REGULATION STRATEGIES FOR PUBLIC SERVICE PROVISION

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Regulation strategies for public service provision

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Abstract

Public service provision has undergone a significant process of reform through the reduction of vertical integration in its supply and the introduction of competition. The aim of these reforms is to increase efficiency and ultimately to improve welfare, but these goals can be reached only if the appropriate regulation tool is chosen. In this paper we compare different ways of regulating the market in order to extract the information rent from the provider, in an environment where the regulator cannot observe quality and production costs and the workforce is represented by devoted workers. In particular, we will compare forms of competition in the market, such as spatial competition, with several forms of Dutch first price auctions for the market.

Keywords: Asymmetry of information, devoted worker, spatial competition, auctions. JEL Classification: I11, I18

1 Introduction

The institutional design of the public sector is more and more oriented towards a reduction of vertical integration and the introduction of forms of competition in the provision of public services. The actual process is quite heterogeneous. For essential facilities such as energy, gas and rail a separation has been created between the provider of the network and the companies that exploit it; in health care quasi markets have been introduced; for education and other local services new models of competition between public and private providers are sought.1 The aim of these reforms is to increase efficiency and ultimately to improve welfare, but their application to the provision of public services is difficult because of the specific characteristic of the sector. On the supply side, the technology of production, although universally available, usually needs fixed, sunk investments that restrict the number of firms that can acquire it. The workforce is often characterized by the presence of devoted workers whose behaviour is not simply motivated by the salary received. The services are usually produced on demand; they cannot be stocked or transported and their quality is often difficult to verify using objective parameters.2 As regards the price, the nature of merit

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1 See (Malyshev, 2006) 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 for its value. See (Chalkley and Malcomson, 1998).
goods of the service produced means that it is still set by the regulator which can observe costs imperfectly. All these elements contribute to the creation of local monopoly and information rents; the market moves away from a pure competitive structure, and the regulator should use more sophisticated tools to improve the performances of such pseudo markets.

Privatization may improve efficiency, but it leads to less public information on production costs; as a result, the relationship between cost and the effort of the provider becomes unknown. This is a problem that the literature has long recognized (Baron and Myerson, 1982) and offered solutions for specific sectors (Laffont and Tirole, 1993). As concerns the provision of public utilities, health care and education, several solutions have been proposed (Chalkley and Malcomson, 1998; 2000; Gravelle, 1999; Sappington, 2005; Levaggi, 2005; 2007) but none of them has proven to be optimal.

Another important characteristic of public service provision is related to workers’ motivation. The literature has shown that most of the public sector workers are devoted, because they receive utility from their salary and the output they produce. In a vertically integrated structure, this aspect is welfare improving since it reduces the production cost or it enhances the quality level. When a separation between the purchaser and the provider exists, the advantages of employing devoted workers become a rent to the provider (Francois, 2000; 2001; Glazer, 2004; Levaggi et al., 2005). The regulator should then try to induce the provider to pass (part) of this rent to the consumer.

The empirical evidence of the effect of competition is not conclusive; for education, it does not seem to have an impact on the cost of providing the service, but it might improve school performances (Harrison, 2005; Henry and Gordon, 2006; Fischer et al., 2006; De Fraja and Landeras, 2006). For hospital care the evidence is fairly mixed (Kessler and McClellan, 2000; Enthoven, 2002; Duggan, 2004; Abraham et al., 2005; Gaynor and Vogt, 2003); in both sectors cream skimming practices might arise.

This brief review of the literature shows that there is no consensus in both the theoretical and empirical literature on the strategy the regulator should use in this context.

In this paper we examine spatial competition and several forms of Dutch first price auctions to compare their effectiveness in extracting the information rent and reducing the monopoly power of the providers. We show that there is not a superior model: the form of regulation depends on the information each provider possesses about its competitor. Spatial competition should be preferred if the providers are very different in their degree of efficiency and if they have perfect information on their competitors. When they are quite similar and do not know each other well, the use of an auction mechanism should be preferred. In the latter environment, a multiple object auction allows to extract more rent from the provider.

The paper will be organised as follows. In Section 2 we present the model. Next, in Section 3 we restrict the analysis to one service and compare the performances of spatial competition with an auction, while Section 4 is devoted to the extension of the analysis to $N$ services. Conclusions are then drawn in Section 5.

2 The model

In the model presented here we abstract from any risk-sharing considerations, i.e. we assume that the cost of producing the service does not depend on the state of nature and that the basic technology is available to all the competitors. However, given that the investment in the technology is high and sunk, only a restricted number of firms are willing to enter into the market. The service usually has the nature of a merit or an impure public good; its quality can be privately observed but cannot be verified before a court because the service is often used as an intermediate good in an unobservable process producing utility.

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For a definition see (Cornes and Sandler, 1986).
The environment
In a specific community $N$ services are produced and are used by local and external users. The production $S_i^* i = 1, \ldots, N$ of each service is fixed, i.e. the quantity demanded is set outside this model. The services can be produced by two multiproduct firms ($A$ and $B$) that use a specific technology. These technologies are separated and each firm may produce all the $N$ services. The cost incurred by a firm to produce a specific service can be written as:

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

where $k_i$ 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, $e_{ij}$ is the effort of the staff and $\beta_{ij}$ is a function that captures reduction in costs due to several factors such as special contracts with the supplier and the ability of the specific provider in cost reduction activities. We define $\beta_{ij}$ as a productivity parameter; it cannot be observed by the purchaser and characterizes the production function of each firm. It can alternatively be private information to the provider or it can be observed by its competitor. For each service $i$, the cost can be lowered through the effort $e_{ij}$ of the provider and we assume that for both $A$ and $B$ this produces a disutility $f$ linear in the number of services produced, but increasing in the effort, i.e.:

$$f(e, S) = S \ f(e) \quad S \ f(e) > 0; \quad S \ f(e) > 0;$$

Given that the disutility is linear in the services produced, the choice of the number does not affect the marginal production cost. The quality of each service produced can be observed, but it cannot be verified before a court. This is a problem common to production of public services, where quality cannot be measured with the outcome of the service supplied.\(^4\) In health care, for example, the quality and the appropriateness of the treatment cannot be measured with 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. For this reason, we assume that a minimum verifiable level of quality, set to zero for simplicity, can be contracted for, while any improvement on such a level can only be obtained using indirect incentives to the provider.

The provider
We identify the objectives pursued by the provider with the utility function of the management. The provider participates in the production process only if the reward received, net of the production cost, produces a positive utility. The staff are devoted workers, i.e. they receive utility from the outcome of their effort. The utility is separate and additive in the services produced. The utility function of provider $j$ for a generic service $i$ can be written as:

$$U(t_i + d_{ij} - C_{ij} - f(e_{ij})) \quad i = 1, \ldots, N, \ j = A, B$$

where $t_i$ is the reimbursement scheduled. The devoted quality of the effort of the staff is private information, i.e. $d_{ij}$ cannot be observed by the purchaser.\(^5\) To simplify the analysis, we assume that the utility is linear in the net reward

$$U = t_i + d_{ij} - C_{ij} - f(e_{ij}) \quad i = 1, \ldots, N, \ j = A, B$$

\(^4\)For health care, see (Chalkley and Malcomson, 1998; 2000; Bos and De Fraja, 2002).

\(^5\)The formulation of the cost function in equation (1) can in any case be interpreted in terms of devoted worker in a more traditional way. In fact $\beta_{ij}$ can be interpreted as a lower cost that derives from the devoted characteristic of the staff.
The purchaser

The purchaser acts as the agent of the citizens and buys services on their behalf. The purchaser’s behaviour can be represented by the maximisation of a function defined over the consumers’ surplus. Its objective should be to find the best trade-off between quality and the cost of the service, defined as the sum of the user charge the consumer has to pay and the cost the purchaser has to reimburse. Given that in this article the main focus is on the definition of a structure that allows reduction of the information rent of producers, we assume that a process of welfare maximisation has already been performed to allocate the resources to each service. In this environment we define the purchaser’s optimal strategy as the choice of the form of regulation that allows the maximum rent to be extracted from the provider.

The rules of the game

Two providers, located at the extremes of a line of length one, provide $N$ services using linear additive production functions, separate in each aspect. The purchaser can imperfectly observe the technology of production and the utility of the provider. This information can be private or it can be observed by the other competitor. The reimbursement $t_i$ to the provider is higher than the price $p_i$ charged to the consumer, since a part of the cost is financed through general taxation $g_i$, i.e.:

$$t_i = p_i + g_i$$

(4)

The rules for determining the initial share between price and subsidy are determined outside the model. The provider receives a budget $g_i$ for each service and has to regulate the market by choosing between spatial competition and Dutch first price auction. Given that quality cannot be verified, for spatial competition the purchaser has to decide if competition should be made on the quality of the service or on the price charged to the consumer (the user charge); for the auction, the game can be developed only in terms of cost reduction, which will then be split between a lower user charge (through $p_i$) and/or a subsidy reduction (through $g_i$).

2.1 Benchmark price

Now we show how the purchaser sets the benchmark (maximum) reimbursement. Given that quality beyond a minimum requirement cannot be verified, $q_i$ will be set to zero. For a generic service $i$ and provider effort $e_i$, the cost observed by the purchaser is equal to $C_i = k_i - e_i$, while the true cost for a purchaser is $C_{ij} = k_i - e_{ij} - \alpha_{ij}$. 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 ($\beta_{ij}$) and can be interpreted as the information rent of the provider. Given that each technology is independent, we can replicate the game for each service. The problem can be written in general terms as:

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

where $t_i$ is the reimbursement that should be paid to the provider of the service. The F.O.C for the problem can be written as:

$$f'(e_i^*) = 1$$

(5)

$$t_i^* = C_i + f(e_i^*)$$

(6)

The optimal effort $e_i^*$ is determined by the equation $f'(e_i^*) = 1$, which by (6) sets the reimbursement to $t_i^* = k_i - e_i^* + f(e_i^*)$. This represents the maximum reimbursement for the service from the observation of
The true cost is equal to $k_i - \alpha_{ij} - e_i^* + f(e_i^*)$; this means that the provider receives an information rent equal to $\alpha_{ij}$, which derives from the inability of the purchaser to observe its utility and cost function. In some specific settings, this contract can be improved upon using an incentive compatible scheme (Laffont and Tirole, 1993), but in a context where the price paid by the user is fixed or the service is free at the point of use, (Levaggi and Levaggi, 2005) show that the use of a straight agency model is not an efficient instrument to extract the information rent from the provider, unless the benefits deriving from such private information are proportional to the effort of the agent. For this reason, in a setting where the budget and/or the number of services to be produced is fixed, other regulatory instruments have to be used.

3 Competition over one service

In this section we assume that each provider supplies only one service and regulatory instruments introducing competition among providers involve each service separately. We analyse both spatial and quality competition à la Hotelling and a Dutch first price auction mechanism.

A word on notation: since we are considering just one service the subscript $i$ will be dropped throughout the section.

3.1 Spatial competition

In the market for health care and education the providers use a part of the information rent to compete for patients on quality (Gravelle, 1999; Levaggi, 2005; 2007; Fischer et al., 2006). The main characteristic of this setting is that the service is supplied free of charge (or for a very low price compared to the cost of provision), but the consumer has to bear private costs to use the service. These features are common to health, education and many local public services (sport and recreation facilities, social services) and for this reason in this section we examine spatial competition as a regulatory instrument. The demand is fixed, but the consumer can choose its preferred provider by comparing the net utility derived from the use of the service.

Service users are uniformly distributed on a unit line and normalised to one; providers $A$ and $B$ are 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. Their utility $U$ depends on the quality of the service and the cost they have to incur to use it:

$$U(x) = \varphi q_j - c_x$$

where $q_j$ is the quality of the service offered by competitor $j$: they can observe directly or through an agent that acts in their own interest. The quantity $c_x$ reflects several aspects relating to cost: 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 $m$, equation (7) can be written as:

$$U(x) = \begin{cases} \varphi q_A - p_A - mx & \text{if he chooses supplier A} \\ \varphi q_B - p_B - m(1 - x) & \text{if he chooses supplier B.} \end{cases}$$

Here $\varphi q_A$ 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. For some services, $p_j$ might be equal to zero, i.e. the service might be free at the point of use and in this case competition can be made on quality only. This depends on the rules of the game. If the purchaser allows price competition between the 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. As per quality, given that it cannot be verified in court, the purchaser sets a minimum verifiable level which we assume equal to zero and when suppliers compete on this element they may increase it to \( q_j \).

In what follows we examine the choice of provider \( A \) as regards the use of its rent for competing with \( B \). From equation (8) we can derive the location \( \bar{x} \) of customers that are indifferent in the choice between \( A \) and \( B \):

\[
\bar{x} = \frac{\varphi(q_A - q_B) + (r_A - r_B)}{2m} + \frac{1}{2}.
\]

Then, the demand function for \( A \) can be obtained by multiplying \( \bar{x} \) by the density which, given the unit length of the line, is equal to 1. The information rent \( \alpha_A \) can be transformed into a quality increase (acting on \( q_A \)) or a price reduction (using \( r_A \)).\(^6\) Which of the two policies can be pursued depends on the rules of the game set by the purchaser. For quality competition the demand will be written as

\[
D_A^q = \left[ \frac{\varphi(\alpha_A^* - \alpha_B^*)}{2m} + \frac{1}{2} \right],
\]

while for price competition the demand can be written as

\[
D_A^p = \left[ \frac{\alpha_A^* - \alpha_B^*}{2m} + \frac{1}{2} \right].
\]

We can therefore analyse both cases by taking \( D_A := D_A^q \), since \( D_A^p \) corresponds to \( \varphi = 1 \).

The choice of \( \alpha_A^* \), i.e. the part of the information rent to be used to compete with \( B \), can be obtained by maximising the following utility function:

\[
\max \left[ (t^* + \alpha_A - k - \alpha_A^* + e - f(e))D_A \right].
\]

Given that \( t^* = k - e^* + f(e^*) \), we can rewrite the following expression as:

\[
\max_{\alpha_A^* \in [0, \alpha_A]} [D_A (\alpha_A - \alpha_A^*)].
\]

The general maximisation process is presented in Appendix A. Whenever \( \alpha_A \) and \( \alpha_B \) are not too small w.r.t. the ratio \( s = \frac{m}{\varphi} \), the optimal revelation for \( A \) is equal to:

\[
\alpha_A^{*q} = \min \left\{ \frac{1}{2} \left( \alpha_B^{*q} + \alpha_A - \frac{m}{\varphi} \right), \alpha_A \right\}
\]

for quality competition and to

\[
\alpha_A^{*p} = \min \left\{ \frac{1}{2} \left( \alpha_B^{*p} + \alpha_A - m \right), \alpha_A \right\}
\]

for price competition. The general solution is given by

\(^6\)The information rent of provider \( j \) is \( \alpha_j \). Due to the form of the production cost, the part \( \alpha_j^* \) can be transformed into higher quality (\( q_j \)) or a price reduction (\( r_j \)).
\[ (\alpha_A, \alpha_B) \in A: \quad \alpha_A^* = \alpha_A, \quad \alpha_B^* = \frac{1}{2}(\alpha_B + \alpha_A - s) \]
\[ (\alpha_A, \alpha_B) \in B: \quad \alpha_A^* = \frac{1}{3}(2\alpha_A + \alpha_B) - s, \quad \alpha_B^* = \frac{1}{3}(2\alpha_B + \alpha_A) - s \]
\[ (\alpha_A, \alpha_B) \in C: \quad \alpha_A^* = \frac{1}{2}(\alpha_A + \alpha_B - s), \quad \alpha_B^* = \alpha_B \]
\[ (\alpha_A, \alpha_B) \in D: \quad \alpha_A^* = 0, \quad \alpha_B^* = \frac{1}{2}(\alpha_B - s) \]
\[ (\alpha_A, \alpha_B) \in E: \quad \alpha_A^* = 0, \quad \alpha_B^* = 0 \]
\[ (\alpha_A, \alpha_B) \in F: \quad \alpha_A^* = \frac{1}{2}(\alpha_A - s), \quad \alpha_B^* = 0, \]

where regions A-F presented in Figure 1 are defined in (22). If \( \alpha_A \leq \frac{m}{\varphi} \), no rent is passed on to the consumer; after this threshold, the equilibrium depends on the information competitor \( A \) has on \( \alpha_B \) and on the relative size of \( \alpha_A \) and \( \alpha_B \). In this context, we present three different solutions.

**Symmetric Nash solution**

With identical providers, it is reasonable to assume the existence of a symmetric Nash equilibrium, in which firms assume that competitors have their same \( \alpha_j \) and behave symmetrically. The information rent they pass on to the service user as an increased quality \( q_A^* \), from (10) (see also equations (12)) will be equal to:

\[ \alpha_A^q = \max \left\{ 0, \alpha_A - \frac{m}{\varphi} \right\} = q_A^*. \]
The solution for the price competition case can be found setting $\varphi = 1$ and the price reduction solution will be equal to:

$$\alpha_A^p = \max \left\{ 0, \alpha_A - m \right\} = r_A^*$$. 

**Perfect information on the other provider**

In this case, each provider can observe the $\alpha_j$ of its competitor. This assumption can be justified on several grounds: given that the providers share the same technology, they might be able to have better information than the purchaser on the possible methods of improving efficiency. Also, they employ the same type of workers and they might be able to evaluate their degree of devotion. Let’s then assume that $\alpha_B$ is known to $A$; the optimal revelation by provider $A$, for both quality and price competition, is derived in equations (12). In general if $\alpha_B > \alpha_A$, competitor $A$ has to give away all his information rent only if $\alpha_A \leq \alpha_B - 3s$. Note also that $\alpha_A^*$ is increasing with $\alpha_A$, no matter what the position of player $A$ is w.r.t. its competitor $\alpha_B$. 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 $\alpha_A > \frac{m}{\varphi}$, i.e. if $\alpha_A$ is not too small, the solution can be written as $\alpha_A^q = \frac{1}{2}(\alpha_A - \frac{m}{\varphi})$ and $\alpha_A^{sp} = \frac{1}{2}(\alpha_A - m)$ respectively, that is half the value found in the case of symmetric players.

**Imperfect information**

Let’s now assume that $\alpha_j$ is private information to each provider $j$, i.e. in defining their reaction function, they have to guess what the other will do. In this context, each provider can have some information on the range of values of the function of the competitor and on its more probable values. Let’s assume that player $A$ models $\alpha_B$ as a random variable which is uniformly distributed in the range $[0, a]$, that is its density function is given by $f(\alpha) = \frac{1}{a}$. In this case, it is reasonable for $A$ to use the expected value, i.e. $E(\alpha_B) = \frac{a}{2}$ and also to suppose that this mean value is not too small. Recalling the optimal revelation values found in equations (12), if $a \geq 6s$, provider $A$ will set

$$\alpha_A^* = \alpha_A$$ \hspace{1cm} if $\alpha_A \in \left[0, \frac{a}{2} - 3s\right]$

$$\alpha_A^* = \frac{1}{3}(2\alpha_A + \frac{a}{2}) - s$$ \hspace{1cm} if $\alpha_A \in \left[\frac{a}{2} - 3s, \frac{a}{2} + 3s\right]$

$$\alpha_A^* = \frac{1}{2}(\alpha_A + \frac{a}{2} - s)$$ \hspace{1cm} if $\alpha_A \geq \frac{a}{2} + 3s$.

For smaller values of $a$ the solution can be found using (12).

### 3.2 Auction

In this section we use a Dutch first price auction as an instrument to make the providers reveal their private information. As before, quality cannot be verified, therefore the auction can only be done on the service reimbursement $t$.

Given the nature of the private information held by the provider, the benchmark solution (6) represents the maximum bid price and we implement a Dutch first price auction on it. Depending on the environment and on its objectives, the purchaser will then decide how to split the gain (in terms of reduction in the total cost) between $p$ and $q$ as in (4).

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7In what follows it is assumed that $r_A^* \leq p$; if this is not the case, a part of $\alpha_A^*$ will be used for price reduction and the rest for quality improvement.

8For a review and a solution of repeated auctions in the presence of non-verifiable quality see (Calzolari and Spagnolo, 2007).
Each provider has to make a bid for $t$ and can use its private information $\alpha_j$ to lower it by declaring some $t(\alpha_j^*) = k - \alpha_j^* - e + f(e)$ 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 $\alpha_A^*$ in order to maximise the function

$$[t(\alpha_A^*) + \alpha_A - k + e - f(e)] \mathbb{P}(\alpha_A^* \geq \alpha_B^*)$$

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

**Perfect information**

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

$$\alpha_A^* = \epsilon + \alpha_B^*, \quad \epsilon > 0.$$  

Let's 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 $\alpha_A^* \approx 0$.

**Imperfect information**

Let's now see how provider $A$ behaves when the parameter for its competitor cannot be observed. In this case, $\alpha_B$ can be modelled as a random variable, distributed in the range $[0, a]$ with density $f$. The optimization can be carried out as in (Krishna, 2002, Section 2.3 p. 16) and the equilibrium bid can be written as

$$\alpha_A^* = \alpha_A - \int_0^{\alpha_A} \frac{\mathbb{P}(\alpha_B \leq \alpha)}{\mathbb{P}(\alpha_B \leq \alpha_A)} \, d\alpha.$$
Let’s assume that the distribution is uniform, i.e. its density function is \( f(\alpha) = \frac{1}{a} \). By the above formula
\[
\alpha^*_A = \alpha_A - \frac{a}{\alpha_A} \int_0^{\alpha_A} \frac{\alpha}{a} \, d\alpha = \frac{\alpha_A}{2}.
\]
In this case, the auction allows half of the provider’s rent to be obtained in the form of cost reduction.

### 3.3 Comparing the results

In this section we discuss the choice of the regulator, which has to choose between spatial competition or an auction. The decision depends both on the effectiveness of each competing model to make the provider reveal its private information and on the shape of the regulator’s objective function, as regards the trade-off between quality and cost. Spatial competition may be used to increase quality or to reduce the user charge; an auction produces a reduction in the cost and, as an outcome, a lower user charge or a subsidy reduction. Quality, user charges and subsidies have different effects (both in sign and size) on the welfare function which ultimately depends on the shape of the latter. We wish to abstract from these considerations and for this reason we compare the two regulation frameworks simply on their ability to extract private information from the provider.

From a pure “effectiveness” point of view, defined as the power of the model to make the provider reveal its private information, the ranking of the two spatial models depends on \( \phi \), i.e. consumers’ evaluation of quality. If this parameter is greater than one, quality competition is more effective.

The choice between spatial competition and auction depends on the information the purchaser has about the game and on the degree of local monopoly the two firms can enjoy.

The most interesting result is that there is not a superior model in this context. Spatial competition should be preferred if the providers are very different in their abilities and if they have perfect information on their competitor. In this case, in fact, the use of spatial competition enables some of this private information to be passed on to the consumers in terms of quality (or price), while in the auction such rent would stay with the provider. If instead the two providers are quite similar and know each other well, the use of an auction mechanism should be preferred. In this case, in fact, the local monopoly rent of the Hotelling game disappears and possibly all the provider’s rent is passed on to the consumers.

Finally, travel costs increase the monopoly rent, as would be expected. Other things being equal, spatial competition will be more effective the lower the value of \( m \).

### 4 Extension to \( N \) goods

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

#### 4.1 Spatial competition

For quality and price competition, the solution is still represented by equations (12). In this case, in fact, given that the production of each service is separated and the consumers of both services might not necessarily be the same, the conditions for competition are set on each service separately as shown in Appendix B.
4.2 Auction

For the auction case, even in the presence of separated production processes and different consumers, competition is stronger than in the previous case, especially when providers have no prior information on the productivity parameters of their competitors. This is because by auctioning $N$ services at the same time, the prize for winning the auction is increasing. 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.

**Auction for $N$ goods, no prior 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, i.e. the provider that declares the minimum average cost wins the auction. The cost for a generic service $i$ produced by supplier $A$ can be written as:

$$k_i - \alpha_i^* a_i - e^* + f(e^*)$$

and the average price can be written as

$$\frac{\sum_{i=1}^{N} k_i}{N} - \frac{\sum_{i=1}^{N} \alpha_i^* a_i}{N} - e^* + f(e^*).$$

Therefore provider $A$ wins if

$$\sum_{i=1}^{N} \alpha_i^* A \leq \sum_{i=1}^{N} \alpha_i^* B.$$

Let’s analyse the game strategy of player $A$. Supposing that no information on $\alpha_i B$ is available, we can assume that each $\alpha_i B$ is a random variable distributed according to a distribution function $f_i$ in the support interval $[0, a_i]$ for all $i = 1, ..., N$. By linearity, the expected payoff of player $A$ is

$$\left[\sum_{i=1}^{N} (\alpha_i A - \alpha_i^* A)\right] P\left(\sum_{i=1}^{N} \alpha_i^* B \leq \sum_{i=1}^{N} \alpha_i^* A\right) = \left[\sum_{i=1}^{N} (\alpha_i A - \alpha_i^* A)\right] P\left(\sum_{i=1}^{N} \alpha_i^* B \leq z\right)$$

where the second term represents the probability for player $A$ of winning the auction. Let now $z_A^* = \sum_{i=1}^{N} \alpha_i^* A$, $z_A = \sum_{i=1}^{N} \alpha_i A$, and $Z_B$ be the random variable $Z_B = \sum_{i=1}^{N} \alpha_i B$. 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 good auction in $z$ and the solution is found as in (Krishna, 2002). The optimal revelation for player $A$ solves the functional equation

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

therefore

$$z_A^* = z_A - \frac{1}{P(Z_B \leq z_A)} \int_{0}^{z_A} P(Z_B \leq z) dz. \hspace{1cm} (14)$$

Since $Z_B = \sum_{i=1}^{N} \alpha_i B$ we have

$$P(Z_B \leq z) = \int_{K} f_1(x_1) \cdots f_N(x_N) dx_1 \cdots dx_N = \int_{0}^{z} f_{\Sigma}(x) dx$$

where the set $K$ is given by $K = \{(x_1, ..., x_N): \sum_{i=1}^{N} x_i \leq z, x_i \geq 0\}$ and $f_{\Sigma}$ is the density function of the random variable $Z_B$. By standard probability theory $f_{\Sigma}$ 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 $(h * g)(x) = \int h(x-y)g(y) dy$. 

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If no prior information is available on $\alpha_i$, we can assume that its distribution is uniform on $[0, a_i]$, so that $f_i(t) = \frac{1}{a_i}$ for $t \in [0, a_i]$ and zero otherwise. In (Levaggi and Levaggi, 2007) it is shown how, under technical conditions on the sequence $(a_i)$, the problem can be solved for increasing $N$. Results show that more rent can be extracted in this case, compared to performing separate auctions for different services. The effectiveness of the auction in extracting rent, depends on the mean, and especially on the variance of the productivity parameters, rather than on the number $N$ of services. The results show that if the purchaser thinks providers have no information on their opponent, a multiple object auction should be implemented. 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.

For $N = 2$ the density $f_{\Sigma}$ can be easily computed and optimisation can be carried analytically as shown in Appendix C. Results are summarised in equation 16

\[
Z_A^* = \begin{cases} 
\frac{2}{3} Z_A & Z_A \in [0, a_2] \\
\frac{3}{2} Z_A - a_2 & Z_A \in [a_2, a_1] \\
\frac{1}{2} Z_A^2 - \frac{2}{3} Z_A^2 + \frac{3}{2} - a_3^2 & Z_A \in [a_1, a_1 + a_2]. 
\end{cases} 
\]

The optimal declaration of the productivity parameter in 16 is always greater than $\frac{a}{2}$. Since the optimal $\alpha_A^*$ for a single-good auction is one half of the devoted characteristic $\alpha_A$, the optimal value exceeds the sum of what is obtained by two different auctions.

In the actual implementation of this auction, the regulator should avoid the winner stipulating a sub-contract 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 purchaser to extract rent from the providers.

If the competitors can observe some of the cost-saving parameters, the rent extracted will be lower than in the previous case. When there is perfect information at competitor level, the $N$-goods auction reduces to the one good case, i.e. the competitor with the greatest $z$ will be able to declare just a fraction more than the $z$ of his competitor. If $z = 0$ for one of the two competitors, all the rent deriving from efficiency will be appropriated by the winning provider.

5 Conclusions

The provision of services by the public sector has been radically reformed in recent years through privatization and competition. This process leads to less information on costs and technology, a problem that the literature has long recognized, and for which specific solutions have been proposed. When privatization concerns a public service, regulation is more complicated: most of these services are merit goods, their quality is not verifiable and their price is heavily subsidized.

In this paper, we have examined the comparative advantages of regulation through spatial competition and auctions in a market where providers have private information on their cost function. These can be derived from specific characteristics of the workforce they employ (devoted workers) or from their superior ability in organising the production process.

The distinguishing feature of these instruments is the use of the information about efficiency parameters in the decision-making process of each competitor. While this element essentially determines the bid in the auction, in spatial competition the monopoly rent mitigates the role of information. In terms of rent
extraction, spatial competition is more powerful whenever competitors’ efficiency is very different and there is no asymmetry of information between providers. When efficiency is private information, an auction should be preferred and in this case it would be optimal to use a multiple object auction.

Finally, the regulator should also take into account the different effects on welfare of each mechanism. The gains deriving from spatial competition can be shared only by service users, and the regulator can choose between price and quality competition. Auctions produce a price decrease which can be used for a reduction of the user charge or of the subsidy. In the first case service users share the benefit; in the latter it is spread among the community of tax payers. 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.

Welfare considerations can only be taken into account if a specific objective function is defined for the regulator, an aspect that has not been modelled in this paper and on which we wish to focus our future research.

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References


A Solution to the Hotelling game

If $\alpha_A > 0$ the competing provider $A$ has to perform the following optimization:

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

with $\varphi = 1$ for price competition and $\varphi > 1$ in the case of quality competition. The first derivative of the objective function is

$$V_A'(\alpha) = -\frac{\varphi}{2m}(2\alpha - \alpha_B^* - \alpha_A) - \frac{1}{2} \tag{17}$$

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

$$V_A'(0) = \frac{\varphi}{2m}(\alpha_B^* + \alpha_A) - \frac{1}{2} \tag{18}$$

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 $V_B$ and $\alpha_B^*$. For the present, let’s set aside cases where at least one of the optimal values is zero. Then from equation (17) we search for optimal couples $(\alpha_A^*, \alpha_B^*)$ satisfying

$$\alpha_A^* = \min \left\{ \frac{1}{2} \left( \alpha_A + \alpha_B^* - \frac{m}{\varphi} \right), \alpha_A \right\},$$

and

$$\alpha_B^* = \min \left\{ \frac{1}{2} \left( \alpha_B + \alpha_A^* - \frac{m}{\varphi} \right), \alpha_B \right\} \tag{19}$$

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

$$\alpha_A^* = \frac{1}{4} \left[ \alpha_B^* + 3\alpha_A - s - |\alpha_B^* - \alpha_A - s| \right] \tag{19}$$

$$\alpha_B^* = \frac{1}{4} \left[ \alpha_A^* + 3\alpha_B - s - |\alpha_A^* - \alpha_B - s| \right] \tag{20}$$
and substituting the second equation in the first one

\[
\alpha_A^* = \frac{1}{16} \left[ \alpha_A^* + 12 \alpha_A + 3 \alpha_B - 5s - |\alpha_A^* - \alpha_B - s| - |\alpha_A^* - 4 \alpha_A + 3 \alpha_B - 5s - |\alpha_A^* - \alpha_B - s| \right].
\] (21)

Now we have to examine different cases: firstly let’s search for a solution \(\alpha_A^*\) satisfying \(\alpha_A^* - \alpha_B - s \geq 0\). Under this assumption, equation (21) yields

\[
\alpha_A^* = \frac{1}{4} \left[ 3 \alpha_A + \alpha_B - s - |\alpha_B - \alpha_A - s| \right] = \frac{1}{2} \min\{\alpha_A + \alpha_B - s, 2\alpha_A\}.
\]

By standard algebraic tools, since \(s > 0\), it can be shown that the above solution satisfies the constraint \(\alpha_A^* - \alpha_B - s \geq 0\) only if \(\alpha_A \geq \alpha_B + 3s\). Moreover, this inequality implies \(\alpha_A + \alpha_B - s \leq 2\alpha_A\), so that in this case \(\alpha_A^* = \frac{1}{2} (\alpha_A + \alpha_B - s)\). Also, note that here \(\alpha_A^* \geq \alpha_B + s > 0\). Substituting back in (20) we get \(\alpha_B^* = \alpha_B \geq 0\), so that our couple of optimal values is always admissible in this case.

Now let’s examine the existence of solutions of (21) satisfying \(\alpha_A^* - \alpha_B - s < 0\). From (21) we obtain

\[
\alpha_A^* = \frac{1}{8} \left[ \alpha_A^* + \alpha_B + 6 \alpha_A - 3s - |\alpha_A^* - 2 \alpha_A + \alpha_B - 3s| \right] = \frac{1}{4} \min\{\alpha_A^* + 2 \alpha_A + \alpha_B - 3s, 4 \alpha_A\}.
\]

Solving the equation \(\alpha_A^* = \frac{1}{4} (\alpha_A^* + 2 \alpha_A + \alpha_B - 3s)\) we find \(\alpha_A^* = \frac{1}{4} (2 \alpha_A + \alpha_B) - s\), which is admissible iff

\[
\begin{align*}
\frac{1}{4} (2 \alpha_A + \alpha_B) - s + 2 \alpha_A + \alpha_B - 3s &\leq 4 \alpha_A \iff \alpha_A \geq \alpha_B - 3s \\
\frac{1}{4} (2 \alpha_A + \alpha_B) - s - \alpha_B - s &< 0 \iff \alpha_A < \alpha_B + 3s \\
\frac{1}{4} (2 \alpha_A + \alpha_B) - s > 0 &\iff \alpha_A > \frac{3s - \alpha_B}{2}.
\end{align*}
\]

From equation (20) we find the corresponding \(\alpha_B^* = \frac{1}{4} (2 \alpha_B + \alpha_A) - s\). Note that this is in fact the “symmetric” case for the optimal values, thus also the constraint \(\alpha_B \geq \frac{3s - \alpha_A}{2}\) has to be imposed to validate the optimal couple in this case.

Reciprocally, \(\alpha_A^* = \alpha_A\) is a solution iff

\[
\begin{align*}
\alpha_A + 2 \alpha_A + \alpha_B - 3s &> 4 \alpha_A \iff \alpha_A < \alpha_B - 3s \\
\alpha_A - \alpha_B - m &< 0 \iff \alpha_A < \alpha_B - s.
\end{align*}
\]

Up to now we have considered only cases where both maximum points can be obtained from equations (19) and (20). By the above analysis, this covers the union of regions A, B and C in Figure 1, i.e. it is valid outside the set

\[
\{(\alpha_A, \alpha_B) : \alpha_A \in [0, s], \alpha_B \in [0, 3s - 2 \alpha_A]\}
\]

\[
\cup \left\{(\alpha_A, \alpha_B) : \alpha_A \in [s, 3s], \alpha_B \in \left[0, \frac{3s - \alpha_A}{2} \right]\right\}.
\]

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

\[
\alpha_A^* = \min\left\{\frac{1}{2} (\alpha_A - s), \alpha_A\right\} = \frac{1}{2} (\alpha_A - s)
\]

16
exists only if $\alpha_A > s^9$ and, from (18), if $V_0' (0) < 0$, that is iff $\alpha_B < \frac{3s - \alpha_A}{2}$, otherwise we will have $\alpha_A^* = 0$. Lastly, note that both $\alpha_A^*$ and $\alpha_B^*$ are zero iff $\alpha_A \leq s$ and $\alpha_B \leq s$.

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

$$A = \{(\alpha_A, \alpha_B) : \alpha_B \geq 3s, \alpha_A \in [0, \alpha_B - 3s]\}$$

$$B = \left\{(\alpha_A, \alpha_B) : \alpha_A \in [0, 3s], \alpha_B \in \left[\max \left\{3s - 2\alpha_A, \frac{3s - \alpha_A}{2}\right\}, \alpha_A + 3s\right]\right\}$$

$$C = \{(\alpha_A, \alpha_B) : \alpha_A \geq 3s, \alpha_B \in [\alpha_A - 3s, \alpha_A + 3s]\}$$

$$D = \{(\alpha_A, \alpha_B) : \alpha_A \in [0, s], \alpha_B \in [s, 3s - 2\alpha_A]\}$$

$$E = \{(\alpha_A, \alpha_B) : \alpha_A, \alpha_B \in [0, s]\}$$

$$F = \{(\alpha_A, \alpha_B) : \alpha_A \in [s, 3s], \alpha_B \in [0, \frac{3s - \alpha_A}{2}]\}$$

we have

$$(\alpha_A, \alpha_B) \in A : \alpha_A^* = \alpha_A, \quad \alpha_B^* = \frac{1}{2}(\alpha_B + \alpha_A - s)$$

$$(\alpha_A, \alpha_B) \in B : \alpha_A^* = \frac{1}{3}(2\alpha_A + \alpha_B) - s, \quad \alpha_B^* = \frac{1}{3}(2\alpha_B + \alpha_A) - s$$

$$(\alpha_A, \alpha_B) \in C : \alpha_A^* = \frac{1}{2}(\alpha_A + \alpha_B - s), \quad \alpha_B^* = \alpha_B$$

$$(\alpha_A, \alpha_B) \in D : \alpha_A^* = 0, \quad \alpha_B^* = \frac{1}{2}(\alpha_B - s)$$

$$(\alpha_A, \alpha_B) \in E : \alpha_A^* = 0, \quad \alpha_B^* = 0$$

$$(\alpha_A, \alpha_B) \in F : \alpha_A^* = \frac{1}{2}(\alpha_A - s), \quad \alpha_B^* = 0.$$

### B Hotelling with more than one good

Provider $j$ maximises the following utility function:

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

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

$$\max \left(\sum_{i=1}^{N} [(\alpha_{ij} - \alpha_{ij}^*) D_{ij}]\right).$$

Since the demand functions are separate in each service $i$ and all summands are non-negative, each of them can be optimized separately, so that the F.O.C. can be written as:

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

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

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*Observe that this condition also implies $V_0'(0) > 0$. 

17
The case \( N = 2 \) with uniform distributions

Assume that players \( A \) and \( B \) are competing over two goods and let’s examine the game strategy for player \( A \). By equation (14), through integration by parts we can write

\[
z_A^* = \frac{1}{\mathbb{P}(Z_B \leq z_A)} \int_0^{z_A} z f(z) dz
\]

where \( f \) is the density of the random variable \( Z_B = \alpha_1 B + \alpha_2 B \). If the unknown functions \( \alpha_{Bi} \) are modelled as two uniformly distributed random variables on intervals \([0, a_i]\) with \( a_1 \geq a_2 \), their sum is distributed in \([0, a_1 + a_2]\) with the following density

\[
f(z) = \frac{1}{a_1 a_2} \begin{cases} 
z & z \in [0, a_2] \\
a_2 & z \in [a_2, a_1] \\
a_1 + a_2 - z & z \in [a_1, a_1 + a_2],
\end{cases}
\]

therefore

\[
\mathbb{P}(Z_B \leq z_A) = \int_0^{z_A} f(z) dz = \frac{1}{a_1 a_2} \begin{cases} 
z_A^2 & z_A \in [0, a_2] \\
a_2(z_A - \frac{a_2}{2}) & z_A \in [a_2, a_1] \\
(a_1 + a_2 - z_A)^2 & z_A \in [a_1, a_1 + a_2].
\end{cases}
\]

and

\[
\int_0^{z_A} z f(z) dz = \frac{1}{a_1 a_2} \begin{cases} 
z_A^3 & z_A \in [0, a_2] \\
\frac{a_2}{3} + \frac{2}{3} z_A^3 - \frac{a_2^2}{2} & z_A \in [a_2, a_1] \\
\frac{2}{3}(a_1 + a_2) z_A^2 - \frac{2}{3} z_A^3 - \frac{a_2^3}{3} & z_A \in [a_1, a_1 + a_2].
\end{cases}
\]

Finally we get

\[
z_A^* = \begin{cases} 
\frac{2}{3} z_A & z_A \in [0, a_2] \\
\frac{1}{3} z_A^3 - \frac{a_2^2}{3} & z_A \in [a_2, a_1] \\
\frac{1}{3} (a_1 + a_2) z_A^2 - \frac{2}{3} z_A^3 - \frac{a_2^3}{3} & z_A \in [a_1, a_1 + a_2].
\end{cases}
\]

Note that we always have \( z_A^* \geq \frac{z_A^2}{2} \), with equality holding only for \( z_A = a_1 + a_2 \) (this is obvious for the first case and is easily verified by standard manipulations for the other two). Recall that for a single-good auction, the optimal \( \alpha_{A*} \) is one half of the devoted characteristic \( \alpha_A \), thus here the optimal value exceeds the sum of what is obtained by two different auctions.
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