Regional regulators in healthcare service under quality competition: A game theoretical model

Bisceglia, Michele and Cellini, Roberto and Grilli, Luca

Università degli Studi di Bergamo (Dipartimento di Scienze aziendali, economiche e metodi quantitativi), Università degli Studi di Catania (Dipartimento di Economia e impresa), Università degli Studi di Foggia (Dipartimento di Economia).

10 July 2017

Regional regulators in healthcare service under quality competition: A game theoretical model*

Michele Bisceglia[†], Roberto Cellini[‡], Luca Grilli[§]

July 10, 2017

Abstract

In several countries, healthcare services are provided by public and/or private subjects, and they are reimbursed by the Government, on the basis of regulated prices. Thus, providers take prices as given and compete on quality to attract patients. In some countries, regulated prices differ across regions. This paper focuses on the interdependence between regional regulators within a country: it proposes a model of spatial competition to study how price-setters of different regions interact, in a simple but realistic framework. We show that the decentralisation of price regulation implies higher expenditure, but higher patients' welfare.

Keywords: Healthcare Services; Diagnosis Related Group; 2-Stage Non Cooperative Game; Quality Competition.
Mathematical Subject Classification: 91A20, 91A25, 49N90, 91A80, 91B15, 91A10.
JEL Classification: H42, I11, L13, R12, R38.

*We thank Rosella Levaggi, Luca Lambertini and Luigi Siciliani for helpful comments. However, the responsability remains on the Authors only.

†Dipartimento di Scienze aziendali, economiche e metodi quantitativi, Università degli Studi di Bergamo, Via dei Caniana 2, 24127 Bergamo, Italy, michele.bisceglia@unibg.it.

‡Dipartimento di Economia e Impresa, Università degli Studi di Catania, Corso Italia 55, 95129 Catania, Italy, cellini@unict.it.

§Dipartimento di Economia, Università degli Studi di Foggia, Largo Papa Giovanni Paolo II, I-71100 Foggia, Italy, luca.grilli@unifg.it.

1 Introduction

In several countries, healthcare services are provided by public and/or private subjects, and they are reimbursed by the Government. Typically, the reimbursement mechanism is based on a prospective per case payment system, with the ultimate goal of leading providers to compete on quality, in order to attract consumers/patients, and to increase the average quality of offered services. In the specific case of hospital services, for instance, the payment system is based on DRG (Diagnosis Related Group) mechanism, firstly introduced in the US in 1983, and currently adopted in most European countries (Busse et al. 2011). According to the DRG system, each specific diagnosis treatment is associated to a specific price. This means that healthcare providers are reimbursed a fixed tariff for each patient treated, according to DRG classifications. Thus, providers take price as given, and the competition to attract patients is mainly based on quality.

Not surprisingly, the design of the reimbursement mechanism differs across countries. Differences mainly concern the extent of the use of the DRG system to finance hospital care (the system can hold only for a subset of healthcare services), and the size of the specific reimbursement associated to each DRG. Within a given country, differences can occur across the prices paid to different providers: in some countries, the same DRG treatment can be reimbursed allocating different prices to different provider types; this can be justified on the basis of some institutional specificity of providers, or differences in other aspects of the overall financial transfer to providers.

It is more surprising that, in several countries, the payment design also differs across the regions. In Italy, for instance, the reimburse mechanisms, and the price levels for the same treatment, significantly differ across regions: more specifically there are "national tariffs" for each DRG, but the Regions, that have the institutional duty of supervising the health care provision, can decide –and have decided indeed– to reimburse their hospitals according to different prices. The same holds for Spanish regions and autonomous communities, or in Sweden, just to mention a few countries.

The theoretical literature concerning the adoption of per-case payment (rather than simple cost reimbursement) in health economics is large and well-established. We can mention the seminal contributions of Ellis and McGuire (1986), Ma (1994), Street (2011), among others. This research stream shows that hospital payment schemes based on full reimbursement of the incurred costs lead to a "medical arms race" among hospitals and, thus, to an escalation of health care costs (Cavalieri et al. 2016); a prospective per case reimbursement system seems to be appropriate, to lead hospitals to more efficient choices.

There is also a wide body of empirical literature concerning the determinants and the effects of DRG prices (see. e.g., various chapters in Culyer and Newhouse 2000, and Pauly et al, 2011; see also Mikkala et al., 2002, and Schreyoegg et al, 2006). The determinants of price levels typically include the estimated cost, taking into consideration different components, with a different weight of past history and prospective evolution, according to different countries. It goes without saying that different reimbursement schemes imply different incentives for health care providers. Just to give some intuitive examples, if providers were paid by a fixed price for every treatment, they would be expected to cream-skim patients by selecting the more lucrative cases. A re-payment system based on DRG should limit (though not completely overcome) this obvious problem (Ellis and Miller 2008; Cavalieri et al. 2016). The fixed price per each DRG treatment should induce the providers to reduce the average length of stay, in order to reduce inpatient costs and increase profit margins; to reduce unnecessary medical procedures for each patient treated, and so on. However, the effectiveness of this mechanism rests on the specific way in which prices are set.

The body of theoretical investigation concerning *price design* is more restricted. In particular, to the best of our knowledge, interaction of *price* regulation between regions within a given country, is an aspect which is overlooked by available literature, even if relevant contributions are available as far as the difference in quality levels of service across regions are concerned (Brekke et al. 2014, 2016; Aiura, 2016).

It is well-known that regional differences in the provision and utilization of healthcare service (and hospital services) may be relevant, due to both demand and supply side factors. Skinner (2011) provides an excellent overview: regional differences in demographic structure, consumers/patients' preferences or income, health status, price levels and dynamics drive to different demand functions; heterogeneity in factor endowments, public budget choices, and other institutional characteristics may drive to different supply functions. It has been suggested, and empirically shown, that the different payment mechanisms across regions impact on the composition of hospital care supply side across regions, e.g., in terms of public-private mix, condition of private and public subjects, and the degree of competition in the health care market (Cavalieri et al. 2013). The payment design (and the DRG specifically) affects the efficiency of providers (Busse et al. 2011; Moreno and Wagstaff, 2010); moreover, it affects the high technology equipment choices, and technology diffusion (Bech et al. 2009, Bokhari 2009; Finocchiaro Castro et al. 2014; Levaggi et al. 2012, 2014). Hence, different reimbursement mechanisms have an impact on patients' satisfaction.

It is worth underlying that, if patients are free to choose the healthcare provider, expected satisfaction drives individual choices about the provider, and patient mobility has to be expected. Patient mobility –both across the regions of any given country, and even across countries– is a widely observed phenomenon indeed (see, e.g., Rosenmoller et al. 2004; Balia et al. 2014); the phenomenon is expected to increase in next future, at least in the EU in front of recent Directives.[1] This mobility, *per se*, is not a negative by-product of the system; it associates with the aim of stimulating competition and increasing quality. However, the mobility entails social and monetary costs, and has welfare implication. Reasoning by backward induction, it is clear that the regional price-setter, while fixing the price, has to take into account the reaction of health providers, and, in turn, patient choices. Moreover, it is clear that the choice of each regional regulator affects the outcome for all hospitals and regions.

Here, we propose a simple sequential game to describe the relevant interdependence links that are in operation in a similar framework, with the final aim to investigate the individual and social welfare implications of different institutional rules. For instance, our model permits to evaluate pros and cons of the introduction of national coordination, or national fixing of DRG prices, as compared to regionally decentralized regulation. In our model we will assume that regional authorities aim to maximise the regional social welfare, and we will overlook a potentially large set of considerations concerning the real goals of policy-makers and regional regulators in this sector. In any case, if consumers/patients are free to choose the provider to patronize, then inter-regional mobility occurs, with relevant effects for regional social welfare. Though specific to the health sector, our theoretical model may be of interest for industrial economics in general, provided that competition among different regional regulators occurs in several sectors (education, long term care, transportation, and so on) and in several countries. In all these cases, consumers, providers and regional Authorities are characterised by different objective functions, and related by similar strategic interdependence links. Inter-regional competion across providers, mainly based on product quality, and consumers' mobility are the rule.

Two specific available articles are very close to our present investigation, namely Brekke et al. (2014, 2016). In the former, differentiated levels of skills, and hence differences in "potential" quality levels across regions are considered, and the point under investigation is whether or not patient mobility is desirable from a welfare perspective. The article employs a Hotelling spatial competition model and

[1] E.g., Directive 2011/24/EU of the European Parliament; Brekke et al (2016), among others, provide further references to norms entailing a higher expected mobility.

shows that consumer (patient) mobility enhances the quality of offered service in "high skill" regions and improves the number of treated patients there, but such an outcome depends on the payment mechanism: price has to exceed marginal cost; otherwise, a "race to the bottom" occurs, with lower welfare levels in all regions. In general, the effects of different transfer mechanisms to pay the region attracting extra-regional demand are studied: welfare implications and the ability of different rules to lead to Pareto improvements are investigated. However, there is no room to deal with a price setting problem, since both firm (hospital) and regional policy-maker consider quality as the choice variable. In the latter (Brekke et al. 2016) the spatial competition model considers a Salop circle, where three regions exist, characterised by different income levels: regional policy makers choose quality to maximise the utility of its own residents and the total cost of health services is financed by general income taxation, in the presence of budget constraint. The model studies the implications of consumer mobility upon quality choice and public expenditure, the welfare effects of change in monetary and non-monetary costs of mobility, and the effects of income distribution, within and across regions, upon equilibrium allocation, i.e., quantity and quality of regional services. Also in this model there is no distinction between provider and regional policy-maker, and the game is not sequential: regional policy makers set by themselves the quality of the service offered in each region; therefore, hospitals are not considered as autonomous subjects.

We propose here a theoretical model with a focus on the effects of interaction among *regional regulators as price-setters*. We spend attention in articulating the objectives of providers and in modelling their interaction with patients, on the one side, and policy-makers on the other side. Moreover, our present model allows to analyse spatial competition among providers as articulated in intra-regional and inter-regional competition. Three different classes of subjects are relevant in our model: (1) the patients, who choose the provider (i.e., the hospital) to patronize, within or outside the region where they live; (2) the healthcare providers, which are profit-oriented, face given price (set by the regional policy-maker), compete on quality to attract patients, in front of a spatial monopoly position which is weakened by costly patient mobility; (3) the regional authorities, i.e., price-setters, that fix the price, ideally taking care of the regional welfare, and are aware that interdependence links with other regional price-setters exist. The value added of our present model, with respect of the two specific articles mentione above, rests on the clear distinction between regulator and provider: this distintion has a relevant counterpart in the real world, where the decision chain is well structured, and the links and reciprocal influences between providers and regulators play a relevant role.

The structure of the article is as follows. Section 2 presents the basic set-up of the model, introducing the characteristics of demand and supply side, and the characteristics of the game under scrutiny. Section 3 provides the equilibrium of the game. Section 4 depicts the equilibrium outcome under the assumption of centralised decision concerning DRG prices. Section 5 draws the policy implications of our game theoretical model. Section 6 mentions possible extensions, including the discussion about the effect of quadratic (rather than linear) production cost assumption. Section 7 provides concluding comments.

2 The model set-up

We propose a model to study quality competition between hospitals, taking into due account that prices are set by a regulator at regional level. The competition between hospitals occurs both in the same region and outside the region, under different regulation rules. For this purpose, we consider a two stage non-cooperative game with complete information, with prices that are fixed by different regional authorities. Our model differs from the existing literature in which Brekke et al. (2011) consider the case of an unique price and Ma and Burgess (1993) study a model with different prices that are fixed by the hospitals and are paid by the patients. Unlike in Brekke et al. (2012, 2014), in our model hospitals are profit-seeking and autonomous subjects with respect to the regional regulator. In our model, at the first stage the regions fix the DRG prices to be paid in; then, at the second stage, the hospitals -taken the prices as given- choose the quality levels of their services, which in turn determine the demand, with possible mobility of patients across regions. The market is fully covered: each patient demands one unit of service, and can choose the provider to patronize, within or outside the region where (s)he lives. The price is paid by the Government, which attaches an opportunity cost to such public expenditure. Thus, hospitals can compete on quality to attract patients.

As in Siciliani et al. (2013) and Brekke et al. (2016), we adopt a localization model *à la* Salop (1979)[2] where the hospitals are exogenously and equally localized around a circle with circumference equal to 1, so that the distance between any two neighbouring hospitals is equal to $1/n$. The patients are uniformly distributed along the circumference with *total mass* normalized at 1.

[2]See also Ishida and Matsishima (2004) and Hamoudi and Risueno (2012), inter alia, as examples of models employing the circular city localization model in the presence of regulation policies.

The utility of a consumer located at x and served by hospital H, located at z_H, is given by

$$u(x, z_H) = v + q_H - \tau |x - z_H|, \tag{1}$$

where v is the gross valuation of consumption, $q_H \geq 0$ is the quality offered by Provider H, and τ is the marginal disutility of travelling. The assumption $v > \tau$ ensures that the market is fully covered.[3]

Each patient can only move to the two adjacent hospitals. The consumer who is indifferent between hospital i and hospital $i+1$ is located at $\widehat{x}_i^{i+1}$, which, measured clockwise from hospital i, is given by

$$\widehat{x}_i^{i+1} = \frac{1}{2n_H} + \frac{q_i - q_{i+1}}{2\tau}. \tag{2}$$

Similarly, the consumer indifferent between hospital i and $i-1$ is located at $\widehat{x}_i^{i-1}$, which, measured anticlockwise from hospital i, is given by

$$\widehat{x}_i^{i-1} = \frac{1}{2n_H} + \frac{q_i - q_{i-1}}{2\tau}. \tag{3}$$

Thus, the demand function for each hospital $i \in \{1, \ldots, n_H\}$ is:

$$x_i^D = \frac{1}{n_H} + \frac{q_i - q_{i+1}}{2\tau} + \frac{q_i - q_{i-1}}{2\tau}. \tag{4}$$

We propose to consider here the case of a country (the circle) with two regions ($n_R = 2$) and two hospitals in each region ($n_H = 2$). Thus, each of the four hospitals in the country is in "direct competition" (in quality) with both one hospital in the same region and one hospital in the other region, and the regions are in "direct competition" (in prices). Therefore we consider the simplified localization model in Figure 1, in which the region R_A is located above the segment L_1L_2 and contains the hospitals H_1 and H_2, similarly the region R_B with hospitals H_3 and H_4, are located in under the segment L_1L_2.

Let us assume that the cost function of each hospital is linear in the quantity and quadratic in the quality of the produced service and may also include a fixed cost : $C_i = c_i x_i + \frac{\beta}{2} q_i^2 + F_i$ where c_i and β are positive parameters. Each hospital receives a price p_i (set by the regional regulator) for each unit of produced service, and a possible lump-sum transfer T_i to break-even, if the operative profit was negative. Hence, the profit function for hospital i is:

$$\Pi_i = T_i - F_i + (p_i - c_i)x_i^D - \frac{\beta}{2} q_i^2 \tag{5}$$

[3]Further economic interpretations of these assumptions are provided by Siciliani et al (2013). We also note that the existence of a minimum quality standard is not explicitly considered in the present model (see, e.g., Cellini and Lamantia 2016), but parametric restrictions consistent with $q_H \geq 0$ will be assumed.

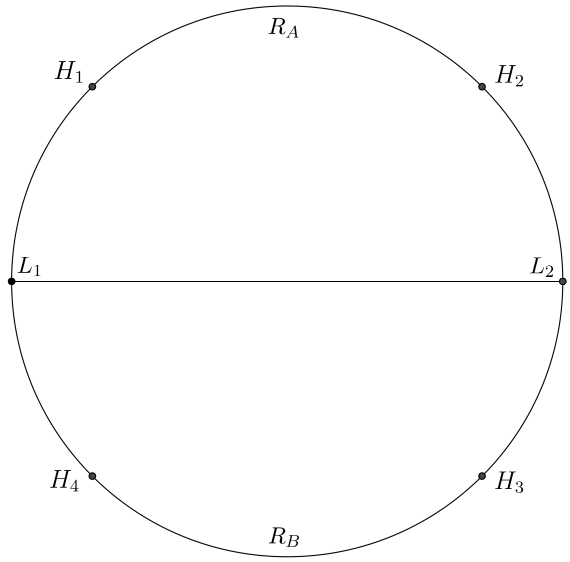

Figure 1: Localized model à la Salop with two regions and four hospitals.

where x_i^D is given by (4). To make the model easier, we assume nil fixed cost, and nil public transfer, i.e., $T_i = F_i = 0$ for all i ; thus, negative profits are in principle admitted.

In what follows, we assume that constant marginal c_i is equal for the hospitals of the same region, while it differs across regions; this corresponds to the fact that institutional (organizational) aspects matter on the cost structure. It is well known, as in the Italian or Spanish cases among many others, that differences in efficiency between hospitals in different regions exist, which result in different (marginal and average) costs for hospitalization and treatments. Clearly, the assumption of a common marginal cost for the hospitals belonging to the same region is a simplification that can be removed in a more general version of the model with differences across providers of the same region. Again, the fact that parameter β is equal for all hospitals in all regions is a simplifying assumption that can be removed in a more general model.

3 The game

We propose to analyze the interaction between regulators and hospitals, by resorting to a (very simple) sequential two-stage game. In the first stage, each regional regulator sets the (DRG) price for the hospital in its region. In the second stage, each hospital chooses the quality level of its service; hospitals' choices about quality are taken simultaneously. Then, patients make their choice, to maximise individual utility; the demand functions have already been derived in the previous Section. Each hospital aims to maximise its profit. The regional regulator aims to maximise a social welfare function that takes into account the welfare of the inhabitants of the region, the profit of the hospitals belonging to the region, and attaches an opportunity cost to public spending for health. The sub-game perfect Nash equilibrium can be simply found, solving the model by backward induction.

3.1 Second Stage Game

The Nash equilibrium strategy of the game at the second stage for the hospitals is obtained from the equation (5):

$$q_i = \frac{p_i - c_i}{\beta \tau} \tag{6}$$

It is worth noting that the optimal qualities for each hospital only depend on the DRG price of its own region and on its marginal costs as a consequence of the constant marginal costs hypothesis; in game theory terms, qualitities are strategic independent (in Section 6 we show that different results arise in the case of a quadratic cost function in both quality and patients' number). Not surprisingly, the equilibrium quality level is increasing in the DRG price: the higher the price, the stronger the incentive for the hospital of attracting additional patients, and hence the stronger the incentive to provide higher quality services. Costs of quality and quantity exert a negative effect on the equilibrium quality. The negative effect of patients' transportation cost simply tells that higher transportation costs imply less fierce quality competition among hospitals, that is, higher (local) monopoly power.

3.2 Regional Welfare Functions

In principle, the differences in terms of DRG prices across regions may be motivated by structural differences across regions (e.g., in populations structure, preferences and even income levels), and by differences in efficiency between hospitals of different regions (which drive, as already mentioned, to different costs for hospitalization and treatments), not to mention policy considerations which could matter when defining the regional social welfare. Here we consider the occurrence of differences across regions, concerning both the DRG prices (p_A and p_B) and the costs (c_A and c_B).

As a result, the quality levels of the hospitals in the same region are the same, and so the patients located between H_1 and H_2 will go the the closer hospital (similarly for the patients between H_3 and H_4): a demand quota of $\frac{1}{8}$ is ensured to each hospital.

Therefore, given the strategies (6), the DRGs fixed by the region (and the cost differences) will affect competition between hospitals in different regions, in particular H_1 and H_4 from one side, H_2 and H_3 from the other (see again Figure 1): the competition occurs between two providers located at the edges of a Hotelling line of length $\frac{1}{4}$. From Equations (4) and (6) it follows that the patients (that are $\frac{1}{4}$) located between the hospital i and j, where $(i, j) \in \{(1,4),(2,3)\}$, will move to the hospital i according to the following quota:

$$x_i^E = \frac{1}{8} + \frac{\Delta p - \Delta c}{2\beta\tau^2}$$

where $\Delta p = p_i - p_j$ and $\Delta c = c_i - c_j$.

It is necessary to consider two different cases:

1. if $\Delta p > \Delta c$ then the patients using hospital in region i are: patients resident in region i which remain in region i that are $x_i^i = \frac{1}{8}$; patients from the region j moving to region i that are $x_i^j = \frac{\Delta p - \Delta c}{2\beta\tau^2}$. Obviously in this case $x_j^i = 0$;
2. if $\Delta p < \Delta c$ then patients in region i remaining in the same region are given by $x_i^i = \frac{1}{8} + \frac{\Delta p - \Delta c}{2\beta\tau^2}$ and patients moving from region i to j are $x_j^i = -\frac{\Delta p - \Delta c}{2\beta\tau^2}$. In this case we have $x_i^j = 0$.

Due to symmetry reasons, the same happens both in the competition between H_1 and H_4 and in the competition between H_2 and H_3.

Given the structure of the model, at the first stage of the game the regions R_A and R_B fix their own DRG price in order to maximise a regional social welfare function which takes into account: public expenditure, with opportunity cost $\lambda > 0$; regional hospitals' profits; the region inhabitants' welfare.

As a result the social welfare of each region R_i, with $i \in \{A, B\}$, writes as follows:

$$W_i = W_i^I + 2W_i^E - \beta q_i^2,$$

where W_i^I is the "internal" welfare, that is the welfare computed in the zone between the two hospitals of the same region, while W_i^E is the "external" welfare which is computed in the area between two hospital in two different regions. In particular we have:

$$W_i^I = \frac{1}{4}(-\lambda p_i - c_i) + 2\int_0^{\frac{1}{8}} (v + q_i - \tau x)\, dx.$$

If $\Delta p > \Delta c$ then it results:

$$W_i^E = \frac{1}{8}(-\lambda p_i - c_i) + (p_i - c_i)\left[\frac{1}{8} + \frac{\Delta p - \Delta c}{2\beta\tau^2}\right] + \int_0^{\frac{1}{8}} (v + q_i - \tau x)\, dx;$$

while, if $\Delta p < \Delta c$ then:

$$W_i^E = (-\lambda p_i - c_i)\left[\frac{1}{8} + \frac{\Delta p - \Delta c}{2\beta\tau^2}\right] - (1+\lambda)p_j\left[-\frac{\Delta p - \Delta c}{2\beta\tau^2}\right] +$$

$$+\int_0^{\frac{1}{8}+\frac{\Delta p - \Delta c}{2\beta\tau^2}} (v + q_i - \tau x)\,dx + \int_{\frac{1}{8}+\frac{\Delta p - \Delta c}{2\beta\tau^2}}^{\frac{1}{8}} (v + q_j - \tau(\frac{1}{4} - x))\,dx$$

Let us assume, without loss of generality: $c_A < c_B$. Furthermore, let us consider the case:

$$p_A - p_B > c_A - c_B \tag{7}$$

that is, $\Delta p > \Delta c$.

Remark. In this model, in order to assure feasibility of the obtained solutions, that is, assuring strictly positive quality levels which also constitute a Nash equilibrium for the static first stage game between the regions and a maximum point in the central Government decision case, we have to make the following:

Assumption:

$$\frac{1}{\beta\left(\lambda + \frac{1}{2}\right)} < \tau < \frac{1}{\beta\lambda}. \tag{8}$$

Verbally, assume that the parameter capturing the marginal disutility of distance to travel, τ, is: (i) above a lower-bound, and (ii) below an upper-bound threshold level. Among other implications, the latter entails that the second order condition of the price-setters' problems is met; otherwise, the maximum problem of price-setting would have no finite solution. The former entails positive quality levels in equilibrium, and optimal price levels above marginal costs; these features -though not strictly necessary- make the solutions more immediate to understand and comparisons across different solutions easier. More in general, it makes sense to assume that the travel cost disutility is included in a limited range. Loosely speaking, if the disutility of travel was "too low", only service quality would matter in the consumer choice, and the problem of local regulation would lose significance, along with the problems linked to patients' mobility. On the contrary, if the disutility of travel was "too high", a world without mobility across regions would emerge, with no interest for the investigation at hand. A closed range for the parameter capturing the disutility of travel is consistent with the existence of an economically meaningful equilibrium, with a positive degree of inter-regional mobility of consumer/patients. This is consistent with the empirical evidence provided by the real world.

3.3 First stage game: DRG price setting by regional regulators

We now determine the Nash equilibrium of the non-cooperative first-stage static game between the regions.

Given the Nash equilibrium strategies of the hospitals, it holds:

$$W_i^I = \frac{1}{4}(-\lambda p_i - c_i) + \frac{1}{4}\left(v + \frac{p_i - c_i}{\beta\tau}\right) - \frac{\tau}{64}$$

for $i \in \{A, B\}$.

Under the assumption (7), $p_A^* - p_B^* > c_A - c_B$, and in the case of the Region A (R_A), we have:

$$W_A^E = \frac{1}{8}(-\lambda p_A - c_A) + (p_A - c_A)\left[\frac{(p_A - p_B) - (c_A - c_B)}{2\beta\tau^2}\right] + \frac{1}{8}\left(v + \frac{p_A - c_A}{\beta\tau}\right) - \frac{\tau}{128}$$

For the Region B (R_B) we obtain:

$$W_B^E = (-\lambda p_B - c_B)\left[\frac{1}{8} + \frac{(p_B - p_A) - (c_B - c_A)}{2\beta\tau^2}\right] - (1+\lambda)p_A\left[\frac{(p_A - p_B) - (c_A - c_B)}{2\beta\tau^2}\right] +$$

$$+\left(v + \frac{p_B - c_B}{\beta\tau}\right)\left[\frac{1}{8} + \frac{(p_B - p_A) - (c_B - c_A)}{2\beta\tau^2}\right] - \frac{\tau}{2}\left[\frac{1}{8} + \frac{(p_B - p_A) - (c_B - c_A)}{2\beta\tau^2}\right]^2 +$$

$$+\left(v + \frac{p_A - c_A}{\beta\tau} - \frac{\tau}{4}\right)\left[\frac{(p_A - p_B) - (c_A - c_B)}{2\beta\tau^2}\right] + \frac{\tau}{2}\left\{\frac{1}{64} - \left[\frac{1}{8} + \frac{(p_B - p_A) - (c_B - c_A)}{2\beta\tau^2}\right]^2\right\}$$

Notice that R_A receives a welfare benefit from the fact that patients from R_B are served by hospitals located in R_A, as long as $p_A^* > c_A$. For these "migrant patients" the payment is done from R_B to R_A; however, it is reasonable to include the individual welfare of these patients in the social welfare function of origin region.

After some algebra, we have:

$$W_A = W_A^I + 2W_A^E - \beta q_A^2 = \frac{16(c_A - p_A)(2p_B - 2c_B - \tau) - \beta\tau^2(16c_A + 16\lambda p_A + \tau - 16v)}{32\beta\tau^2}$$

$$W_B = W_B^I + 2W_B^E - \beta q_B^2 = \frac{1}{32\beta^2\tau^3}\{-\beta^2\tau^3[16\lambda p_B + \tau + 16(c_B - v)] +$$

$$+16\beta\tau\{2c_A[\lambda(p_A - p_B) + p_A - c_B] + 2\lambda(p_A - p_B + c_B)(p_B - p_A) - 2p_A^2 + 2p_A p_B + (c_B - p_B)(2p_B - \tau)\} +$$

$$+16(c_A - p_A + p_B - c_B)^2\}$$

Notice that W_A is linear in the choice variable p_A; thus, the best-reply function $p_A = p_A(p_B)$ is a degenerate function in which p_A is plus (or minus) infinite, according to the fact that the coefficient of p_A in W_A is positive (negative). The only finite solution corresponds to the case in which the coefficient of p_A in W_A is nil (which, by the way, correspond to the condition $\partial W_A/\partial p_A = 0$). From the first order condition $\partial W_B/\partial p_B = 0$ a well-behaved best reply function of the regulator of Region B can be easily derived. It is immediate to verify that the function $p_B = p_B(p_A)$ is positively sloped, as long as Assumption (8) is met. Thus, the Nash equilibrium can be derived from the system:

$$\begin{cases} -\dfrac{\beta\lambda\tau^2 + 2p_B - \tau - 2c_B}{2\beta\tau^2} = 0 \\ -\dfrac{\beta^2\lambda\tau^3 + \beta\tau[2\lambda c_A - 2\lambda(2p_A - 2p_B + c_B) - 2p_A + 4p_B - \tau - 2c_B] - 2(c_A - p_A + p_B - c_B)}{2\beta^2\tau^3} = 0 \end{cases}$$

Since it holds that:

$$\frac{\partial^2 W_A}{\partial p_A^2} = 0, \quad \frac{\partial^2 W_B}{\partial p_B^2} = \frac{1 - 2\beta\tau(\lambda + 1)}{\beta^2\tau^3}$$

the first order conditions are also sufficient if:

$$\tau > \frac{1}{2\beta(\lambda + 1)}$$

This condition is verified under Assumption (8).

Therefore, in this case, the Nash equilibrium is given by:

$$p_A^* = \frac{\beta^2\tau^3\lambda(2\lambda + 1) - \beta\tau[2\lambda c_A + \lambda(3\tau + 2c_B) + \tau + 2c_B] + 2c_A + \tau}{2[1 - \beta\tau(2\lambda + 1)]}, \quad p_B^* = c_B + \frac{\tau}{2}(1 - \lambda\beta\tau) \quad (9)$$

In order (p_A^*, p_B^*) to be the Nash equilibrium we have to check that: $p_A^* - p_B^* > c_A - c_B$ (7). Since we have assumed $c_A < c_B$, this condition is verified if:

$$\tau > \frac{1}{\beta\left(\lambda + \dfrac{1}{2}\right)}$$

The last condition is implied by Assumption (8).

Furthermore, under Assumption (8), it holds: $p_A^* > p_B^*$.

Some comments are in order. First, the cost parameter of hospitals located in R_A does not enter the optimal price of R_B, while the opposite is not true. We do not spend several words on this feature, since it depends on the very simple structure of the problem, and the linearity of the objective function of the R_A's regulator: the problem of the R_A's regulator has a finite solution only if the DRG price set by R_B is given by the production cost in that region plus a mark-up. Second, in equilibrium, the optimal DRG price is higher in the region where hospitals are more efficient. Third, DRG price exceeds marginal cost, in all regions.

By substituting p_A^* and p_B^* in the Nash equilibrium strategies of the hospitals we obtain the subgame perfect solution:

$$q_A^*(p_A^*) = \frac{\beta^2\tau^2\lambda(2\lambda+1) + \beta[2c_A(\lambda+1) - \lambda(3\tau+2c_B) - \tau - 2c_B] + 1}{2\beta[1-\beta\tau(2\lambda+1)]}$$

$$q_B^*(p_B^*) = \frac{1-\beta\lambda\tau}{2\beta}$$

It holds that:

$$q_A^*(p_A^*) - q_B^*(p_B^*) = \frac{(c_B-c_A)(\lambda+1)}{\beta\tau(2\lambda+1)-1} > 0$$

under Assumption (8), since it must hold: $\tau > 1/\left[\beta\left(\lambda+\frac{1}{2}\right)\right]$. Hence, the larger the difference in cost efficiency, the larger the difference in quality level, with the more efficient region providing the higher quality service. Finally, it is worth noting that the condition $\tau < \frac{1}{\beta\lambda}$ in Assumption (8) assures positivity of the Nash equilibrium quality levels: $q_A^*(p_A^*) > q_B^*(p_B^*) > 0$.

We can also compute the Nash Equilibrium profits (or, more precisely the operative profits which disregard fixed cost and possible transfer):

$$\Pi_A^* = \frac{[1-\beta\tau(\lambda+1)]\{\beta^2\lambda\tau^2(2\lambda+1) + \beta[2c_A(\lambda+1) - \lambda(3\tau+2c_B) - \tau - 2c_B] + 1\}}{8\beta[\beta\tau(2\lambda+1)-1]}$$

$$\Pi_B^* = \frac{\beta^3\lambda\tau^3(\lambda+1)(2\lambda+1) + \beta^2\tau[2\lambda c_A(\lambda+1) - \lambda(\lambda+1)(5\tau+2c_B) - \tau] - 2\beta[c_A(\lambda+1) - \lambda(2\tau+c_B) - \tau - c_B]}{1-8\beta[\beta\tau(2\lambda+1)]}$$

Therefore we have:

$$\Pi_A^* - \Pi_B^* = \frac{\beta\tau(\lambda+1)(c_B-c_A)}{4[\beta\tau(2\lambda+1)-1]} > 0$$

Finally we notice:

$$\Pi_A^* \wedge \Pi_B^* > 0 \iff \theta_1 < c_B - c_A < \theta_2$$

where, under Assumption (8):

$$\theta_1 = \frac{\beta^2\lambda\tau^2(2\lambda+1) - \beta\tau(3\lambda+1) + 1}{2\beta(\lambda+1)} < 0 \tag{10}$$

$$\theta_2 = \frac{\beta^2\tau^2(\lambda+1)(2\lambda+1) - \beta\tau(3\lambda+2) + 1}{2\beta(\lambda+1)} > 0$$

It is interesting to note that the operative profit of both providers are strictly positive in equilibrium if the gap in cost efficiency between regions is below a threshold level; on the contrary, in the presence of a large difference in cost efficiency, negative operative profits are possible to observe in equilibrium for the less efficient hospital, while the more efficient ones obtain positive profit in any case.[4]

[4] To keep our analysis consistent, negative profits of hospital have to be repaid by the Government, without attaching the opportunity cost λ to such transfer: in this case, transfer from Government to hospital is immaterial to total social welfare.

All the above results, obtained in the case $\Delta p > \Delta c$, symmetrically hold under the opposite assumption $\Delta c > \Delta p$. In the latter case, patients will move from R_A to R_B, and the welfare functions switch between regions. Thus, equilibrium prices will be:

$$p_B^* = \frac{\beta^2\tau^3\lambda(2\lambda+1) - \beta\tau[2\lambda c_B + \lambda(3\tau + 2c_A) + \tau + 2c_A] + 2c_B + \tau}{2[1-\beta\tau(2\lambda+1)]}, \quad p_A^* = c_A + \frac{\tau}{2}(1-\lambda\beta\tau)$$

The corresponding Second Order Condition requires $\tau > 1/[2\beta(\lambda+1)]$. Moreover, the condition $\Delta p < \Delta c$, joint with $c_A < c_B$, requires $\tau < 1/[\beta(2\lambda+1)]$. The latter implies that the condition ensuring positive quality levels, i.e. $\tau < 1/(\beta\lambda)$, is met. Hence, the appropriate assumption to make in the case $\Delta c > \Delta p$, replacing Assumption (8), is:

$$\frac{1}{2\beta(\lambda+1)} < \tau < \frac{1}{\beta(2\lambda+1)}$$

So, also in this case, the parameter capturing the marginal disutility of distance has to be included in a interval, to provide an economically meaningful solution, with the coexistence of hospitals in both regions and patients' mobility.

4 DRG price setting under a central authority decision

We now determine the price levels that, given the Nash equilibrium strategies of the hospitals, a central government would fix in order to maximise the aggregated social welfare function, in which we consider:

$$q_A = q_1^*(p_A) = q_2^*(p_A),\ q_B = q_3^*(p_B) = q_4^*(p_B).$$

We develop the computations in the benchmark case $c_A < c_B$ where we observe:

$$x_1^D + x_2^D = \frac{1}{4} + 2\left(\frac{1}{8} + \frac{q_A - q_B}{2\tau}\right) = \frac{1}{2} + \frac{q_A - q_B}{\tau}.$$

Analogously:

$$x_3^D + x_4^D = \frac{1}{2} + \frac{q_B - q_A}{\tau}$$

Therefore, by considering the same opportunity cost λ of public expenditures, we obtain the following aggregated social welfare function:

$$S = (-\lambda p_A - c_A)\left(\frac{1}{2} + \frac{q_A - q_B}{\tau}\right) + (-\lambda p_B - c_B)\left(\frac{1}{2} + \frac{q_B - q_A}{\tau}\right) - \beta(q_A^2 + q_B^2) +$$

$$+2\int_0^{\frac{1}{8}}(v+q_A-\tau x)dx+2\int_0^{\frac{1}{8}}(v+q_B-\tau x)dx+$$

$$+2\int_0^{\frac{1}{8}+\frac{q_A-q_B}{2\tau}}(v+q_A-\tau x)\,dx+2\int_{\frac{1}{8}+\frac{q_A-q_B}{2\tau}}^{\frac{1}{4}}(v+q_B-\tau(\frac{1}{4}-x))dx$$

where the terms in the first row represent the hospitals' profits and the public expenditures, the terms in the second row are the "internal" welfare of the patients of the two regions and the terms in the third row constitute their "external" welfare.

By substituting the Nash equilibrium qualities we obtain the First Order Conditions:

$$\begin{cases}\dfrac{\partial S}{\partial p_A}=0 \iff \dfrac{\beta^2\lambda\tau^3-\beta\tau[2c_A(\lambda+1)+2\lambda(2p_B-c_B)+\tau+2c_B]+2(c_A+p_B-c_B)}{2[1-2\beta\tau(\lambda+1)]}=0\\ \dfrac{\partial S}{\partial p_B}=0 \iff \dfrac{\beta^2\lambda\tau^3-\beta\tau[-2c_A(\lambda-1)+2\lambda(2p_A+c_B)+\tau+2c_B]+2(c_B+p_A-c_A)}{2[1-2\beta\tau(\lambda+1)]}=0\end{cases}$$

The solution of this system is given by:

$$\begin{cases}\bar{p}_A=\dfrac{\beta^2\lambda\tau^3(2\lambda+1)-\beta\tau[2c_A(3\lambda+1)+\lambda(3\tau+2c_B)+\tau+2c_B]+4c_A+\tau}{4[1-\beta\tau(2\lambda+1)]}\\ \bar{p}_B=\dfrac{\beta^2\lambda\tau^3(2\lambda+1)-\beta\tau[2c_A(\lambda+1)+3\lambda(\tau+2c_B)+\tau+2c_B]+4c_B+\tau}{4[1-\beta\tau(2\lambda+1)]}\end{cases} \tag{11}$$

This solution provides the absolute maximum of S if and only if:

$$\tau>\frac{1}{\beta(2\lambda+1)} \tag{12}$$

In fact, the Hessian matrix of S is given by:

$$H_S=\begin{pmatrix}\dfrac{1-2\beta\tau(\lambda+1)}{\beta^2\tau^3} & \dfrac{2\lambda\beta\tau-1}{\beta^2\tau^3}\\ \dfrac{2\lambda\beta\tau-1}{\beta^2\tau^3} & \dfrac{1-2\beta\tau(\lambda+1)}{\beta^2\tau^3}\end{pmatrix}$$

and it holds:

$$\mathrm{tr}H_S=2\frac{1-2\beta\tau(\lambda+1)}{\beta^2\tau^3}<0 \iff \tau>\frac{1}{2\beta(\lambda+1)}$$

$$\det H_S>0 \iff \tau>\frac{1}{\beta(2\lambda+1)}$$

so the sufficient condition for a maximum implies: $\tau>\max\left(\frac{1}{2\beta(\lambda+1)},\frac{1}{\beta(2\lambda+1)}\right)$, but since $\frac{1}{\beta(2\lambda+1)}>\frac{1}{2\beta(\lambda+1)}$, we obtain the condition (12), which is implied by Assumption (8).

It is worth noting that, if this condition is not satisfied, then $(\bar{p}_A,\bar{p}_B)$ constitutes a saddle point. The economic meaning is immediate: if the condition is not met, the problem is not concave, and the solution is not an internal, finite solution: the optimal DRG prices would be either plus or minus infinite - which is clearly meaningless from an economic point of view.

Since we are considering $c_A < c_B$, if condition (12) holds, we have that:

$$\bar{p}_A > \bar{p}_B \iff \frac{1}{\beta(2\lambda+1)} < \tau < \frac{1}{\beta\lambda}$$

and this must be verified because of Assumption (8). Thus, even under a central authority setting the DRG prices in all regions, the optimal price is higher for the regions with more efficient hospitals. Hence, it is intriguing to observe that the price setting rule suggested by our theoretical model is the opposite with respect to what we often observe in the real world, where higher DRG prices are in operation in regions where hospitals are more inefficient.

The corresponding optimal qualities are thus given by:

$$q_A^*(\bar{p}_A) = \frac{\beta^2\tau^2\lambda(2\lambda+1) + \beta[2c_A(\lambda+1) - \lambda(3\tau+2c_B) - \tau - 2c_B] + 1}{4\beta[1-\beta\tau(2\lambda+1)]}$$

$$q_B^*(\bar{p}_B) = \frac{\beta^2\tau^2\lambda(2\lambda+1) + \beta[-2c_A(\lambda+1) - \lambda(3\tau-2c_B) - \tau + 2c_B] + 1}{4\beta[1-\beta\tau(2\lambda+1)]}$$

and it holds, since we are considering $c_A < c_B$ and assuming (8):

$$q_A^*(\bar{p}_A) > q_B^*(\bar{p}_B)$$

Thus, even under a central authority setting the DRG prices in all regions, the quality of the services is higher for the region with the more efficient hospitals, and higher regulated price.

5 Policy implications: a brief comparison among the solutions

A comparison between the equilibrium solution in the case of regionally decentralised regulation and the national regulation can be easily made. Table 1 reports price and quality levels in equilibrium under the two regimes.

Table 1. Price and quality under different institutional rules

$$
\left|\begin{array}{l}
\text{Price - Regional Regulation} \\
p_A^* = \dfrac{\beta^2\tau^3\lambda(2\lambda+1) - \beta\tau[2\lambda c_A + \lambda(3\tau+2c_B) + \tau + 2c_B] + 2c_A + \tau}{2[1-\beta\tau(2\lambda+1)]} \\
p_B^* = c_B + \dfrac{\tau}{2}(1-\lambda\beta\tau) \\
\text{Price - National Regulation} \\
\bar{p}_A = \dfrac{\beta^2\lambda\tau^3(2\lambda+1) - \beta\tau[2c_A(3\lambda+1) + \lambda(3\tau+2c_B) + \tau + 2c_B] + 4c_A + \tau}{4[1-\beta\tau(2\lambda+1)]} \\
\bar{p}_B = \dfrac{\beta^2\lambda\tau^3(2\lambda+1) - \beta\tau[2c_A(\lambda+1) + 3\lambda(\tau+2c_B) + \tau + 2c_B] + 4c_B + \tau}{4[1-\beta\tau(2\lambda+1)]} \\
\text{Quality - Regional Regulation} \\
q_A^*(p_A^*) = \dfrac{\beta^2\tau^2\lambda(2\lambda+1) + \beta[2c_A(\lambda+1) - \lambda(3\tau+2c_B) - \tau - 2c_B] + 1}{2\beta[1-\beta\tau(2\lambda+1)]} \\
q_B^*(p_B^*) = \dfrac{1-\beta\lambda\tau}{2\beta} \\
\text{Quality - National Regulation} \\
q_A^*(\bar{p}_A) = \dfrac{\beta^2\tau^2\lambda(2\lambda+1) + \beta[2c_A(\lambda+1) - \lambda(3\tau+2c_B) - \tau - 2c_B] + 1}{4\beta[1-\beta\tau(2\lambda+1)]} \\
q_B^*(\bar{p}_B) = \dfrac{\beta^2\tau^2\lambda(2\lambda+1) + \beta[-2c_A(\lambda+1) - \lambda(3\tau-2c_B) - \tau + 2c_B] + 1}{4\beta[1-\beta\tau(2\lambda+1)]}
\end{array}\right.
$$

It holds $\bar{p}_A < p_A^*$ and $\bar{p}_B < p_B^*$. In fact we have:

$$c_B - c_A > \theta_1 \tag{13}$$

with $\theta_1 < 0$ given by (10). It is also easy to see that: $q_A^*(\bar{p}_A) = \frac{1}{2}q_A^*(p_A^*)$ and $q_B^*(\bar{p}_B) < q_B^*(p_B^*)$ (since the opposite would hold if and only if the previous inequality (13) does not hold). It is interesting to notice that the inter-regional mobility –and, as a consequence, the hospitals demand levels– coincide under both decision regimes (the regional decentralised regulation and the central national authority), since we get the same Δp value:

$$\Delta p = \frac{(1-\beta\lambda\tau)(c_B - c_A)}{\beta\tau(2\lambda+1) - 1}$$

Thus, the following conclusions emerge from this simple model. (1) Regionally decentralised price regulation leads to higher price levels. (2) This entails higher quality levels of the produced services, under regionally decentralised price regulation. (3) The degree of inter-regional consumers' mobility does not change between the regimes of regional *vs.* national price regulation. (4) Hence, regional decentralisation entails higher consumer welfare, in front of the same degree of inter-regional mobility and higher quality levels. (5) No clear-cut analytical conclusions can be reached concerning the providers' operative profits: indeed, price (and hence revenue) levels are higher under the regional regulation, but quality levels are also larger, entailing larger costs; thus, operative profit may be larger or smaller, depending on parameter configuration. (6) Under both the regional decentralized regime and the central national authority, the lower the providers' marginal cost of production, the higher the optimal regulated price. (7) The differential between regulated price levels across regions is proportional to the differential in marginal costs.

Surely, strategic interdependence among regional price regulators is a source of allocative inefficiency, but at the same time this characteristic is beneficial to consumers/patients. It is also worth underlining, as already noted by Miraldo et al (2011), that, in contexts like this, price has two effects, or plays a double role: the first is the usual one in terms of attaining allocative efficiency; the second is in terms of rent extraction.

6 Extensions

The present article flows in a literature where similar –and even more detailed and extended– models are already available. Our present analysis contributes in highlighting the sequential structure of decision chain, where policy-makers set price in a previous stage and then profit-oriented providers take their decisions on quality, which in turn determines the patients' choice. The model can be extended along different routes. As already mentioned, we could consider the possibility that the health care providers within any region are different as far as their nature and cost parameter is concerned (see, e.g., Weber, 2014). In such a case, one can investigate the model under the assumption that the local regulator has to fix one price, or differentiated prices across providers are possible.

A different line of development can concern the size of regions: following the seminal paper of Kanbur and Keen (1993),one could assume that the mass of people populating the regions is different. In such a circumstance, one can consider the case that the more populated region is the one with the hospital with higher or lower cost efficiency. In this case, the problem of endogeneous spatial location of providers does make sense (see, e.g., Gravelle et al., 2016) and the location choice can be made by providers themselves, or by regional regulators.

Again, a further asymmetry between regions can be introduced as far as the opportunity cost of public spending for health is concerned: parameter λ may differ across regions, representing different political views between local authorities.

For future research, it could also be interesting to consider the coexistence of differentiated regional DRG prices for regional residents, joint with an unique DRG price, fixed by a national authority, for *extra-regional* treatments; this configuration is the closest to the current situation in countries like

Italy.[5] Finally, in the introduced framework of regional DRG price setting, also a differential game approach, as in Brekke et al. (2010, 2012), Cellini et al. (2015) and Siciliani et al. (2013), can be a fruitful research direction, since it makes possible to study in a dynamic context the hospital investments and to introduce some realistic features, such as a sluggish demand or sticky prices.

In this Section we limit to sketch how the outcome of the second stage of our basic model changes, by assuming a cost function which is quadratic not only in the quality levels, but also in the produced quantity. Clearly, the linear *vs.* convex form of the cost function (that is, the assumption of constant *vs.* increasing marginal cost) corresponds to different features concerning the pattern of productivity and diseconomies of scale.[6]

Under the assumption of increasing marginal cost, and specifically the quadratic cost function, the profit function for hospital i (still apart from fixed cost and lump-sum transfer) is given by:

$$\Pi_i = p_i x_i^D - c_i [x_i^D]^2 - \frac{\beta}{2} q_i^2 \tag{14}$$

where:

$$x_i^D = \frac{1}{4} + \frac{q_i - q_{i+1}}{2\tau} + \frac{q_i - q_{i-1}}{2\tau}$$

The First Order Condition for the profit function maximization with respect to the choice variable q_i leads to:

$$q_i = \frac{2\tau p_i + c_i[2(q_{i-1} + q_{i+1}) - \tau]}{2(\beta\tau^2 + 2c_i)}$$

Without loss of generality, we assume that, for the considered hospital i, the hospital $i-1$ belongs to his region, while the hospital $i+1$ belongs to the other region. Then, due to the symmetry between the regions, we impose: $q_i = q_{i-1}$. This lets us to obtain the optimal response function of the hospital i to the quality set by the hospitals belonging to the opponent region:

$$q_i(q_j) = \frac{\tau p_i + c_i(q_j - \frac{\tau}{2})}{\beta\tau^2 + c_i}$$

with $i, j \in \{A, B\}, i \neq j$. Finally, by solving this algebraic 2-equations system, we get the Nash Equilibrium of the second-stage game:

$$q_A^*(p_A, p_B) = \frac{2[c_A(p_B - c_B) + p_A c_B] - \beta\tau^2(c_A - 2p_A)}{2\beta\tau(\beta\tau^2 + c_A + c_B)}$$

[5] Brekke et al. (2014) specifically investigates the effects of different regimes in the extra-regional treatment prices.

[6] A large body of theoretical and empirical literature is available concerning the linear *vs.* convex cost function for production by hospitals. A convex function captures the presence of excess demand and/or capacity constraint. See, e.g., the review in Folland et al. (2004); see also Brekke et al. (2010) where constant or increasing marginal costs are associated to equilibria with strongly different properties.

$$q_B^*(p_A,p_B) = \frac{2[c_A(p_B-c_B)+p_A c_B] - \beta\tau^2(c_B-2p_B)}{2\beta\tau(\beta\tau^2+c_A+c_B)}$$

Therefore, the quadratic structure of the costs leads to Nash Equilibrium strategies for all the hospitals which depend on the DRG prices chosen by both regions.

It is easy to check that:

$$q_A^*(p_A,p_B) - q_B^*(p_A,p_B) = \frac{\tau[2(p_A-p_B)+c_B-c_A]}{2(\beta\tau^2+c_A+c_B)}$$

Hence we get:

$$q_A^*(p_A,p_B) > q_B^*(p_A,p_B) \iff p_A - p_B > \frac{c_A-c_B}{2}$$

And finally we note:

$$x_A^D = x_1^D + x_2^D = \frac{1}{2} + \frac{2(p_A-p_B)+c_B-c_A}{2(\beta\tau^2+c_A+c_B)}$$

$$x_B^D = x_3^D + x_4^D = \frac{1}{2} - \frac{2(p_A-p_B)+c_B-c_A}{2(\beta\tau^2+c_A+c_B)}$$

Straightforward implications and comparisons with the case of constant marginal cost are left to the readers.

7 Concluding remarks

In this paper we have proposed a modification of the spatial competition model *à la* Salop, able to distinguish between intra- and inter- regional competition. Our model is particularly appropriate to study markets in which producers (or, more generally, service providers) compete in quality, and prices are regulated by local public authorities. In such a framework, interdependence links do exist not only among providers and between providers and authorities, but also among authorities. The healthcare markets, and specifically the market for hospital services is the most clear empirical counterpart for our theoretical model. However, the theoretical model can be easily applied to other sectors, like school and eduction, or long-term care, where competition is typically based on quality, and prices are regulated -usually by local or regional authorities.

The interdependence among regional regulators as price setters is the key contribution of the present article to the theoretical literature dealing with service provision with quality competition under regulated prices. We have specifically thought of the healthcare markets, where the interactions between local authorities, and their consequences, are well documented by empirical investigations, but are overlooked by theoretical models which mainly focus on quality decisions.

We are aware that alternative models with spatial competition in healthcare markets exist, sometimes more detailed than this present variant. Admittedly, our model is very simple and conclusions may be sensitive to specific simplifying assummptions. Nevertheless, the present model has relevant elements of realism, and it can be a useful starting point for policy analysis and the investigation about the effects of different institutional designs in the presence of links of strategic interdependence in the stage of price design. We have underlined that the interdependence among regional price regulators is an important aspect overlooked by available literature, but deserving theoretical attention. In the simple framework at hand we have shown that some (possibly counterintuitive) conclusions emerge. For instance, higher regulated prices associate, in equilibrium, with more efficient providers; however, this also joins with higher quality levels of the provided service. From a policy perspective, our model suggests that national price regulation drives to lower regulated price levels, and hence to smaller public expenditure. However, this fact is detrimental to the consumers/patients' welfare, since the fierceness of (inter-regional) competition is more limited. So, in other words, the well-known static trade-off between sound public finance and citizens' welfare emerges, here with respect to costs and benefit of decentralisation: decentralised regulation is detrimental to public finance but beneficial to consumers.

References

[1] Aiura H (2016), *The effect of cross-border healthcare on quality, public health insurance, and income redistribution*, Institute for Sammfunsokonomi Working Paper 4/2016 (SSRN wp 2766847).

[2] Balia S, Brau R, Marroccu E (2014), *What drives patient mobility across Italian regions? Evidence from hospital discharge data*, Development in Health Economics and Public Policitcs 12: 133-54.

[3] Bech M, Christiansen T, Dunham K, Lauridsen J, Lyttkens CH, McDonald K, et al. (2009), *The influence of economic incentives and regulatory factors on the adoption of treatment technologies: a case study of technologies used to treat heart attacks*, Health Economics 18: 1114-32.

[4] Bokhari F (2009), *Managed care competition and the adoption of hospital technology: the case of cardiac catherization*, International Journal of Industrial Organization 27: 223-37.

[5] Brekke K, Cellini R, Siciliani L, Straume O R (2010), *Competition and quality in health care markets: A differential game approach* , Journal of Health Economics, 29: 508-523.

[6] Brekke K, Siciliani L, Straume O R (2011), *Hospital competition and quality with regulated prices*, The Scandinavian Journal of Economics, 113: 444-469.

[7] Brekke K, Cellini R, Siciliani L, Straume O R (2012), *Competition in regulated markets with sluggish beliefs about quality*, Journal of Economics & Management Strategy, 21: 131-178.

[8] Brekke K, Levaggi R, Siciliani L, Straume O R (2014), *Patient mobility, healthcare quality and welfare*, Journal of Economic Behavior & Organization, 105: 140-57.

[9] Brekke K, Levaggi R, Siciliani L, Straume O R (2016), *Patient mobility and health care quality when regions and patients differ in income*, Journal of Health Economics, 50: 372–87.

[10] Busse R, Geissler A, Quentin W, Wiley M (Eds.) (2001), *Diagnosis-related groups in Europe: moving towards transparency, efficiency and quality in hospitals*, European Observatory on Health System and Policies Series. Maidenhead, UK: Open University Press - McGraw Hill.

[11] Cantù E, Carbone C, Anessi Pessina E (2001), *Do Italian regions effectively use DRG funding to steer provider behavior?*, in: Ongaro E, Massey A,Holzer M, Wayenberg E (Eds.). Policy, performance and management in governance and intergovernmental relations: transatlantic perspectives. Cheltenham, UK: Edward Elgar Publishing, p. 341-59.

[12] Cavalieri M, Gitto L, Guccio C (2013), *Reimbursement systems and quality of hospital care: An empirical analysis for Italy*, Health Policy 111: 273-89

[13] Cavalieri M, Guccio C, Lisi D, Pignataro G (2016), *Does the extent of per case payment system affect hospital efficiency? Evidence from the Italian NHS*, Public Finance Review, DOI: 10.1177/1091142116651487.

[14] Cellini R, Lamantia F (2016), *Quality competition in markets with regulated prices and minimum quality standards*, Journal of Evolutionary Economics 25: 345-70.

[15] Cellini R, Siciliani L, Straume O R (2015), *A dynamic model of quality competition with endogenous prices*, NIPE, Universidade do Minho.

[16] Culyer A J, Newhouse J P (Eds) (2000), *Handbook of health economics. Volume 1, Part A*, Amsterdam: Elsevier.

[17] Ellis R P, McGuire T (1986), *Provider behavior under prospective reimbursement: Cost sharing and supply*, Journal of Health Economics, 5: 129-51.

[18] Ellis R P, Miller M (2008), *Provider payment methods and incentives*, in Heggenhougen K (Ed.) International Encyclopedia of Public Health. San Diego, CA: Academic Press - Elsevier, p. 395-402.

[19] Finocchiaro Castro M, Guccio C, Pignataro G, Rizzo I (2014), *The effects of reimbursement mechanisms on medical technology diffusion in the hospital sector in the Italian NHS*, Health Policy 115: 215-29.

[20] Folland S, Goodman A C, Stano M (2004), *The economics of health and health care*. Upper Saddle River, NJ: Prentice Hall.

[21] Gravelle H, Scott A, Sivey P, Yong J, 2016. *Competition, price and quality in the market for physician consultations*, Journal of Industrial Economics 64: 135-69.

[22] Hamoudi H, Risueno M (2012), *The effect of zoning in spatial competition*, Journal of Regional Sciences 52: 361-74.

[23] Kanbur R, Keen M (1993), *Jeux sans frontières: tax competition and tax coordination when countries differ in size,* American Economic Review 83: 877-92.

[24] Ishida J, Matsushima N (2004), *A Noncooperative Analysis of a Circular City Model* Regional Science and Urban Economics 34: 575-589.

[25] Levaggi R, Moretto M, Pertile P (2012), *Static and dynamic efficiency of irreversible health care investments under alternative payment rules*, Journal of Health Economics 31: 169-79.

[26] Levaggi R, Moretto M, Pertile P (2014), *Two-part payments for the reimbursement of investments in health technologies*, Health Policy 115: 230-36.

[27] Ma A, Burgess J (1993), *Quality competition, welfare, and regulation*, Journal of Economics 58: 153-73.

[28] Ma A (1994) *Health care payment systems: Cost and quality incentives*, Journal of Economics and Managehcare facilities, ment Strategy 3: 93-112.

[29] Mikkala H, Keskimaki I, Hakkinene U (2002), *DRG related prices applied in a public health care system: Can Finland learn form Norway and Sweden?* Health Policy 59: 37-51.

[30] Miraldo, M., Siciliani, L., Street, A., 2011. *Price adjustment in the hospital sector*, Journal of Health Economics 30: 112–125.

[31] Moreno Serra R, Wagstaff A (2010), *System-wide impacts of hospital payment reforms: evidence from Central and Eastern Europe and Central Asia*, Journal of Health Economics 29: 585-602.

[32] Pauli M, McGuire T, Barros P (2011), *Handbook of health economics. Volume 2.* Amsterdam: Elsevier.

[33] Romeo A A, Wagner J L, Lee R H (1984), *Prospective reimbursement and the diffusion of new technologies in hospitals*, Journal of Health Economics 3: 1-24.

[34] Rosenmoller M, McKee M, Baeten R (Eds) (2004), *Patient mobility in the European Union: Learning from experience*, Bruxelles: The European Observatory on Health Systems and Policies. http://www.euro.who.int/data/assets/pdf_file/0011/120332/E88697.pdf

[35] Salop S C (1979), *Monopolistic competition with outside goods*, Bell Journal of Economics 10: 141-56.

[36] Schreyoegg J, Stargardt T, Tiemann O, Busse R (2006), *Methods to determine reimbursement rate for DRG: A comparison of nine European countries,* Healthcare Management 9: 215-23.

[37] Siciliani L, Straume O R, Cellini R (2013), *Quality competition with motivated providers and sluggish demand*, Journal of Economic Dynamics & Control 37: 2041-61.

[38] Street A, O'Reilly J, Ward P, Mason A (2011), *DRG based hospital payment and efficiency: Theory, evidence and challenges*, in Busse R, Geissler A, Quentin W, Wiley M (Eds.) Diagnosis related groups in Europe: Moving towards transparency, efficiency and quality in hospitals. Maidenhead, UK: Open University Press, p. 93-114.

[39] Weber E, 2014. *Measuring welfare from ambulatory surgery centers: A spatial analysis of demand for health care facilities*, Journal of Industrial Economics 62: 591-631.