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Public rationing and private cost incentives

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Abstract

This paper considers a public provider's strategic use of rationing in a market served by both public and private providers. Such a 'mixed' market structure is common in many industries such as health care, telecommunication, postal service, and public utilities. The technology in the private sector exhibits increasing returns: each firm can expend 'effort' in the form of fixed cost to reduce the marginal cost. Firms in the contestable private sector compete and the market equilibrium is characterized by average-cost pricing. The equilibrium private sector market size is too low, resulting in deficient cost effort. Efficient rationing forces more consumers to use the private sector, restoring cost incentives and implementing the first best. Random rationing may reduce cost inefficiency but does not implement the first best.

JEL classification: D45; H40

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1. Introduction

In most countries, the government plays an active role in many markets. Utilities, communications, transportation, education and health care markets are subject to government interventions; the government may even be the sole provider. More generally, the 'mixed' system—consumers obtaining services or goods from public and private firms—is common. The interaction between private and public firms is the subject of this paper.

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My theory employs a strategic approach, studying the equilibrium in a game between a public provider and a private sector. In the formal model the public provider attempts to maximize social welfare, and can commit to a capacity limit. Then firms in the private sector compete by selecting prices and levels of investment to reduce costs. Each consumer may obtain the good from the public provider subject to any capacity constraint, and has the option of buying the good from a firm in the private sector. I analyze the public provider's strategic use of rationing to remedy a market failure.

The market failure in the economy stems from the technology and the result of competition under increasing returns. In the model, each private firm may reduce its marginal cost by expending 'effort' or fixed costs. Due to the combination of constant marginal and fixed costs, the average cost is decreasing. This sort of technology is used in many models of regulation and investment incentives; see Chalkley and Malcomson (1998a,b), Laffont and Tirole (1993) and Ma (1994). Moreover, the empirical literature suggests that returns to scale are common and important; see Dranove (1998), Gaynor and Anderson (1997) and Wilson and Carey (2000). The private sector is assumed to be a contestable market. A contestable market equilibrium is described by stability: an active firm chooses price and effort investment to maximize profit, but the active firm must make zero profit so that other firms will not enter. In other words, in equilibrium only one firm remains active but must use an average-cost pricing rule.

It is this equilibrium average-cost pricing rule that leads to an underinvestment in effort. The first best allocates consumers across the public and private sectors on the basis of marginal production costs in these sectors. Without rationing, consumers choose their suppliers according to the prices they face. Because the equilibrium price at the private sector is equal to the average cost, and because of increasing returns, that price is strictly higher than the marginal cost. Therefore, the equilibrium market size in the private sector is lower than the first best. Now the social benefit of cost-reduction investment (effort) is proportional to the private firm's market size. Due to its smaller market, the private sector's benefit from effort is too low. So the equilibrium in the contestable private sector is characterized by suboptimal cost-reduction effort.

I show that a rationing scheme can reduce the effort inefficiency. By imposing a capacity constraint, the public provider limits access to its supply. Consumers must then buy from the private sector. The bigger market in the private sector results in a bigger incentive to invest in effort. Although some consumers are rationed, having no access to the public provider, the gain in effort incentives outweighs this loss. The welfare-improving rationing scheme relies on a monotonicity property and is related to the efficient rationing scheme that scholars in industrial organizations used previously (see Kreps and Scheinkman, 1983; Davidson and Deneckere, 1986). Under efficient rationing, the first best is implemented. Nevertheless, random rationing may not be an equilibrium and will not perform as well as efficient rationing. I also extend the model to consider quality investment by firms in the private sector; the efficiency enhancement effect of efficient rationing remains valid.

Although I have used a general model to study the efficiency effect of rationing, it offers a particularly important insight for the health care industry. Cost efficiency in the health care industry has been a public policy issue for the past two decades in many countries. Rationing in the medical market by public providers is common. Significant interaction between public and private health care sectors exist in many countries; among 29 OECD countries, the private sector accounted for about 28% of total health expenditure in 1998.[1] My model connects these three issues together. In fact, it appears to be the first to derive a cost-incentive effect of rationing in a mixed system. This connection is especially interesting for the health sector as governments explore many new ways to increase efficiency in the health care market.

Various papers have studied separately these three issues in the health market. Earlier theoretical models about cost efficiency (and such issues as quality, dumping, and skimping) include Ma and Burgess (1993), Ma (1994), Che and Gale (1997), and Ellis (1998); these papers consider neither the public firm nor rationing. In Feldman and Lobo (1997), rationing is used by a hospital administrator who operates under a global budget constraint and who may not aim at satisfying consumers' demand. Lindsay and Feigenbaum (1984) propose a theory of rationing by waiting lists; more discussion on this will be found in Section 5. Iversen (1997) considers a dynamic model of rationing by waiting lists. His main result shows that the existence of a private sector can make the list longer.[2] Pita-Barros and Martinez-Giralt (2002) use a Hotelling model of oligopoly to study the interaction between public and private health care; their results, together with those in Ma and Burgess (1993), confirm the role for public intervention for efficient cost and quality.

A major concern in the public finance literature is whether increased public financing will tend to crowd out private provisions (Epple and Romano, 1996a,b). I do not address financing issues, but my model demonstrates a cost-efficiency perspective on crowding out. Rationing by the public provider corresponds to less crowding out and results higher cost efficiency in the private sector. Besley et al. (1998) address empirically the interaction between public and private health insurance, and show that waiting lists in the UK National Health Services are positively associated with private insurance. Cost incentives are the major concern in the regulation literature (see Baron and Myerson, 1982; Laffont and Tirole, 1993). A number of papers in regulatory economics do study the interaction between private firms and public organizations, as well as between regulated and unregulated firms (see Biglaiser and Ma, 1995, 1999); nonprice rationing and cost incentives have not been a focus.

The model will be defined in the next section. Section 3 derives the contestable market equilibrium when the public provider does not ration consumers, and obtains the basic inefficient effort result. Then, in Section 4, I introduce efficient rationing and characterize the equilibrium. I show that efficient rationing will be used to motivate an efficient effort level at the private sector. Section 5 presents an example in which random rationing is not an equilibrium, and then a sufficient condition for such an equilibrium. Some relationship

[1] Calculations were done by the author using OECD data available from the OECD web site. The range was big: Luxembourg's private sector was smallest and responsible for 8.3% of expenditure, while Turkey's was the largest at 58.3%, with United States a close second at 55%.

[2] The theory of managed care in the health market is of course concerned with nonprice rationing; the focus there is mainly on how rationing can control moral hazard without having consumers bear more financial risks. For a recent empirical assessment of rationing in a public service, see Tengs (1996). Ma and Riordan (2002) consider a model where physicians ration consumers to reduce moral hazard and improve risk sharing.

between rationing by waiting lists (Lindsay and Feigenbaum, 1984) and the model in this paper is also discussed. Section 6 contains a heuristic extension on quality investment by private firms. The last section draws some conclusions.

2. The model

Each of a set of consumers would like to consume a unit of a good. A consumer may get the good at marginal cost from a public provider, which produces the good at a fixed quality, normalized at 1. Alternatively, for a price, a consumer can buy the good from a firm in the private sector. The good at the private sector has a higher quality, $q > 1$; an extension in Section 6 allows private firms to choose quality. Horizontal product differentiation exists in the two sectors, and is modeled in the Hotelling fashion. The consumers have a total unit mass and are uniformly distributed on the unit interval. A consumer with parameter x is located a distance of x unit from point 0. The public provider is assumed to locate at point 0; each firm in the private sector is at point 1. If a consumer at x obtains the good from the public provider, his utility is $1 - x$; if he buys from the private sector at a price p, his utility is $q - p - (1 - x)$. The consumer's location can be interpreted as a 'mismatch' parameter with respect to the two sectors.[3]

Although I use an abstract, Hotelling framework to model consumers' preferences on the goods supplied by the public and private firms, this can be given very practical interpretations. The mismatch parameter can be related to income. For example, consumers with higher incomes naturally prefer the goods in the private sector, whose firms may have more flexible hours of services and more amenities. In other examples, especially in developing countries, the distance parameter can be related to wealth. Wealthier consumers have access to better transport and prefer the locations of private firms more than poor consumers. A practical interpretation on the product differentiation framework is important because rationing often works in terms of parameters that are easily verifiable, such as income, age, or asset. Rationing schemes in my model must formally work in terms of the distance parameter, and it is important that the parameter can be interpreted broadly.

The public provider produces its goods at a constant marginal cost, which is normalized at 0. Each firm in the private sector also produces its goods at a constant marginal cost, but it can vary this level by expending fixed costs or 'efforts.' The marginal cost is $c(e)$ if the effort level is e. The effort level is associated with a fixed cost or disutility of $\gamma(e)$. The function c is strictly decreasing and convex; that is, $c'(e) < 0$ and $c''(e) > 0$. Moreover, the disutility or fixed cost function $\gamma(e)$ is strictly increasing and convex; that is, $\gamma'(e) > 0$ and $\gamma''(e) > 0$. Their cost function consisting of marginal and fixed costs, firms in the private sector have an increasing returns technology.

[3] The private and public sectors are assumed to interact. That is, the entire market will be served in an equilibrium (but note that in Section 5, under random rationing, some consumers will not obtain any good ex post).

Firms in the private sectors compete; I use contestability to describe the outcome of competition (see Baumol et al., 1982). In the private sector, each firm may set a price and its effort level. Suppose that there is an active firm charging a certain price to consumers and adopting a certain effort of level. This price–effort pair is *stable* if no other firm can make a positive profit by charging consumers another price and adopting another effort level. Contestability requires that an incumbent firm charges a price so low that entry is unprofitable. Although in the private sector there is one active firm in equilibrium, the threat of entry prevents this firm from making a profit.

The public and private sectors are treated asymmetrically. While it may be natural to assume a homogenous public sector (a single public provider), the assumption of identical firms competing rigorously in the private sector deserves more discussion. If product differentiation exists between the public and private sectors, then perhaps it also exists between firms in the private sector. Extending the product differentiation in that direction will not alter my basic results. What is convenient is that a competitive private sector reduces the possibility of market failures. In a monopolistic private sector, equilibrium prices there must be above marginal and average costs, creating more deadweight loss. I have chosen to eliminate the loss due to firms' market power in the private sector. The assumption of a competitive private sector allows me to concentrate on a more fundamental misallocation of resources due to increasing returns, and to illustrate the effect of rationing most succinctly.[4]

I analyze the interaction between the public and private sectors by two Stackelberg games, which differ only in the first stage. In the regime with no rationing, the public provider commits to supply its goods at marginal cost to consumers who choose to get them. In the rationing regime, the public provider commits to a capacity limit; if the capacity cannot satisfy demand, consumers will be rationed, and details of the rationing scheme will be spelt out later. In each regime, in the second stage, firms in the private sector compete for consumers, selling a higher quality good at a higher price to consumers who have the option to obtain the public provider's supply. The equilibrium in the private, contestable market is given by the stable price and effort level defined above.

I first define the first best as a benchmark. Suppose that the public provider can dictate the effort level in the private sector, as well as allocate consumers across the public and private suppliers. An allocation is given by (x, e): consumers located between 0 and x obtain goods from the public provider, while those between x and 1 from the private sector; e is the effort level. Social welfare of this allocation is:

$$\int_0^x (1-z)\mathrm{d}z + \int_x^1 (q - c(e) - (1-z))\mathrm{d}z - \gamma(e) \tag{1}$$

which is assumed to be concave. The first best is the allocation that maximizes (1). I summarize the first best by Proposition 1, whose proof consists of solving the first-order conditions, and is omitted.

[4] More discussions can be found in the last section.

Proposition 1. *The first best is given by the solution of the following simultaneous equations:*

$$1 - x = q - c(e) - (1 - x) \tag{2}$$

$$-(1 - x)\, c'(e) - \gamma'(e) = 0 \tag{3}$$

The above two equations are interpreted as follows. First, given the marginal cost $c(e)$, the allocation of consumers across the two suppliers minimizes the disutility due to the mismatch. Eq. (2) describes the marginal consumer, one who is just indifferent between obtaining the good supplied by the public provider, and the good supplied by the private sector at marginal cost $c(e)$. Second, the choice of effort ensures that the social marginal benefit of effort equals the marginal cost of effort $\gamma'(e)$. The social marginal benefit is the term $-(1 - x)\, c'(e)$. If effort increases by one unit, then the marginal cost $c(e)$ reduces by the amount $-c'(e)$. The private sector serves those consumers located between x and 1, a total of $1 - x$ consumers. So the aggregate cost savings due to an increase in effort is $-(1 - x)\, c'(e)$, the social marginal benefit of effort. Denote the first-best effort by e^{fb}.

Consider just for now the optimal effort level when the market allocation x is assumed to be exogenous. Then the optimal effort is increasing in the private sector's market size $1 - x$. Total differentiation of (3) yields:

$$\frac{\mathrm{d}e}{\mathrm{d}x} = \frac{-c'(e)}{-(1 - x)\, c''(e) - \gamma''(e)} < 0 \tag{4}$$

where the inequality follows from the fact that the denominator is the negative second-order derivative of (1) with respect to e. As the share of the market served by the private firm increases, the return to effort investment also increases, because a reduction in marginal cost $c(e)$ results in cost savings for all consumers served by the private firm.

3. Contestable market equilibrium and cost incentives

Now I study the regime in which the public provider offers its supplies to consumers at zero marginal cost without limiting its capacity while firms in the private sector actively compete for customers. I derive the contestable market equilibrium in the private sector, and then compare the equilibrium effort with the first best. A contestable market equilibrium in the private sector consists of a price p and an effort level e. The equilibrium price must be equal to the average cost, so that no other firm can profitably enter. Furthermore, the effort level must also be chosen to maximize the active firm's profit. Suppose that the price in the private sector is p. The consumer indifferent between the products supplied by the public provider and the private sector has a location x given by $1 - x = q - p - (1 - x)$. The private sector's demand is:

$$(1 - x) = \frac{q - p}{2} \tag{5}$$

and the profit function:

$$\frac{q-p}{2}[p-c(e)]-\gamma(e) \tag{6}$$

A contestable market equilibrium is the pair (p,e) such that:

$$e = \arg\max_{e'} \ \frac{q-p}{2}[p-c(e')]-\gamma(e') \tag{7}$$

$$\frac{q-p}{2}[p-c(e)]-\gamma(e)=0 \tag{8}$$

Using the first-order condition for (7) with respect to e, I summarize the contestable market equilibrium by Proposition 2.

Proposition 2. *The contestable market equilibrium price and effort, (p*,e*), are given by the solution of the following:*

$$-\frac{q-p^*}{2}c'(e^*)-\gamma'(e^*)=0 \tag{9}$$

$$\frac{q-p^*}{2}[p^*-c(e^*)]-\gamma(e^*)=0 \tag{10}$$

How is the equilibrium effort level e^* compared with the first best? First, because of the fixed cost $\gamma(e)$, the average cost is always higher than the marginal cost. In a contestable market equilibrium, the price is higher than the marginal cost: $p^* > c(e^*)$. So the equilibrium market size for the private sector is smaller than if its price is at marginal cost:

$$\frac{q-p^*}{2}<\frac{q-c(e^*)}{2}$$

Proposition 3. *The equilibrium effort level in the private sector is smaller than the first best:* $e^*<e^{fb}$. *Moreover, the equilibrium market size of the private sector is smaller than the first best.*

Proposition 3, whose proof is in Appendix A, demonstrates the fundamental problem in effort investment in the private sector. Given its market size, the active firm in the private sector fully internalizes the social cost and benefit of effort. Nevertheless, the equilibrium market size is too low. The first best allocates consumers across the two sectors by comparing the qualities and marginal costs. In the contestable market equilibrium, the equilibrium allocation is determined by the quality and the price at the private sector. In the private sector, firms compete in the presence of the fixed cost $\gamma(e)$. The equilibrium price, being equal to the *average* cost, is strictly higher than the marginal cost. Increasing returns technology in the private sector leads to equilibrium average-cost pricing and a suboptimal consumer allocation across the two sectors. If public policy is to play a role to enhance efficiency, it must lead to a bigger private sector.

Before I move on to consider rationing, I must note that there is a budget-balanced tax-subsidy scheme to implement the first best. Suppose the government imposes a fee t on each consumer who gets the good from the public provider and pays a subsidy s to each consumer who buys from the private sector. Let x consumers get the goods from the public firm; budget balance requires $xt = (1 - x)s$. Since the scheme is budget balanced, it does not affect aggregate welfare. The active private firm's optimal effort is only determined by its market size, not by the consumer tax or subsidy. But now the government can choose t and s to implement the socially efficient market distribution. Specifically, pick the tax and subsidy such that they are budget balanced, and satisfy:

$$1 - t - x^{fb} = q + s - p - (1 - \hat{x})$$

where x^{fb} is the first-best private market size in (2), and p equals the private firm's average cost when it chooses the first-best effort and supplies $1 - x^{fb}$ consumers.

The use of such taxes and subsidies may be problematic. First, I have ignored distributional issues. If consumers near position 0 have lower incomes, the above scheme taxes the poor and subsidizes the rich, a politically questionable policy. Second, other distortions may be created. The tax-subsidy scheme for the first best creates another distortion in order to counteract an existing one: consumers pay more than cost buying from the public sector; less, from the private sector. It is very likely that these new price–cost margins will create deadweight losses in other markets.

The most important reason for ruling out such taxes and subsidies is perhaps efficiency: it may be *optimal* for the public provider to set a price at or even *below* marginal cost. The most obvious example comes from the health care market. In many countries, a public provider supplies both insurance *and* health services. Due to nonverifiable health status information, Arrow (1963), Pauly (1968) and Zeckhauser (1970) have shown that second-best insurance takes the form of coinsurance, simultaneously shielding the consumers from the full medical expenses and preventing excessive medical uses.[5] Optimal social insurance requires the public provider to supply services to consumers below marginal costs.[6] Achieving the first best by the tax and subsidy scheme above exposes consumers to more risks. As I show in the next section, rationing solves the cost efficiency problem *without* imposing more financial incentives on the consumers.

In other markets such as postal and education, extensive subsidies are also common. Presumably, this is because access of the postal service and education are regarded as merit goods. Charging high prices by a public provider will deprive poor consumers of vital goods and services. So in many markets, the public provider sets prices below marginal costs. In any case, for my model, setting the price at the public provider to its marginal cost is a natural benchmark.

[5] See also Ma and Riordan (2002).

[6] I assume that the public provider sets its price at marginal cost; allowing it to set the price below marginal cost will only strengthen the results.

4. Efficient rationing and cost incentives

In this section, I study rationing as a way to alleviate the inefficient cost investment in the private sector. Rationing limits consumers' access to the supply by the public provider. First, I provide a benchmark in which the public provider does not supply at all. As I will show next, this gives a lower bound on what the public provider should supply.

To begin, I assume that each consumer's utility is 0 if he does not obtain the good. Suppose that the price at the private sector is p. If the public supply is 0, the private sector's demand is given by $(1-x)=q-p$, and the profit is $(q-p)[p-c(e)]-\gamma(e)$. When the public provider is inactive, in the contestable market equilibrium, the active firm in the private sector chooses p and e to maximize its profit subject to the zero profit requirement. The following characterizes the equilibrium:

$$(q-p)[p-c(e)]-\gamma(e)=0 \quad \text{and} \quad -(q-p)\,c'(e)=\gamma'(e) \tag{11}$$

The first is simply the zero-profit condition; the second is the first-order condition for the effort level given the demand $q-p$. Let the equilibrium be (p^m, e^m). It is straightforward to verify that $e^m > e^*$ and $p^m < p^*$: the equilibrium effort is higher when the public provider is not active, while the price is lower.[7] The return to effort investment depends on the size of the market (see Eq. (4)). When the public provider is inactive, the private sector has a bigger market, and the equilibrium cost effort increases. I assume that $q-p^m<1$ so that the private sector does not serve all consumers even when the public does not supply any.

I now consider an explicit capacity constraint. By setting a capacity limit $\hat{x}$, the public provider commits to serve only a subset of consumers who would like to obtain the goods. A consumer at x is said to be *rationed* if he is unable to get the good from the public provider, but has a higher utility if he consumes the public provider's supply than the private firm's at the price $p: 1-x>q-p-(1-x)$. In this section, the distribution of the capacity $\hat{x}$ to consumers is assumed to be *monotonic*: if a consumer at x obtains the good from the public provider, then those at $y<x$ will also obtain the good. Monotonicity corresponds to *efficient rationing* (see Kreps and Scheinkman, 1983; Davidson and Deneckere, 1986): a consumer at y consuming the public provider's good will net a higher utility than a consumer at x when $y<x$. In other words, the rationing scheme distributes the capacity to subscribers who value the goods most. Under efficient rationing, given capacity $\hat{x}$, the public provider can supply only those consumers located between 0 and $\hat{x}$. Monotonic rationing can be implemented in practice if the location parameter is related to income (see also the discussion in Sections 2 and 6). Then this rationing scheme will simply commit to supply consumers whose incomes are lower than a certain threshold.

[7] Consider the following two equations: $\Theta(q-p)[p-c(e)]-\gamma(e)=0$ and $-\Theta(q-p)\,c'(e)=\gamma'(e)$. If $\Theta=1$, then these equations correspond to (11); $\Theta=1/2$, (9) and (10). These two equations define e and p as functions of Θ. The Implicit Function Theorem and total differentiation verify that e is increasing in Θ, and that p is decreasing in Θ. So $e^m > e^*$ and $p^m < p^*$. The derivation makes use of the fact that $p-c(e)<q-p$. This inequality is due to the following argument. If the private firm is able to pick its price to maximize profit, then $p-c(e)=q-p$; it achieves a strictly positive profit, and p is strictly above average cost. Under contestability, the equilibrium price is equal to average cost, hence the inequality $p-c(e)<q-p$ follows.

Recall that when the public sector is inactive, the private sector's equilibrium market size is $q-p^m$; when the public sector does not impose a capacity limit, the private sector's equilibrium market size is $q-p^*$. It is only necessary to consider $\hat{x}$ between $1-(q-p^m)$ and $1-(q-p^*)$. If $\hat{x}<1-(q-p^m)$, the two providers do not interact: the private provider in equilibrium will not supply those not served by the public provider. If $\hat{x}>1-(q-p^*)$, the capacity limit is not binding: some consumers at $x<\hat{x}$ will purchase from the private firm.[8] Given that $1-(q-p^m)\le\hat{x}\le 1-(q-p^*)$, the public provider's capacity constraint is binding, so that the private sector's market size must be $1-\hat{x}$. The contestable market equilibrium in the private sector is given by:

$$-(1-\hat{x})\,c'(e)-\gamma'(e)=0 \tag{12}$$

$$(1-\hat{x})(p-c(e))-\gamma(e)=0 \tag{13}$$

The aggregate consumer utility is:

$$\int_0^{\hat{x}}(1-z)\mathrm{d}z+\int_{\hat{x}}^1(q-p-(1-z))\mathrm{d}z \tag{14}$$

The optimal rationing scheme is the choice of $\hat{x}$ (together with e and p) that maximizes (14) subject to (12) and (13). The first-order conditions with respect to $\hat{x}$, e and p are:

$$(1-\hat{x})-[q-p-(1-\hat{x})]+\alpha_1c'(e)-\alpha_2[p-c(e)]=0 \tag{15}$$

$$\alpha_1[-(1-\hat{x})\,c''(e)-\gamma''(e)]+\alpha_2[-(1-\hat{x})\,c'(e)-\gamma'(e)]=0 \tag{16}$$

$$-(1-\hat{x})+\alpha_2(1-\hat{x})=0 \tag{17}$$

where α_1 and α_2 are the multipliers of (12) and (13), respectively. The second term in (16) is just the constraint (12); it follows that $\alpha_1=0$. From (17), $\alpha_2=1$. Substituting these results to (15) yields:

$$(1-\hat{x})=\frac{q-p}{2}+\frac{p-c(e)}{2} \tag{18}$$

which can be rewritten as:

$$2(1-\hat{x})=q-p+p-c(e)$$

In other words:

$$1-\hat{x}>q-p-(1-\hat{x}) \tag{19}$$

[8] This also says that the public provider can always implement the unconstrained contestable market equilibrium; welfare under efficient rationing must not be lower.

The left-hand side of (19) is the utility of the consumer at $\hat{x}$ when he receives the good from the public provider; the right-hand side, from the private sector. For those consumers located sufficiently close to $\hat{x}$ but farther away from the public provider (that is, those at $\hat{x}+\epsilon$ for $\epsilon > 0$ and sufficiently small), they would obtain higher utilities if they were able to secure the goods from the public provider: the optimal capacity constraint leads to consumer rationing.

The equilibrium effort level under rationing is first best: the optimal capacity and monotonic rationing implements the efficient effort e^{fb}. The constraint (13) can be used to eliminate p in the objective function (14), which then becomes identical to (1). The constraint (12) has a zero multiplier and is redundant. So the equilibrium is given by the unconstrained maximization of (1). Eq. (18) is identical to (2) in Proposition 1.

I summarize these results:

Proposition 4. *When the public provider can impose a capacity constraint $\hat{x}$ and allocate its supply to consumers according to the efficient rationing scheme, it will optimally ration consumers. The public provider's market size under rationing becomes strictly less: $\hat{x}<1-(q-p^*)/2$, and the private sector's equilibrium effort is first best. The allocation in Proposition 1 is implemented by the equilibrium capacity and efficient rationing.*

The proposition captures the following intuition. Suppose the public sector sets a capacity constraint just equal to $1-(q-p^*)$, then rationing does not occur, and the equilibrium will be described by Proposition 3, where the private firm's market size is too small. First, given the price (equal to average cost) at the private sector, too few consumers are using the private firm, compared to the first best where the price at the private firm is at marginal cost. Second, although the private firm fully internalizes the social cost and benefit of effort, its lower market size reduces its cost incentive. By reducing the capacity below $1-(q-p^*)$, the public provider forces some consumers to buy from the private sector, improving *both* the effort as well as the distribution of consumers across the two sectors. This reduction of capacity will reach its optimal value when the first best is attained.

5. Random rationing and cost incentives

The previous section shows that by limiting supply, the public provide can motivate the first-best effort from the private sector. The key to the above result stems from releasing more consumers to the private sector. In this section, I investigate the robustness of the main result by considering another form of rationing. Monotonic rationing achieves a direct allocation of consumers. An alternative and common form of rationing is by random allocation. Under random rationing, each consumer who seeks service from the public provider will obtain it with some probability. Unlike efficient rationing, random rationing does not allocate goods according to consumer total benefits.

I now define random rationing formally. Let θ, $0\leq\theta\leq1$, be the probability that a consumer seeking supply at the public provider will be given the good. Random rationing with probability θ can be implemented by a suitably chosen capacity to be defined later. Under random rationing, consumers participate in a lottery: getting the good for free with probability θ, and not getting it with probability $1-\theta$. A consumer has to incur the transport or mismatch cost to find out whether he can obtain the good. A risk-neutral consumer at x believes that he will obtain an expected utility $\theta - x$ applying at the public provider. Suppose the price at the private sector is p. The location of the consumer who is just indifferent between obtaining services from the two providers is given by:

$$\theta - x = q - p - (1-x) \tag{20}$$

The public sector's demand is:

$$x = \frac{1}{2} + \frac{\theta - q + p}{2} \tag{21}$$

To implement random rationing, for a given θ, the public provider simply sets a capacity limit $\hat{x}$ such that $\hat{x}/x = \theta$, where x is given by (21). The choice of θ therefore determines the public provider's capacity requirement. When $\theta = 1$, $\hat{x}$ becomes x.

For the planning benchmark, the social welfare can be written as:

$$\int_0^x (\theta - z)\mathrm{d}z + \int_x^1 (q - c(e) - (1-z))\mathrm{d}z - \gamma(e) \tag{22}$$

similar to (1) above. Obviously, this new welfare function always has a positive first-order derivative with respect to θ: social welfare is decreasing in the public provider's rationing intensity. Will motivating a higher private sector effort lead to random rationing ($\theta < 1$)?

The active firm in the private sector has a profit function $(1-x)[p - c(e)] - \gamma(e)$. Maximizing this profit function with respect to e yields:

$$-(1-x)c'(e) - \gamma'(e) = 0 \tag{23}$$

Due to contestability, the equilibrium price must equal average cost:

$$(1-x)[p - c(e)] - \gamma(e) = 0 \tag{24}$$

The equilibrium in the private sector is fully characterized by (23) and (24). Anticipating the equilibrium in the private sector, the public provider chooses x, e, p and $\theta \leq 1$ to maximize the aggregate consumer utility function:

$$\int_0^x (\theta - z)\mathrm{d}z + \int_x^1 (q - p - (1-z))\mathrm{d}z \tag{25}$$

subject to (21), (23), and (24).

Random rationing cannot perform as well as efficient rationing. Formally, the equilibrium described in Section 4 and Proposition 4 is the result of the maximization of (14) subject to (12) and (13). Now if the term $(1-z)$ in the first integral of (14) is replaced by $(\theta - z)$, where $0 \leq \theta \leq 1$, (14) becomes (25).[9] So random rationing involves a

[9] If this modified objective function is maximized subject to (12) and (13), the optimal value of θ is 1, so that the replacement of the term involves no loss.

new and binding constraint (21), compared to efficient rationing; random rationing must yield a lower welfare level.

More surprisingly, random rationing may not be optimal; that is, in equilibrium θ may be set equal to 1. The following example illustrates this possibility. Let $c(e) = 1 - e$ and $\gamma(e) = e^2/2$. For a given θ, the following describes the equilibrium in the private sector:

$$p = 1 - \frac{q-\theta}{3}$$

$$e = \frac{2}{3}(q-\theta)$$

$$x = 1 - \frac{2}{3}(q-\theta)$$

Substituting the above into the objective function (25), one can obtain the first-order derivative with respect to θ:

$$1 - \frac{8}{9}(q-\theta) \tag{26}$$

So if q is sufficiently close to 1, the expression in (26) is always positive for any value of θ between 0 and 1. The equilibrium is characterized by a corner solution at $\theta = 1$: rationing is not used by the public provider. The following intuition is captured by the example. Random rationing itself does not avoid the problem of unrestrained contestable equilibrium: consumers pick providers according to the private firm's price, which is above marginal cost. When q is near 1, the product at the private sector does not have very superior quality. Then it is relatively more important that the public provider supplies consumers. Rationing consumers to motivate cost incentives benefits too few consumers, and leads to a deadweight loss since some consumers may not consume the good. In sum, the tradeoff can be completely against rationing.

I now characterize a sufficient condition under which random rationing will be an equilibrium. The sufficient condition is likely satisfied when the public sector's market size under unconstrained contestable equilibrium is small. In this case, the return of cost effort is large; random rationing will be used to move consumers to the private sector. At $\theta = 1$ the equilibrium is simply the contestable market equilibrium. I use the constraints (21), (23), and (24) to substitute for x, e, and p in the objective function (25), expressing it solely in terms of θ. Then, I evaluate its derivative at $\theta = 1$; when this is negative, setting θ at one will not be optimal—random rationing must be part of the equilibrium. The condition is formally stated in the following, whose proof is in Appendix A.

Proposition 5. *Consider the contestable market equilibrium in Proposition 2, (p^*,e^*), and let the corresponding contestable market equilibrium size for the public provider be x^*. Then the public provider randomly rations consumers by picking θ<1 if:*

$$\frac{x^*(q-p^*) - [p - c(e^*)]}{(q-p^*) - [p^* - c(e^*)]} < 0$$

Random rationing can also be interpreted as a quality choice: the variable θ can be regarded as product quality. To discourage consumers from using the public provider, a lower product quality can be offered. Facing a less desirable product, more consumers may choose to purchase from the private sector. In fact, this interpretation can be related to rationing by waiting lists. In many countries, consumers who demand a good supplied by a public firm (such as elective surgeries at a public hospital) has to sign up on the waiting list. As Lindsay and Feigenbaum (1984) have pointed out, under waiting list rationing the equilibrating force is not the dissipation of rent or any other wasteful activities consumers undertake to secure the goods. Instead, because of waiting, the quality of the goods decays over time. The length of the list may be positively associated with quality deterioration, and consumers will decide whether to sign up for the list or seek alternative, private supply depending on the size of the queue. The random rationing extension in this section corresponds to quality decay in the waiting list approach.[10] My result suggests that waiting list rationing may not always improve cost incentives, and it is less effective than efficient rationing. According to this interpretation, a waiting list reduces the public provider's product quality, but still allows consumers to make their decisions between obtaining the good from the public provider (or joining the list) and buying from the private sector based on the product quality and the price at the private sector. Nevertheless, it fails to address the discrepancy between marginal and average costs due to increasing returns.

6. Quality and cost incentives

In this section, I study a simple extension by allowing firms in the private sector to invest in quality enhancement of their product. The extension is heuristic; it does not use the most general model, but does elucidates the robustness of the basic cost incentives of rationing. I now let the product quality, q, be a choice variable. If a firm in the private sector picks product quality q, then it incurs an additional marginal production cost $d(q)$, where the function d is strictly increasing and convex. The technology of quality production does not alter the increasing returns structure, which is due to the effort cost. Furthermore, I have let the marginal cost be separable in quality and effort.

Given the new technological specification, the social welfare function (1) can be rewritten as:

$$\int_0^x (1-z)\mathrm{d}z + \int_x^1 [q - c(e) - \mathrm{d}q - (1-z)]\mathrm{d}z - \gamma(e) \tag{27}$$

which again is assumed concave. The first best is now the choice of the allocation of consumers across the two sectors, x, cost-reduction effort e, and quality q that

[10] The model in this paper uses a static approach while the waiting list model is dynamic, consumers having to consider the expected utility of joining the queue given some assumption about the queue's evolution over time. So the correspondence refers to the idea that waiting list rationing is effectively reducing product quality.

maximize (27). The characterization of the first-best effort and quality, e^{fb} and q^{fb}, is now given by:

$$-\left[\frac{q^{fb} - c(e^{fb}) - d(q^{fb})}{2}\right] c'(e^{fb}) - \gamma'(e^{fb}) = 0 \tag{28}$$

$$1 - d'(q^{fb}) = 0 \tag{29}$$

Quality is like a public good, benefiting all consumers purchasing from the private sector. The social benefit of quality q is $(1-x)q$, while the social cost is $(1-x)\,d(q)$. The first-best quality level equates the marginal social benefit $1-x$ to the marginal cost of quality $d'(q)(1-x)$.

I now study the interaction between the private and public sectors. First, I extend the notion of contestable market equilibrium when firms in the private sector can choose product qualities. Suppose that the public provider offers its products with an unlimited capacity and at zero cost to consumers. If firms in the private sector sell their goods at quality q and price p, their demand is again given by (5). The profit function is $vq - p/2[p - c(e) - d(q)] - \gamma(e)$. A contestable market equilibrium consists of a price, an effort level, and a product quality satisfying the following:

$$e = \arg\max_{e'} \frac{q-p}{2}[p - c(e') - d(q)] - \gamma(e') \tag{30}$$

$$q = \arg\max_{q'} \frac{q' - p}{2}[p - c(e) - dq'] - \gamma(e) \tag{31}$$

$$\frac{q-p}{2}[p - c(e) - d(q)] - \gamma(e) = 0 \tag{32}$$

The active firm in the private sector picks effort and quality to maximize profit but contestability forces an active firm to price at average cost. The characterization of the contestable market equilibrium is in the following proposition, whose proof is in Appendix A.

Proposition 6. *The contestable market equilibrium results in cost effort below the first best, but quality at first best. The equilibrium size of the private sector is smaller than the first best.*

The proposition reports the same kind of inefficiency in cost-reduction effort, but the product quality is efficiently provided by the private sector. The efficient quality result is due to the linear demand function as well as the technology for quality enhancement. As Spence (1975) has pointed out, a firm will supply the socially efficient quality level relative to the size of its market whenever consumers' marginal and average valuations are identical, which is true for demand functions linear in price and quality. When a higher product quality results in only a higher marginal production cost, the socially efficient quality level is independent of the market size. These two factors together imply that a profit-maximizing firm will choose the socially efficient quality.

My results in previous sections extend straightforwardly when quality in the private sector is endogenous. In the equilibrium described by Proposition 6, average-cost pricing in the private sector results in too low a cost effort because the private sector serves too few consumers. To implement the first best, the public provider may impose a capacity limit equal to the first best (the one that maximizes (27)), and allocates the capacity to consumers according to the efficient rationing rule. Now the private sector has enough market size for the efficient cost effort, while its incentive to provide efficient quality remains the same.

My assumption that higher quality requires only a higher marginal cost makes the decisions on cost effort and quality separable. For quality enhancement that requires higher fixed costs, the private sector market size will affect both cost and quality investments. It is straightforward to show that a contestable private market never leads to the first best. Determining the market size for the private sector, rationing will be used to improve both quality and cost incentives, but it is less clear which direction equilibrium cost and quality distortions will take.

7. Concluding remarks

I have used a standard product differentiation model to examine the strategic use of rationing for motivating private firms' cost efforts. The intuition I have obtained does not depend on the specific Hotelling characterization of the market. For comparison, consider a product differentiation model of the Shaked–Sutton class (Shaked and Sutton, 1982). Let v, a uniformly distributed random variable with unit density on $[\underline{v}, \overline{v}]$, denote consumers' valuations of quality. Then a consumer derives a utility v from consuming the product from the public provider, and $vq - p$ from the private firm if p is the price at the private firm.[11] Without rationing, those consumers with valuations below $p/(q-1)$ will choose the public provider. The demand function facing the private firm is $\overline{v} - [p/(q-1)]$. Under this demand structure, the monotonic rationing rule in Section 4 will specify that if a consumer with valuation $\tilde{v}$ is allocated a good by the public provider, consumers with valuations $v < \tilde{v}$ will also be given the good. The main results of the paper go through directly. An income or wealth interpretation for the Shaked–Sutton demand specifications is standard: consumers having lower incomes or wealth have lower valuations. Under monotonic rationing, the public provider intends to supply the goods to them.

Rationing perhaps figures most prominently in the health care sector. The model can be fully applied to the health care industry when risk aversion is included in the analysis. A rationing scheme must then determine jointly efficient risk sharing and cost incentives. Although risk aversion will complicate the notation and the analysis, it seems that the basic

[11] I use a linear utility function for illustration; the Shaked–Sutton formulation uses a more general preference specification.

intuition should remain unchanged. Under contestable market in the private sector with increasing returns, cost incentives will be suboptimal. Rationing remedies the suboptimal market size for the private sector, and promotes cost incentives. Whether allocating more consumers to the private sector will expose consumers to more risk requires further analysis.

As I have mentioned earlier, firms in the private sector are assumed to be identical and the market there is competitive. A monopolistic treatment of the private sector will imply an equilibrium price above average cost; therefore, the equilibrium deviates more from marginal-cost pricing. I have isolated the effect due to returns to scale on cost incentives by eliminating monopolistic competition. This saves notation but the general intuition remains unaffected by the assumption. What can possibly complicate the analysis is the price effect under monopolistic competition when more consumers are seeking services in the private sector. It is unclear if firms will actually compete more or less rigorously when their total market size increases. Further investigation may well turn out to be interesting.

I have not considered distributional issue in this paper. Rationing often is used by a public provider to achieve a more equitable distribution by ensuring that poor consumers have access to a vital good or service. My results here point out that at the margin, the extent of rationing may influence the efficiency of private provision; they do not question rationing as an instrument to achieve a more desirable distribution. I have compared the effectiveness of efficient rationing and random rationing in promoting cost efficiency in the private sector. Each of these schemes may have implementation costs, but I have not considered them here. Any rationing scheme must rely on certain verifiable information: in my model efficient rationing makes use of consumers' characteristic such as income or wealth, while random rationing requires a dissemination of final allocation information to consumers. There is no reason to expect that the operation of one rationing scheme must be more or less costly than another in all situations. In any case, incorporating the operating cost of a rationing scheme does not appear to raise a conceptually new problem.

My purpose in this paper is not to spell out a general theory of rationing. Nor do I deny remedial or incentive powers of taxes and subsidies. The point here is to demonstrate that rationing—allocating quantities via nonprice mechanisms—have incentive consequences. The fact that monotonic rationing can mimic the incentive power of a balanced-budget tax-subsidy scheme is itself remarkable. Furthermore, these incentive effects may depend interestingly on the actual rationing schemes that allocate the limited supply of goods to consumers. While many economists may feel pessimistic about rationing, the theory here demonstrates that such pessimism is unwarranted. Incentive issues of rationing are important and further research may enhance our understanding of their power and limitation, as well as policy implications.

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Appendix A

Proof of Proposition 3
Consider Eq. (9), the first-order condition for the equilibrium effort level in the private sector. Rewrite it as:

$$-\left\{\frac{q-c(e^*)-[p^*-c(e^*)]}{2}\right\}c'(e^*)-\gamma'(e^*)=0$$

or

$$-\left\{\frac{q-c(e^*)}{2}\right\}c'(e)-\gamma'(e^*)+\left\{\frac{p^*-c(e^*)}{2}\right\}c'(e^*)=0 \tag{A.1}$$

Suppose that $e^*\geq e^{fb}$, contrary to the statement of the proposition. By the concavity of (1) and the definition of e^{fb} (see (2) and (3)), if $e^*\geq e^{fb}$, then $-[q-c(e^*)]\,c'(e^*)/2-\gamma'(e^*)\leq 0$. This means that the last term of (A.1) must be positive. Because by assumption $c'<0$, so $p^*\leq c(e^*)$, which contradicts (10). Therefore, $e^*<e^{fb}$.

The equilibrium market size is $(q-p^*)/2$. Because $p^*>c(e^*)$, we have

$$\frac{q-p^*}{2}<\frac{q-c(e^*)}{2}<\frac{q-c(e^{fb})}{2}$$

The second part of the proposition follows. Q.E.D.

Proof of Proposition 5
Consider the Lagrangian of the constrained maximization of (25) subject to (21), (23) and (24). The first-order conditions with respect to e, p and x are:

$$-[(1-x)\,c''(e)+\gamma''(e)]\,\lambda_2-[(1-x)\,c'(e)+\gamma'(e)]\,\lambda_3=0 \tag{A.2}$$

$$-(1-x)-\frac{\lambda_1}{2}+(1-x)\,\lambda_3=0 \tag{A.3}$$

$$(\theta-x)-[q-p-(1-x)]+\lambda_1+c'(e)\,\lambda_2-[p-c(e)]\,\lambda_3=0 \tag{A.4}$$

where λ_1, λ_2 and λ_3 are, respectively, the multipliers of (21), (23) and (24). From (34) and (23), $\lambda_2=0$: the constraint (23) can be ignored.

Combining (A.4) and (21) yields:

$$\lambda_3=\frac{\lambda_1}{p-c(e)} \tag{A.5}$$

Simplifying (A.3), one obtains:

$$\lambda_1=-2(1-x)(1-\lambda_3). \tag{A.6}$$

Substituting this into (A.5) and simplifying:

$$\lambda_3 = \frac{2(1-x)}{2(1-x) - [p - c(e)]}$$

From these values of λ_1 and λ_3, I obtain the first-order derivative of (22) with respect to θ:

$$\frac{2x(1-x) - [p - c(e)]}{2(1-x) - [p - c(e)]} \tag{A.7}$$

So now consider $\theta = 1$, then random rationing is not used, and the equilibrium will be described by Proposition 2. If (A.7) is negative at $\theta = 1$, the equilibrium value of θ must be less than 1. Using (5), I obtain the condition in the Proposition. Q.E.D.

Proof of Proposition 6

Let e, q, p, and $1-x$ be the contestable equilibrium effort, quality, price, and the private sector market size. It is more convenient to replace p in the profit function by x. Using (5), I rewrite the profit function as $(1-x)[q - 2(1-x) - c(e) - d(q)] - \gamma(e)$. The first-order conditions with respect to e and q are:

$$-(1-x)c'(e) - \gamma'(e) = 0$$

$$1 - d'(q) = 0$$

From the second first-order condition, the contestable market equilibrium quality is first best. To show that the equilibrium effort is too low, I write the first-order condition with respect to e as:

$$-\left[\frac{q - c(e) - d(q)}{2} - \frac{p - c(e) - d(q)}{2}\right] c'(e) - \gamma'(e) = 0$$

Because $p > c(e) + d(q)$, the last equation implies the inequality:

$$-\left[\frac{q - c(e) - d(q)}{2}\right] c'\ (e) - \gamma'\ (e) > 0$$

From (28) and the fact that q is first best, the equilibrium effort must be lower than the first best. Finally, because $p > c(e) + d(q)$ and $c(e) > c(e^{fb})$, the equilibrium market size of the private sector must also be smaller than the first best. Q.E.D.

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