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Designing Competition in Health Care Markets

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Abstract

In this paper we propose a simple, market based mechanism to set prices in health care markets, namely a system where the patients are auctioned out to the hospitals. Our aim is to characterize principles as to how such an auction should be designed. In the case of elective treatment, health authorities thus organize a competition between hospitals. The hospital with the lowest price signs a contracts with authority (or the insurer) that commits him to treat a given number of patients within a predetermined period. However, this is not a simple mechanism that identifies the hospital with the lowest treatment cost. Due to potentially rapid and unpredictable shifts in demand, treatment capacity may be hard to know in advance. There is always a risk that treatment must be canceled due to arrival of patients that require acute treatment. This calls for a market design that accounts for the risk of default.

Our main result is that the expected cost for the government is reduced if the government chooses to "subsidize" default. This could be thought of as a system in which the government buys treatment in the spot market in the case of default, and let the hospital pay a default fee that is lower than the spot price. The reason why this reduces expected costs for the government is that the effect on the bids is asymmetric: The second lowest bid is on average reduced more than the winning bid. Hence, the winner's profit tends to shrink. This is due to what we characterize an *endogenous correlation*. Since the cost of treatment increases in the default risk (as the hospital must pay a penalty if it defaults), high cost hospitals typically have larger default risks than low costs hospitals.

1 Introduction

Markets for treatment of patients suffer from various sources of inefficiency. In purchasing health services, governments want to keep costs per treatment as low as possible without inducing hospitals to skimp on quality. Fulfilling this goal seems to constitute a non-trivial problem in most countries and has triggered health care reforms of various forms. Related to hospital financing, there have been a shift from low-powered cost reimbursement policies to more high-powered prospective payment systems, which essentially pay a fixed price per discharge. Although such reforms are expected to improve cost efficiency (and, potentially, quality as well), an important question remains: How should the prices in this quasi-market be set? From a pure contract design point of view, this may be solved as a problem of regulation under asymmetric information (see e.g. Ma (1994), Ellis and McGuire (1990), Sappington and Lewis (1999) and De Fraja (2000)).

In this paper we instead propose a simple, market based mechanism to set prices, namely a system where the patients are auctioned out to the hospitals. Our aim is to characterize principles as to how such an auction should be designed. In the case of elective treatment, health authorities thus organize a competition between hospitals. The hospital with the lowest price signs a contracts with authority (or the insurer) that commits him to treat a given number of patients within a predetermined period. However, this is not a simple mechanism that identifies the hospital with the lowest treatment cost. Due to potentially rapid and unpredictable shifts in demand, treatment capacity may be hard to know in advance. There is always a risk that treatment must be canceled due to arrival of patients that require acute treatment. This calls for a market design that accounts for the risk of default. A credible commitment to treat a patients requires that treatment can be bought in the market (possibly at a very high price) in case of a default.

We consider an auction design in which two hospitals compete for a "treatment-contract" of one single patient. Introducing more hospitals and more patients would not alter our conclusion. Clearly, the optimization problem that governments face is how to deal with a large stock of untreated patients as well as a flow of new patients. Hence, the challenge is to design a mechanism in which these patients are allocated on hospitals in an efficient manner. We know from the literature (see Milgrom, 1999)) that this situation calls for a simultaneous auction procedure. However, as long as there are no cost complementarities, a very simple auction format solves this extended optimization problem, namely a simultaneous open cry increasing auction, where the single patient is the bidding unit, and where each hospital is free to submit as many bids as it wants. Thus, if cost complementarities can be ruled out, we can narrow our focus to an auction of a "representative patient".

Our main result is that the expected cost for the government is reduced if the government chooses to "subsidize" default. This could be thought of as a system in which the government buys treatment in the spot market in the case of default, and let the hospital pay a default fee that is lower than the spot price. The reason why this reduces expected costs for the government is that the effect on the bids is asymmetric: The second lowest bid is on average reduced more than the winning bid. Hence, the winner's profit tends to shrink. This is due to what we characterize an *endogenous correlation.* Since the cost of treatment increases in the default risk (as the hospital must pay a penalty if it defaults), high cost hospitals typically have larger default risks than low costs hospitals.

Our result is related to the literature on ex post distortions in procurement and franchise auctions (see Laffont and Tirole (1987), Riordan and Sappington (1987), McAfee and McMillan (1987)). This literature shows that *ex post* distortions (like price above marginal costs or cost sharing) generally will be optimal in order to promote more competitive bidding *ex ante.* The point is (as explained above) that these distortions affect the expected profitability of the contract differently according to the bidders' private information. Our contribution is that we apply this principle to a simple auction mechanism in a "market" for treatment of patients in which default risks plays a crucial role.

2 The model

Assume the local government signs a contract that entitles hospital i the responsibility of treating a patient. Denote by b_i the hospital's cost of treatment, and by q_i the probability that the hospital defaults on the contract. We assume that b and q are private information, distributed according to the commonly known density function $\varphi(b, q)$. The support of b and q is given by $[0, \bar{b}] \times [0, 1]$. To simplify the exposition, we assume that b and q are independent, but as we show in the appendix this is not necessary for our results to go through.

The probability of default can be interpreted in different ways. It might be due to *exogenous* factors such as the risk of arrival of patients that need immediate treatment. This process is not under the hospital's own control. Alternatively, q might be determined *endogenously,* resulting from the hospital's own optimization problem. If the hospital has signed many contracts, and must default on some of them, it may to some extent select which contracts to default on. Furthermore, the total number of patients treated in the hospital depends on effort, organizational adjustments and so on. The point is that q is stochastic from the government's point of view, and that the government lacks complete knowledge about those factors that determine hospitals' contracts default.

Who is responsible if the hospital does not complete the treatment of the patient? We compare two alternative models. In the first model the government signs a contract that entitles the hospital with the unconditional responsibly to complete the treatment. In this case, the hospital must buy capacity in the spot market at a price $b^s > \bar{b}$ if it happens to become short of capacity (in order to avoid being sued). In the alternative model, the responsibility of treatment is returned back to the government. In this case, the government must buy capacity in the spot market, and charges a penalty b^d from the hospital. We assume that the spot price of treatment is equal in the two models.

The social cost of treating the patient in hospital i is

$$\omega_i = (1 - q_i)b_i + q_i b^s,$$

and represents the weighted average of the internal treatment cost b_i and the spot market price b^s. In the first model, the private cost of treatment in hospital i is

$$v_i = \omega_i$$

and in the second model,

$$v_i = (1 - q_i)b_i + q_i b^d = \omega_i - q_i\beta$$

where β is the subsidy, $\beta := b^s - b^d$. Clearly, the two models collapse to the same model if the spot market subsidy β is set equal to zero.

3 Equilibrium analysis

First consider the model in which the government auctions off the unconditional responsibility of treatment. As we have a symmetric, private value setting, the revenue equivalence theorem applies. Hence any auction format which allocate the patient to the most efficient hospital yields the same expected cost for the government: The hospital with the lowest social cost wins and receives a payment equal to the expected second lowest cost, $Ev_{(2)} =$

$E\omega_{(2)}$, where footscript (j) denotes the j'th rank. This is also an optimal auction format within this setting.

However since default is an observable event, the government may sign a contract that is conditional upon the outcome of this draw. This gives the second model. If the penalty b^d is set equal to b^s, then the two auction procedures are identical. However, if b^d differs from b^s, firms' bidding behavior is affected and hence the government's costs. As the revenue equivalence theorem still applies, we assume that the seller adopts a second price, sealed bid auction format. We know from Vickers (1961) that bidding according to the private cost of treatment is a weakly dominating strategy. Hence, the hospital with the lowest private cost $v_{(1)}$ wins and receives a payment equal to the second lowest bid $v_{(2)}$, and compensates the government in the case of default.

The payment can be written,

$$v_{(2)} = (1 - q_{(2)})b_{(2)} + q_{(2)}b^d = \omega_{(2)} - \beta q_{(2)}$$

The expected social cost of the contract is equal to the payment the winning hospital receives plus the subsidy that follows in the event that the hospital defaults (which occurs with probability $q_{(1)}$):

$$v_{(2)} + q_{(1)}\beta = (1 - q_{(2)})b_{(2)} + q_{(2)}b^d + q_{(1)}\beta = \omega_{(2)} + [q_{(1)} - q_{(2)}]\beta$$

We see that the subsidy affects the bidding, and, hence, the social cost of the contract. In the remaining part of this section we investigate more carefully the optimal level of the subsidy. The optimal subsidy (or, equivalently, the default price b^d) follows from the following problem:

$$\underset{\beta}{Min} E \left\{ \omega_{(2)} + [q_{(1)} - q_{(2)}]\beta \right\}$$

By assumption, b and q are independent variables. However, it follows directly from the definition of v that v and q are positively correlated, we have that $cov(v, q) = cov(qb + (1-q)b^d, q) = (b^d - b)^2 var\ q$. The point is that a firm that has high total costs in expected terms also have high default risk, since this increases total costs. We refer to this as *endogenous correlation*: although the default risk is independent of the internal cost b of treatment, the default risk is positively correlated with total costs (costs of default risk included). Thus, in expected terms, a subsidy of default is more valuable for the looser of the auction than for the winner, since the looser is more likely to have a high default risk. The looser's expected cost reduction of a subsidy, and thus the reduction in his bid, is given by $Eq_{(2)}\beta$. The expected costs associated with subsidizing the winner when he defaults is $Eq_{(1)}\beta$. The

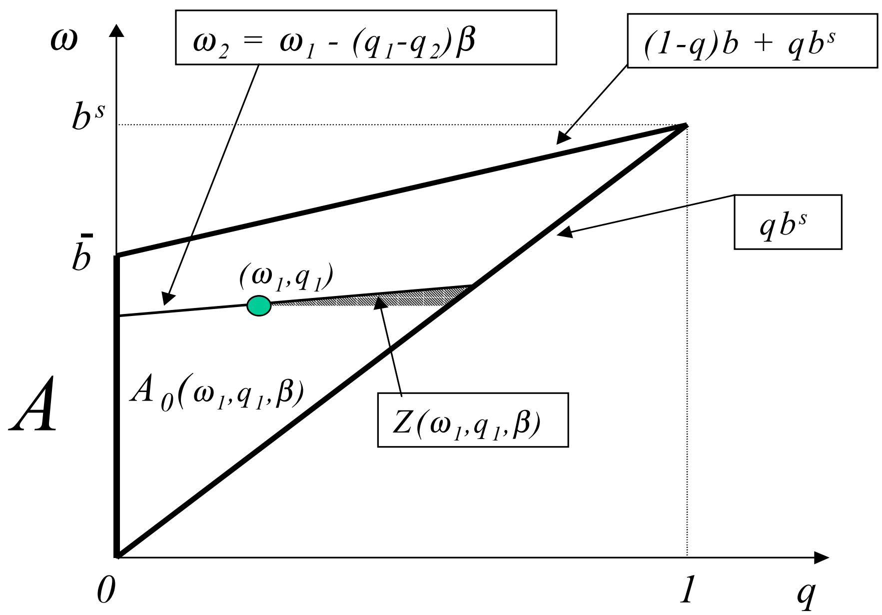

Figure 1:

difference, $\beta(Eq_{(2)} - Eq_{(1)})$ is thus positive, and this indicates that a subsidy may reduce total costs for the government.

However, this is not the end of the story. A subsidy may also change the identity of the winner of the auction. As the bidders don't bid on social costs, one may risk that the hospital with the lowest social costs loses the competition. This is illustrated in figure 1, where we measure expected social cost on the vertical axes and default risk on the horisontal. Assume hospital 1's social cost and default risk is given by (ω_1, q_1). Then hospital 2 wins the auction if (ω_2, q_2) is in the area A_0, otherwize hospital 1 wins. Note that A_0 is constrained upwards by the line $\omega_1 = \omega_1 - (q_1 - q_2)\beta$, which has a slope equal to the subsidy rate β. Social efficiency claims that the hospital with the lowest ω is chosen; which occurs with certainty if the winning hospital covers all costs of a default - that is if $\beta = 0$. If β deviates from zero, an inefficient selection may occur. If (ω_2, q_2) is in the area Z hospital two wins even though $\omega_2 > \omega_1$.

The costs of an inefficient allocation of the patients on hospitals are ultimately borne by the government. We denote this misallocation cost by $C_Z(\beta)$. The government thus faces a trade-off: A high subsidy of default induces aggressive bidding by the looser, and this reduces the expected price the government has to pay. On the other hand, an increased subsidy also increases the costs associated with a misallocation of the patient. An optimal contract is such that the costs and benefits are balanced at the margin.

Still, it is easy to see that the optimal subsidy must be positive. The reason for this is that the costs associated with misallocation is of second order around $\beta = 0$. To see why, note that an optimal allocation is always obtained when there is no subsidy, that is, when $\beta = 0$. The misallocation cost $C_Z(\beta)$ is thus minimized (and equal to zero) at $\beta = 0$. From the envelope theorem it then follows that $C'_Z(0) = 0$. On the other hand, the marginal benefit, $\frac{\partial E\beta(q_{(2)}-q_{(1)})}{\partial\beta} = E(q_{(2)} - q_{(1)})$ is strictly greater than 0 at $\beta = 0$. This gives the intuition behind the following proposition

Proposition 1 *An optimal allocation design implies that the government subsidizes default, that is,* $\beta > 0$

Proof. See appendix. ■

The reason why such a subsidy reduces expected costs for the government is that the bidding effect is asymmetric over bid levels. The second lowest bid is on average reduced more than the winning bid. Hence, the winner's profit and the social costs tends to shrink.

4 Appendix

Recalling that $\omega := (1-q)b + qb^s$, we can construct a new density function $f(\omega, q)$ from the density function $\varphi(b, q)$. The density $f(\omega, q)$ has support in A as shown in figure 1. Referring to figure 1, type 2 wins, for a given (ω_1, q_1)

for type 1, if $(\omega_2, q_2)\ \epsilon A_0$, otherwise type 1 wins. Hence, the expected social cost, $E\left\{\omega_{(2)}+\beta[q_{(1)}-q_{(2)}]\right\}$,can be written,

$$
\begin{aligned}
EC &= \iint_{A}\left[\iint_{A_0^C}[\omega_2+(q_1-q_2)\beta]f(.)d\omega_2 dq_2\right]f(.)d\omega_1 dq_1 \\
&\quad +\iint_{A}\left[\iint_{A_0}[\omega_1+(q_2-q_1)\beta]f(.)d\omega_2 dq_2\right]f(.)d\omega_1 dq_1, \qquad (1)\\
&= \int\cdots\int_{A}[\omega_2+(q_1-q_2)\beta]f(.)f(.)d\omega_2 dq_2 d\omega_1 dq_1 \\
&\quad +\iint_{A}\left[\iint_{A_0}[\omega_1-\omega_2-2(q_1-q_2)\beta]f(.)d\omega_2 dq_2\right]f(.)d\omega_1 dq_1.
\end{aligned}
$$

Differentiate EC with respect to β yields,

$$
\begin{aligned}
\frac{dEC}{d\beta} &= \int\cdots\int_{A}(q_1-q_2)f(.)f(.)d\omega_2 dq_2 d\omega_1 dq_1 \qquad (2)\\
&\quad -2\iint_{A}\left[\iint_{A_0}(q_1-q_2)f(.)d\omega_2 dq_2\right]f(.)d\omega_1 dq_1 \\
&\quad +\iint_{A}\left[\int_{A_0}(q_1-q_2)^2\beta f(\omega_1-(q_1-q_2)\beta,q_2)dq_2\right]f(.)d\omega_1 dq_1
\end{aligned}
$$

The first term is zero due to the symmetry of the model. The second term captures the direct effect of the default subsidy on the player's bidding. Whereas the last term captures the risk of changing the identity of the winner. Observe that the latter effect is always negative. First best claims that the the firm with the lowest social cost wins. This can be guaranteed by not subsidizing default. As β increases above zero, the risk that the inferior firm has the highest bid increases. Starting out from zero, this effect is of second order. The second term, however, is of first order.

In order to derive the result, it is convenient to first solve the model for the case where the joint density can be written:

$$f(\omega,q)=g(\omega)h(q)$$

where $g(\omega)$ and $h(q)$ are strictly positive for all $(\omega, q)\epsilon A$ and that $\int_A g(\omega)h(q) = 1$. In this case the variables are locally independent in the sense that ω and q are independent on any rectangular subset in A. Under this assumption, we can write the effect of an increase in β on the expected cost (in the limit as $\beta = 0$) as follows:

$$
\begin{aligned}
& \frac{dEC}{d\beta}|_{\beta=0} \\
= \;& 2\int_0^{\overline{b}}\left[\int_0^{\frac{\omega_1}{b^s}}\int_0^{\frac{\omega_1}{b^s}}(q_2-q_1)[G(\omega_1)-G(b^s q_2)]h(q_2)h(q_1)dq_2dq_1+\right]g(\omega_1)d\omega_1 \\
& +2\int_0^{\overline{b}}\left[\int_{\frac{(\omega_1-\overline{b})}{(b^s-\overline{b})}}^{\frac{\omega_1}{b^s}}\int_0^{\frac{(\omega_1-\overline{b})}{(b^s-\overline{b})}}(q_2-q_1)[G((1-q_2)\overline{b}+q_2b^s)-G(b^s q_2)]h(q_2)h(q_1)dq_2dq_1\right]g(\omega_1)d\omega_1 \\
& +2\int_0^{\overline{b}}\left[\int_{\frac{(\omega_1-\overline{b})}{(b^s-\overline{b})}}^{\frac{\omega_1}{b^s}}\int_{\frac{(\omega_1-\overline{b})}{(b^s-\overline{b})}}^{\frac{\omega_1}{b^s}}(q_2-q_1)[G(\omega_1)-G(b^s q_2)]h(q_2)h(q_1)dq_2dq_1\right]g(\omega_1)d\omega_1
\end{aligned}
$$

Observe that the second term is strictly negative since q_2 is always lower than q_1. Consider now the first and the third term. Note that the structure of the two parentheses is as follows (set $x = \omega_1/b^s$, $K(q_{2)} = G(\omega_1) - G(b^s q_2)$ and $y =$ either 0 or $(\omega_1 - \overline{b})/(b^s - \overline{b})$.)

$$\int_y^x \int_y^x (q_2 - q_1)K(q_2)h(q_2)h(q_1)dq_2dq_1$$

where $K'(q_2) < 0$. Since

$$\int_y^x \int_y^x (q_2 - q_1)h(q_2)h(q_1)dq_2dq_1 = 0$$

it follows that

$$
\begin{aligned}
& \int_y^x \int_y^x (q_2 - q_1)K(q_2)h(q_2)h(q_1)dq_2dq_1 \\
= \;& [H(x) - H(y)] \int_y^x (q_2 - Eq_1)K(q_2)h(q_2)dq_2 \\
= \;& [H(x) - H(y)] \int_y^x (q_2 - Eq_1)(K(q_2) - K(Eq_1))h(q_2)dq_2 < 0.
\end{aligned}
$$

where Eq_1 is the expected q_1 given $y < q_1 < x$.

Accordingly, increasing β slightly decreases the expected cost if ω and q are locally independent. Before we discuss the more general cases, let us show that $\beta > 0$ indeed is optimal. To see this, it is sufficient to show that expected cost is even higher for all $\beta < 0$. Recall that the third term in (2) captures the cost of changing the identity of the winner - this cost is clearly minimized at $\beta = 0$. Consider the second term. Differentiating twice yields

$$2\iint\limits_{A} \left[\int\limits_{A_0} (q_1 - q_2)^2 f(\omega_1 - (q_1 - q_2)\beta, q_2) dq_2 \right] f(.) d\omega_1 dq_1 > 0$$

Hence an optimum at a negative value of β is ruled out. It should be clear from the calculations above that the result holds also if ω and q are affiliated. Actually, a strong negative dependence between ω and q is the only possibility for our conclusion to change.

A positive correlation between ω and q seems reasonable. Recall that ω is defined as follows :$\omega = (1 - q)b + qb^s$. Let say q and b are independent. In that case ω and q are affiliated - a high value of q tends to a high value of ω. Or in other words: for ω and q to be independent, q and b must be negatively correlated. Furthermore there are reasons to believe that even q and b actually are positively correlated: An hospital which is expected to be closer to the capacity constraint has normally a larger alternative cost of treatment, as well a larger risk of default.

Finally, it is clear that the above reasoning also goes through in a more general model. The risk of a change in winner's identity is still of second order, as is the probability of a change in the identity of the second highest bidder. Hence, to see the effect of an increase in β at $\beta = 0$, it is sufficient to focus on the two highest valuation bidders among the n participants.

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