{N} b_i) = 0$,

$$h'(z_A) = z_A\, f(z_A) - F(z_A), \qquad h''(z_A) = z_A f'(z_A), \tag{D.6}$$

whenever f is differentiable. Since $z_A \geq 0$, the sign of h'' coincides with that of f'. The following can be proved by induction, for any $b_1 \geq \cdots \geq b_N$ and any $N \geq 2$:

Proposition 1 (see [39]). *Let f be the convolution product of N uniform distribution functions on the intervals $[0, b_i]$, $i = 1, \ldots, N$. Then*

(a) *$f > 0$ in $(0, \sum_{i=1}^{N} b_i)$ and is zero outside this interval;*

(b) *$f \in C^{N-2}(\mathbb{R})$, f is strictly increasing in $(0, b_N)$ and strictly decreasing in $(\sum_{i=1}^{N-1} b_i, \sum_{i=1}^{N} b_i)$;*

(c) *for $N > 2$, if there exists $t_1 < t_2$ such that $f'(t_1) = f'(t_2) = 0$, then $f'(t) = 0$ for all $t \in [t_1, t_2]$.*

D.1. The Case $N = 2$. For $N = 2$ we have

$$\mathbb{P}(Z_B \leq z_A) = \frac{1}{b_1 b_2}\begin{cases} \dfrac{z_A^2}{2} & z_A \in [0, b_2] \\ b_2\left(z_A - \dfrac{b_2}{2}\right) & z_A \in [b_2, b_1] \\ b_2 b_1 - \dfrac{(b_1 + b_2 - z_A)^2}{2} & z_A \in [b_1, b_1 + b_2], \end{cases}$$

$$\int_0^{z_A} z f(z) dz = \frac{1}{b_1 b_2}\begin{cases} \dfrac{z_A^3}{3} & z_A \in [0, b_2] \\ \dfrac{b_2^3}{3} + \dfrac{b_2}{2}(z_A^2 - b_2^2) & z_A \in [b_2, b_1] \\ (b_1 + b_2)\dfrac{z_A^2}{2} - \dfrac{z_A^3}{3} - \dfrac{b_2^3}{6} - \dfrac{b_1^3}{6} & z_A \in [b_1, b_1 + b_2], \end{cases} \tag{D.7}$$

thus

$$z_A^* = \begin{cases} \dfrac{2}{3} z_A & z_A \in [0, b_2] \\ \dfrac{1}{3}\dfrac{3z_A^2 - b_2^2}{2z_A - b_2} & z_A \in [b_2, b_1] \\ \dfrac{1}{3}\dfrac{3(b_1 + b_2)z_A^2 - 2z_A^3 - b_2^3 - b_1^3}{2b_1 b_2 - (b_1 + b_2 - z_A)^2} & z_A \in [b_1, b_1 + b_2]. \end{cases} \tag{D.8}$$

It is not difficult to show that $z_A^* \geq z_A/2$, with equality holding only for $z_A = b_1 + b_2$ (this is obvious for the first case and is easily verified by standard manipulations for the other two), thus the optimal value exceeds the sum of what is obtained by two different auctions.

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Endnotes

1. See [40] and the literature therein for a review.
2. A variable can be observed when some agents can privately and subjectively observe its value; it can be verified when it can be measured in an objective way, so that its value can be written in a contract and the provider can be made liable before court. See [8].
3. For health care, see [8, 10, 41].
4. In this model we assume that d is independent of e as in the traditional literature on devoted workers. In [42] d is allowed to be a function of e. Under this assumption the effort for being devoted is higher, but the incentive to pass part of the rent deriving from hiring devoted workers is the same as in a standard approach unless the budget allocated to each service is made dependent on the relative cost of the service.
5. In [42] it is shown that if the utility function of the devoted workers is not always decreasing in the effort and the budget allocated to each service depends on the price, the provider has an incentive to pay back a part of its information rent, but it influences the resources allocation process. In [29] the devoted workers play an important role in determining the timing in the adoption of a new technology.
6. For other public services, where the user charge represents a substantial amount of the cost of production, the regulator may leave the providers free to compete on quality or price. The basic model of competition is the same in both cases.
7. Note that if price competition is allowed the demand takes the form $D_A^p = [(\alpha_A^* - \alpha_B^*)/2m + 1/2]$ and the analysis corresponds to the one in this paper for $\varphi = 1$.
8. It may, for example, depend on the type of contract that a specific type of firm can stipulate.
9. For example, if player A assigns equal probability to any value of the unknown α_B, it will design his guess of α_B as a random variable uniformly distributed in the range $[0, b]$, that is, its density function will be given by $f(\alpha) = 1/b$.
10. In most cases the regulator pays a subsidy to the firm that wins the auction.

11. For a review and a solution of repeated auctions in the presence of nonverifiable quality see [43].

12. A numerical example to clarify this statement: suppose we have two services and $\alpha_{1A} = 3$, $\alpha_{2A} = 1$, $\alpha_{1B} = 1$, and $\alpha_{2B} = 2$. By performing two separate auctions, player A would win the first by declaring $1+ \in$, while B would win the second with the same declaration. By bundling player A has to declare $3+ \in$ in order to win the auction.

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