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**DEREGULATING TAXI SERVICES: A WORD OF CAUTION**

by

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# Deregulating taxi services: a word of caution

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## Abstract

This paper studies pricing and capacity decisions on markets for phone-ordered taxicabs. Taxi firms first choose capacities and then compete in prices. As firm demand increases so does waiting time. This dampens competition and makes prices too high from the social point of view. Efficiency improves if firms choose large capacities in the first stage. In a two firm setting, equilibrium capacities are shown to be larger if both firms maximize profits than if they maximize profits per cab. Hence, if fixed costs for entrant cabs are small, the market is more efficient in the former case. Since entry on the cab level improves efficiency the regulator might want to allow firms to set hook-up fees but require them to accept new entrant cabs. If costs are observable the fees could also be subject to regulation.

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# 1. Introduction

This paper studies the performance of a market for phone-ordered taxi cabs which is subject to negative waiting time externalities. Using the Bertrand oligopoly framework established in Häckner and Nyberg (1992) we examines the role of firm types, private vs cooperative, in determining the market outcomes.

In most countries the taxicab industry is subject to various types of regulation such as entry restrictions and price controls. A common rationale for regulating the industry has been to make transportation available at times when demand is low and in areas where population is dispersed. In return for agreeing to serve relatively thin markets a firm could be granted a monopoly position. Another alleged reason for regulating the market is that a policy maker can maintain a price level that is "reasonable" in the eyes of consumers while producers are ensured a "reasonable" profit level by means of entry restrictions. Critics of regulation would argue that such arguments are thinly veiled excuses for catering to interest groups.[2]

The poor performance of regulated industries in general initiated a wave of deregulation during the 1980s. Whether a deregulation of a taxi market will improve its performance depends on many factors. One of the most important is whether there are inherent market failures that will give rise to inefficiencies in the absence of regulation.[3] Essentially two types of distortions have been discussed in the literature, one arising from imperfect information about prices and the other caused by negative externalities in consumption of taxi-services. The former avenue of research, drawing on search theory, is probably best suited for analyzing the market for street hailed cabs where price information is more likely to be scarce.[4] In this paper we focus on markets for telephone ordered

[2]When deciding on the appropriate number of licenses, regulators in Sweden saw fit to seek guidance from incumbent taxi firms, since they would be best informed about demand conditions. Not surprisingly this resulted in insufficient capacity and long waiting times, not unlike a monopoly situation.

[3]Some evidence of excessive prices can be found in Teal and Berglund (1987). They compare the effects of deregulation in six US cities and find that rates increased after deregulation. Entry was substantial on the cab level, but few radio dispatch services were established. Furthermore, taxicab productivity declined resulting in lower earnings for taxi drivers.

[4]Using search theoretical arguments, Douglas (1972) and Schreiber (1975) claim that prices would be excessively high on an unregulated market. The reason being that unilateral price increases are relatively profitable if price information is scarce and search costs high. Williams (1980a), (1980b) and Coffman (1977) criticize Schreiber's analysis noting that it is confined to the market for cruising cabs while 70-80% of the US taxi demand consist of telephone ordered trips for which price comparisons are relatively easy. Furthermore, most taxi firms have large fleets making price advertizing worthwhile. Finally, on the cruising cab market, the presence of cabstands facilitates

taxicabs, where price information is easier to come by but where waiting time presumably is an important determinant of product quality.

The externality argument was first brought up by Orr (1969)[5] who noticed that demand is likely to depend not just on prices but also on waiting time. Waiting time, in turn, depends on capacity as well as on the equilibrium demand for taxi services. Hence, there is a negative externality in the sense that one consumer's demand will increase waiting time for all other consumers making the service less valuable to them. In a perfectly competitive market this leads to an over-consumption of taxi services, or in other words too low prices.

Although several authors have stressed the interdependence between demand, price and capacity, the economic implications have not been thoroughly analyzed. Prices have been assumed to be competitive, monopolistic [Foerster and Gilbert (1979)] or exogenously given by regulation [De Vany (1975) and Schroeter (1983)]. In the absence of regulation it seems reasonable to assume that prices are set by the Radio Dispatch Services (RDSs), rather than by individual cab owners. [Douglas (1972) and Williams (1980b)] The analysis requires an explicit oligopolistic framework since in setting prices the firms take into account the pricing decisions of their competitors as well as the effects of the waiting time externality. The latter circumstance makes unilateral price cuts less attractive since, for a given capacity, increased demand means longer waiting time and thus a lower willingness to pay.[6] Ceteris paribus, the externality may in fact help firms sustain a higher profit level than would otherwise have been possible. This, in turn, suggests that there might be incentives to cut back on capacity in order to increase waiting time.

The paper is organized as follows. The basic model is presented in section 2 and some results concerning price setting behavior and social welfare are derived. For the sake of expositional clarity the analysis is confined to a duopoly. All results in section 2 can however be generalized to the n firm case. In section 3 the model is extended to allow for entry. Finally, some concluding remarks are made in section 4.

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price comparisons, further reducing search costs.

[5]Assuming price-taking behavior, Orr characterized equilibria under various price- and entry regulations. Although he found it unlikely, he concluded that an increase in capacity might in fact stimulate demand to such extent that profits per cab increase.

[6]That such a mechanism may put an upward pressure on price has in fact been shown in a quite different context, namely in the theory of clubs [Scotchmer (1985)].

## 2. The model

Taxi firms, by which we mean radio dispatch services (RDSs), choose fares and decide on fees for drivers wishing to hook up to their service. Fares are assumed to be linear in the quantity of services consumed, q, and each driver can at most be hooked up to one RDS. The expected waiting time when ordering a taxi from a certain firm is assumed to depend on the demand facing that firm divided by the size of their taxi fleet. The fleets are initially assumed to be of equal size and are normalized to one.

Consumers value two things. First, their utility is assumed to be linearly increasing in the consumption of a composite good, y, representing "everything else". Second, consumer utility is assumed to increase, at a decreasing rate, in the amount of taxi services consumed, e.g. the number of (equally long) trips demanded, and decrease in waiting time. To make the welfare analysis tractable we specify a simple utility function with the above properties. Assuming a continuum of identical consumers, the utility of consumer j patronizing firm 1 is given by

$$U_{j,1} = y_{j,1} + (w - \alpha q_{j,1})q_{j,1} - \beta Q_1 q_{j,1} \tag{1}$$

where the last term reflects the disutility of waiting, caused by others' consumption, $Q_1$. The marginal utility of the first unit of good q consumed is denoted by w. The diminishing utility of additional consumption and waiting time is parameterized by $\alpha$ and ß respectively.[7] Waiting time is assumed to become more important the more taxi trips are consumed, thus affecting marginal utility and individual demand. Furthermore, consumers disregard the effect of their own demand on the price-setting behavior of firms. The demand for taxi services of a single consumer patronizing firm 1 is derived from the individual consumer's utility maximization subject to the budget constraint, $I = y_{j,1} + p_1 q_{j,i}$, where the price of the composite good is normalized to one. That is,

[7] $\beta$ can actually be given two structurally indistinguishable interpretations. The first, and most obvious, interpretation is that it reflects consumers' aversion toward spending time waiting. However, it may also be thought of as a technology parameter that relates capacity to waiting time.

$$q_{j,1} = \frac{w - p_1 - \beta Q_1}{2\alpha} \tag{2}$$

The aggregate demand of firm 1, normalizing the number of consumers to unity, is simply $Q_1 = q_{j,1}m$, where m is firm 1's market share. Consumers will choose to ride with the firm offering the best price - waiting time tradeoff. In equilibrium customers are indifferent between riding with different firms, i.e. in terms of their indirect utility functions, $V(p_1,Q_1,I) = V(p_2,Q_2,I)$. For our specific utility function this yields:

$$p_1 + \beta Q_1 = p_2 + \beta Q_2 \tag{3}$$

Solving for the market shares satisfying the above condition for given prices and letting $m_2=(1-m)$ be firm 2's market share we have

$$m = \frac{2\alpha(p_2 - p_1) + \beta(w - p_1)}{\beta(2w - p_1 - p_2)} \tag{4}$$

and thus the aggregate demand for firm 1's services is given by

$$Q_1 = \frac{2\alpha(p_2 - p_1) + \beta(w - p_1)}{\beta(4\alpha + \beta)} \tag{5}$$

Firm 2's demand is derived analogously. The marginal cost of producing taxi services is assumed to be constant and the profit of firm 1, given there are no fixed costs, is given by

$$\pi_1 = (p_1 - c_1)Q_1 \tag{6}$$

The best-response function for firm 1 is obtained by differentiating profits with respect to $p_1$.

$$\varphi_1(p_2) = \frac{1}{2}\left[c_1 + \frac{2\alpha p_2 + \beta w}{2\alpha + \beta}\right] \tag{7}$$

Thus, prices are strategic complements. Furthermore, the slope being less than one ensures a unique equilibrium. The symmetric case, where firms face equal marginal costs, c, not surprisingly yields a symmetric equilibrium with $p_1=p_2= p^*$, where

$$p^* = \frac{1}{2}\left[c + \frac{\alpha c + \beta w}{\alpha + \beta}\right] \qquad (8)$$

It is easy to see that the equilibrium price, p*, is increasing in $\beta$. If consumers are infinitely patient, $\beta = 0$, firms face true Bertrand competition and prices are driven down to marginal cost. If waiting time does matter firms will earn positive profits. In fact, as ß approaches infinity prices are close to the monopoly level, (c+w)/2. Equilibrium profits are however highest for intermediate values of ß. For low ßs, the market will be fairly competitive and for high ßs aggregate demand is greatly reduced by the impact of the negative externality.

In contrast to the standard Bertrand equilibrium, prices are above marginal cost despite price competition and homogeneous products in equilibrium, costs being equal.[8] [9] Moreover, while the socially efficient price on a market with negative externalities is higher than marginal cost it can be shown that the externality weakens competition to such an extent that the equilibrium price level is actually higher than optimal. Social welfare can thus be improved by means of a price-ceiling given by

$$p^{**} = \frac{1}{2}\left[c + \frac{2\alpha c + \beta w}{2\alpha + \beta}\right] \qquad (9)$$

where p** approaches marginal cost as ß approaches zero. This holds true for p* as well so if ß can be made arbitrarily small, efficiency losses will also become arbitrarily small. [Häckner and Nyberg (1992)] As will be discussed in section 3, an inflow of new cabs can be interpreted precisely as a reduction in ß.

## 3. Entry

The findings in section 2 suggest that price competition alone may not suffice to ensure efficient pricing on the market for taxi services. The results were however derived under the

[8]A similar result can be found in Scotchmer (1985).

[9]In fact, it suffices for a fraction of all consumers to have an aversion towards waiting time for all firms to profitably charge prices above marginal cost. It is fairly easy to construct examples of asymmetric equilibria assuming two consumer groups consisting of "businessmen" with a high willingness to pay for transportation but a large queue aversion and "ordinary people" with a low willingness to pay for transportation and a moderate queue aversion.

assumption of fixed capacity. Insofar regulated capacity is the real culprit, removing the institutional barriers to entry may go a long way in improving conditions.

The natural entry barriers on the cab level are likely to be very low. There is a reasonably efficient market for used cars and leasing may also be a viable option. The only element of sunk cost would appear to be the time and money spent in getting the taxi driving-license. Hence, high industry profits would soon attract new capacity thereby reducing waiting time. Prices would be driven towards marginal costs and industry profits dwindle but the social cost of negative consumption externalities would be negligible. This, however, suggests that RDSs have an incentive to try to restrict the inflow of new cabs.

Entry can of course take place on the RDS level as well. Establishing an RDS may, however, entail substantial fixed costs.[10] [11] First, office staff, marketing costs and equipment costs are more or less independent of scale. Furthermore, it is inconvenient for a consumer to memorize more than a few phone numbers to different taxi firms. There may also be returns to scale in that expected waiting time is likely to decrease in fleet size even if demand per cab is kept constant. This is due to the expected geographical distance between a (randomly located) customer and the nearest taxi being decreasing in the size of the (randomly located) taxi fleet. These effects, benefiting incumbents, may to some extent be approximated by increasing returns to scale in the operation of a service. Some empirical evidence in support of this can be found in Teal and Berglund (1987) who report that US deregulations typically have resulted in massive entry on the cab level while the market structure on the RDS level has been more or less unaffected.

Assuming that entry is most likely to occur on the cab level, we now analyze the effects of entry, keeping the number of RDSs fixed. This is done by introducing an initial stage in which RDSs decide on capacities taking into account the effect on equilibrium prices in the subsequent stage. Technically speaking, we solve for the subgame perfect equilibrium of a two-stage game. Fleet sizes, equilibrium prices and quantities are compared under two

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[10]The airline industry may serve as an interesting comparison. Airline business was widely held to be essentially contestable for much the same reasons put forward in the discussion about the taxi industry. The experience following the airline deregulation in the US was however somewhat disappointing in that factors like gate access and computerized booking systems tended to impede, or at least make entry less attractive [Levine (1987)]. There may be incumbency advantages for established radio dispatch companies that are in some respects parallel to that of the computerized booking systems.

[11]Although high fixed costs per se do not constitute entry barriers in a strict sense they do limit the number of firms that can coexist on the market without running a loss. If prices adjust instantaneously to new market conditions (in contrast to the contestable market framework where hit and run entry is feasible) then, even in the absence of sunk costs, firms may earn positive profits in equilibrium.

different assumptions regarding the organizational structure of the RDSs, denoted regimes I and II. These structures may be thought to reflect different regulatory regimes or market practices. For the sake of tractability the analysis is confined to a duopoly market and RDSs are assumed to be symmetric in terms of organizational structure.

Under regime I, RDSs are cooperatives controlled by the cab drivers. Only members are allowed to vote when deciding on capacities so new memberships are refused (and old ones terminated) if it benefits the majority of the members. Hence, RDSs choose fleet size to maximize per capita profits. In regime II RDSs are privately owned enterprises choosing connection fees to maximize firm profits.

Firm capacity is modelled by making ß firm specific letting, $\beta_i = b/f_i$, where $f_i$ denotes the fleet size of firm i and b reflects aversion towards waiting time. Replacing $\beta$ with $\beta_1$ and $\beta_2$ in expression (3) and proceeding as in section 2, the demand facing firm 1 becomes

$$Q_1 = \frac{f_1[2\alpha f_2(p_2-p_1)+b(w-p_1)]}{b[2\alpha(f_1+f_2)+b]} \tag{10}$$

Straightforward differentiation implies that the gross equilibrium profit of RDS 1 is

$$\pi_1 = \frac{bf_1[w-c]^2[\alpha(2f_1+f_2)+b][2\alpha^2 f_2(2f_1+f_2)+\alpha b(2f_1+3f_2)+b^2]}{4[3\alpha^2 f_1 f_2+2\alpha b(f_1+f_2)+b^2]^2[2\alpha(f_1+f_2)+b]} \tag{11}$$

Note that the waiting time facing firm 1's customers, $Q_1/f_1$, is decreasing and convex in $f_1$ at equilibrium prices, which is reasonable since the first unit of capacity is likely to reduce waiting time to a greater extent than the hundredth unit.

Let $K_c$ denote the fixed cost of an entrant cab and let $K_r$ denote the fixed cost of an RDS.[12] Then $\bar{K}(f_i)=K_c+K_r/f_i$ is the average fixed cost of a cab hooked up to an RDS with fleet size $f_i$.[13] The marginal cost of running a RDS is assumed to be zero.

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[12] $K_r$ could include wages, marketing costs and capital costs while $K_c$ could include leasing fees, and the driver's opportunity cost of working in the cab industry.

[13] The net RDS profit function in all regimes can be shown to be single peaked for positive fleet sizes. Using equation (11) they can be written on the form; $\pi_1(f_1) - f_1K_c - K_r = f_1[\pi_1/f_1 - K_c] - K_r$ where $\pi_1/f_1$ is decreasing in fleet size. It then follows that profits per cab are also single peaked.

### 3.1 The fleet size equilibria

When the RDSs maximize profits per cab, $\pi_I \equiv \pi_i/f_i - \bar{K}(f_i)$, with respect to fleet size, there is a clear incentive to keep the fleet small. A privately owned RDS maximizes total profits, i.e. connection fees times fleet size minus costs. The highest connection fee possible to extract is $Z = \pi_i/f_i - K_c$ which yields a per cab profit amounting to $\pi_i/f_i - \bar{K}(f_i)$ just as under regime I. Hence, firms maximize $\pi_{II} \equiv f_i\pi_I = f_i(\pi_i/f_i - \bar{K}(f_i))$ with respect to $f_i$. For a given size of the competitor's fleet the relation between $\pi_I$ and $\pi_{II}$ is illustrated in figure 1.[14]

*Lemma 1: Fleet sizes are strategic complements under regime I and strategic substitutes under regime II.*

*Proof:* Profit per cab, $\pi_I$, is at least quasiconcave in $f_i$ since $\pi_i/f_i$ and $\bar{K}(f_i)$ are both decreasing and strictly convex in $f_i$ and intersect twice. It is then obvious that $\pi_{II}$ has the same property. Strategic complementarity (substitutability) follows from applying the implicit function theorem to the first order condition noting that the cross derivative of $\pi_I$ ($\pi_{II}$) wrt fleet sizes is positive (negative). □

If firm 2 increases its capacity, firm 1 will lose some customers to firm 2, reducing $Q_1$ and hence waiting time. When demand is reduced, waiting time becomes less sensitive to changes in $f_1$ which also makes firm demand less sensitive. In turn, gross profits, $\pi_1$ and gross profits per cab, $\pi_1/f_1$, become more robust to changes in $f_1$. Under regime I, firm 1 can therefore increase its fleet size, spreading the fixed cost, $K_r$, over a larger number of cabs, incurring only a small loss in terms of $\pi_1/f_1$. Conversely, under regime 2, firm 1 can reduce its fixed cost payments, $f_1K_c + K_r$, by reducing its fleet size, without affecting $\pi_1$ very much.

FIGURE 1 ABOUT HERE

[14] In figure 1 maximal profits per cab is higher than maximal profits per RDS. This is simply due to the optimal fleet sizes being smaller than one which, in turn, follows from normalizing the total number of consumers to one.

*Proposition 1: Under both regimes, there exists a unique and symmetric equilibrium in fleet sizes.*[15]

*Proof:* The reaction-functions, $f_i(f_j)$, are identical. Under regime I they are concave and upward sloping (by strategic complementarity) and under regime II they are downward sloping (by strategic substitutability). □

*Proposition 2: (i) Under regime I, the equilibrium fleet size decreases in consumers' valuation of taxi services, w, and increases in marginal cost, c. (ii) Increases in w raise prices while the effect on quantity is ambiguous. Increased costs, c, have indeterminate effects on prices and quantities. (iii) Increased RDS fixed cost, $K_r$, increases $f_i$ given any $f_j$, resulting in lower prices and larger equilibrium quantities. The fixed cost per cab, $K_c$, does not affect fleet sizes.*
*Proof:* In appendix

As consumers' valuation of taxi services increases, (or marginal cost decreases), the firm will want to trade some of this off for a reduction in fleet size in order to increase per cab profits.

The direct effect of increases in w is to raise both prices and quantities. However, at the same time firms cut back on capacity, which increases prices and reduces quantities. Hence, only the effect on prices is clear. Similarly, when c increases, the direct effect is to raise prices and reduce quantities. At the same time, capacities increase which lowers prices and increases quantities so the net effect is unclear. Finally, when the fixed cost of an RDS, $K_r$, increases, there is a tendency to spread it among a greater number of members, which lowers prices and increases equilibrium quantities. A policy maker could therefore induce lower prices through imposing a lumpsum tax on RDSs which is a somewhat paradoxical result. Raising the fixed cost per cab, $K_c$, does not affect the maximization problem.

*Proposition 3: (i) Under regime II, if consumers are patient, i.e. for small b, the equilibrium fleet size decreases in consumers' valuation of taxi services, w, and increases in marginal cost, c. For large b the opposite is true. (ii) For small b, increases in w raise prices while*

[15] It should be noted that since equilibrium taxi fleets are symmetric under all regimes, the assumption of identical RDSs in section 2 can in fact be rationalized as a result.

*the effect on quantity is ambiguous. Increased costs, c, have indeterminate effects on prices and quantities. For large b, w has a positive effect on quantities while the effect on prices is ambiguous. Increases in marginal cost raise prices and reduce quantities. (iii) Increased per cab fixed costs, $K_c$, reduces $f_i$ given any $f_j$. This raises prices and reduces quantities. The RDS fixed cost, $K_r$, has no effect on capacities.*

*Proof:* In appendix

If consumers have a large aversion towards waiting, the willingness to pay for reductions in waiting time will increase to a great extent when w increases which makes it profitable to expand capacity. When consumers are patient, waiting time is not a major issue and increases in w are immediately traded off for reductions in capacity in order to reduce the fixed cost payments.

When b is small, price and quantity derivatives with respect to w and c are the same as in regime I and for the same reasons. Therefore assume b is large. The direct effect of increases in w is to raise both prices and quantities. However, at the same time firms increase capacity, which tend to reduce prices and increase quantities. Hence, the only clear effect is on quantities. When c increases, the direct effect is to raise prices and reduce quantities. At the same time, firms cut back on capacity which also tend to raise prices and reduce quantities so the effect is in this case unambiguous.

Finally, when the fixed cost of taxicabs, $K_c$, increases, firms naturally cut back on capacity which raises prices and reduces equilibrium quantities. Consequently, one way for a policy maker to induce lower prices is to subsidize the fixed cost of entrant cabs. Raising the fixed cost of an RDS, $K_r$, does not affect the maximization problem.

From a welfare perspective, it is interesting to compare the equilibrium fleet sizes. In figure 1, which is drawn for an arbitrary $f_j$, we can see that the equilibrium fleet size of regime II, $f_{II}$, is larger than that of regime I, $f_I$. Indeed, given any $f_j$ it will be optimal to choose a higher $f_i$ under regime II than under regime I. In terms of equilibrium prices and quantities, $p_I > p_{II}$ and $Q_I < Q_{II}$.

Of course one could also imagine a situation where a regime I firm competes with a regime II firm.[16] Assume that the market initially is in a regime I equilibrium. Then one firm, say firm 2, is reorganized as a regime II firm. Since the best response to a given $f_1$ is larger for a regime II firm than for a regime I firm its reaction function shifts out. Firm 1's reaction function is increasing in $f_2$ so both firms will have larger fleet sizes in the new equilibrium but firm 2 will have the largest one. Compared to a symmetric regime II equilibrium, firm 2 will have a larger fleet size in the hybrid equilibrium and firm 1 a smaller one. All drivers would of course prefer to belong to the cooperative firm but only a limited number of members are accepted.

### 3.2 Policy implications

The main conclusion from the last section is that market profits will be positive despite "free" entry of taxicabs. The reason is the endogenous entry barrier, in terms of high connection fees and exclusion, that is created by the RDSs.

If the fixed cost of entrant cabs, $K_c$, is low, it would be socially desirable to reduce entry barriers to a minimum since a large number of new cabs would drive ß towards zero, without causing society a great cost. Consumers' valuation of taxi services would increase and market prices be driven towards marginal cost. In other words, the market would become more and more similar to the standard Bertrand market with constant marginal cost pricing and approximately no externalities. Clearly, the market outcome will not be efficient in this case but regime II is relatively more efficient than regime I. If the industry could be costlessly reregulated one might therefore want to prevent the RDSs from refusing entrants to hook up. If costs are observable, the fees could also be subject to regulation.

However, if the fixed cost of entrant cabs is substantial, some entry barrier may be needed to prevent the positive price-cost margin from attracting too many cabs from the social point of view. More specifically, when a cab enters on the margin, the consumers' valuation of the price decrease and the waiting-time reduction may be smaller than the fixed cost. Regime I might then be relatively efficient since equilibrium fleet sizes are small.

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[16] The two major firms on the Stockholm taxicab market are organized in this manner.

## 4. Conclusions

The sunk cost of an entrant cab is likely to be small since cabs can be leased and there are well functioning second hand markets for taxicab equipment. Also the fixed cost is likely to be moderate, basically including a leasing fee and perhaps the opportunity cost of working in the industry. This makes a strong case for deregulation, but price competition alone does not ensure efficiency. Cooperatively run RDSs will, however, be relatively less efficient as compared to privately owned RDSs. Since firms will not voluntarily choose large capacities, one could even argue for a regulation of the RDSs guaranteeing free access and, if costs are observable, low connection fees. Thus, a case could be made for stimulating competition between independent taxi firms, but to separate the production of the services from the ordering system which could be run as a regulated monopoly or be publicly operated. Then, of course, the costs of regulation would have to be taken account of explicitly. Specifically, information asymmetries may make it difficult to induce cost efficiency.

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# Appendix

$$p_1^* = \frac{6\alpha^2 c f_1 f_2 + \alpha b(c(2f_1+3f_2)+w(2f_1+f_2))+b^2(c+w)}{2(3\alpha^2 f_1 f_2+2\alpha b(f_1+f_2)+b^2)} \tag{A1}$$

$$Q_1^* = \frac{f_1(w-c)(2\alpha^2 f_2(2f_1+f_2)+\alpha b(2f_1+3f_2)+b^2)}{2(3\alpha^2 f_1 f_2+2\alpha b(f_1+f_2)+b^2)(2\alpha(f_1+f_2)+b)} \tag{A2}$$

**Proof of Proposition 2:**

(i) Follows from applying the implicit function theorem on the first order condition, noting that

$$\frac{\partial^2 \pi_I}{\partial f_i \partial w} < 0, \; \frac{\partial^2 \pi_I}{\partial f_i \partial c} > 0$$

(ii) Differentiating equilibrium price, equation (A1), wrt w yields

$$\frac{dp^*}{dw} = \frac{\partial p}{\partial f_1}\frac{\partial f_1}{\partial w} + \frac{\partial p}{\partial f_2}\frac{\partial f_2}{\partial w} + \frac{\partial p}{\partial w}$$

where fleet sizes affect price negatively. As w has a negative effect on fleet sizes and the direct effect of w is to increase prices, the total effect must be positive.

Differentiating equilibrium price, equation (A1), wrt c yields

$$\frac{dp^*}{dc} = \frac{\partial p}{\partial f_1}\frac{\partial f_1}{\partial c} + \frac{\partial p}{\partial f_2}\frac{\partial f_2}{\partial c} + \frac{\partial p}{\partial c}$$

where fleet sizes affect price negatively. As c has a positive effect on fleet sizes and the direct effect of c is to increase prices, the total effect is indeterminate.

Differentiating equilibrium quantity, equation (A2), wrt w yields

$$\frac{dQ^*}{dw} = \frac{\partial Q}{\partial f_1}\frac{\partial f_1}{\partial w} + \frac{\partial Q}{\partial f_2}\frac{\partial f_2}{\partial w} + \frac{\partial Q}{\partial w}$$

where fleet sizes affect quantity positively. As w has a negative effect on fleet sizes and the direct effect of w is to increase prices, the total effect is indeterminate.

Differentiating equilibrium quantity, equation (A2), wrt c yields
where fleet sizes affect quantity positively. As c has a positive effect on fleet sizes and the direct effect of c is to reduce quantities, the total effect is indeterminate.

$$\frac{dQ^*}{dc} = \frac{\partial Q}{\partial f_1}\frac{\partial f_1}{\partial c} + \frac{\partial Q}{\partial f_2}\frac{\partial f_2}{\partial c} + \frac{\partial Q}{\partial c}$$

(iii) The effect of fixed costs on fleet size is derived applying the implicit function theorem to the first order condition, noting that

$$\frac{\partial^2 \pi_I}{\partial f_i \partial K_c} = 0, \; \frac{\partial^2 \pi_I}{\partial f_i \partial K_r} > 0$$

Fleet sizes, in turn, affect equilibrium prices negatively and equilibrium quantities positively. This follows trivially from differentiating (A1) and (A2). □

**Proof of Proposition 3:**

(i) Follows from applying the implicit function theorem on the first order condition, noting that

$$\frac{\partial^2 \pi_{II}}{\partial f_i \partial w} < 0, \; \frac{\partial^2 \pi_{II}}{\partial f_i \partial c} > 0$$

when b is small and

$$\frac{\partial^2 \pi_{III}}{\partial f_i \partial w} > 0, \; \frac{\partial^2 \pi_{III}}{\partial f_i \partial c} < 0$$

when b is large. In the first case price and quantity derivatives with respect to w and c are the same as under regime I, and for the same reasons. Therefore. assume b is large.

(ii) Differentiating equilibrium price, equation (A1), wrt w yields

$$\frac{dp^*}{dw} = \frac{\partial p}{\partial f_1}\frac{\partial f_1}{\partial w} + \frac{\partial p}{\partial f_2}\frac{\partial f_2}{\partial w} + \frac{\partial p}{\partial w}$$

where fleet sizes affect price negatively. As w has a positive effect on fleet sizes and the direct effect of w is to increase prices, the total effect is indeterminate.

Differentiating equilibrium price, equation (A1), wrt c yields

$$\frac{dp^*}{dc} = \frac{\partial p}{\partial f_1}\frac{\partial f_1}{\partial c} + \frac{\partial p}{\partial f_2}\frac{\partial f_2}{\partial c} + \frac{\partial p}{\partial c}$$

where fleet sizes affect price negatively. As c has a negative effect on fleet sizes and the direct effect of c is to increase prices, the total effect must be positive.

Differentiating equilibrium quantity, equation (A2), wrt w yields

$$\frac{dQ^*}{dw} = \frac{\partial Q}{\partial f_1}\frac{\partial f_1}{\partial w} + \frac{\partial Q}{\partial f_2}\frac{\partial f_2}{\partial w} + \frac{\partial Q}{\partial w}$$

where fleet sizes affect quantity positively. As w has a positive effect on fleet sizes and the direct effect of w is to increase prices, the total effect is must be positive.

Differentiating equilibrium quantity, equation (A2), wrt c yields

$$\frac{dQ^*}{dc} = \frac{\partial Q}{\partial f_1}\frac{\partial f_1}{\partial c} + \frac{\partial Q}{\partial f_2}\frac{\partial f_2}{\partial c} + \frac{\partial Q}{\partial c}$$

where fleet sizes affect quantity positively. As c has a negative effect on fleet sizes and the direct effect of c is to reduce quantities, the total effect is must be negative.

(iii) The effect of fixed costs on fleet size is derived applying the implicit function theorem to the first order condition, noting that

$$\frac{\partial^2 \pi_{II}}{\partial f_i \partial K_c} < 0, \ \frac{\partial^2 \pi_{II}}{\partial f_i \partial K_r} = 0$$

Fleet sizes, in turn, affect equilibrium prices negatively and equilibrium quantities positively. This follows trivially from differentiating (A1) and (A2). □

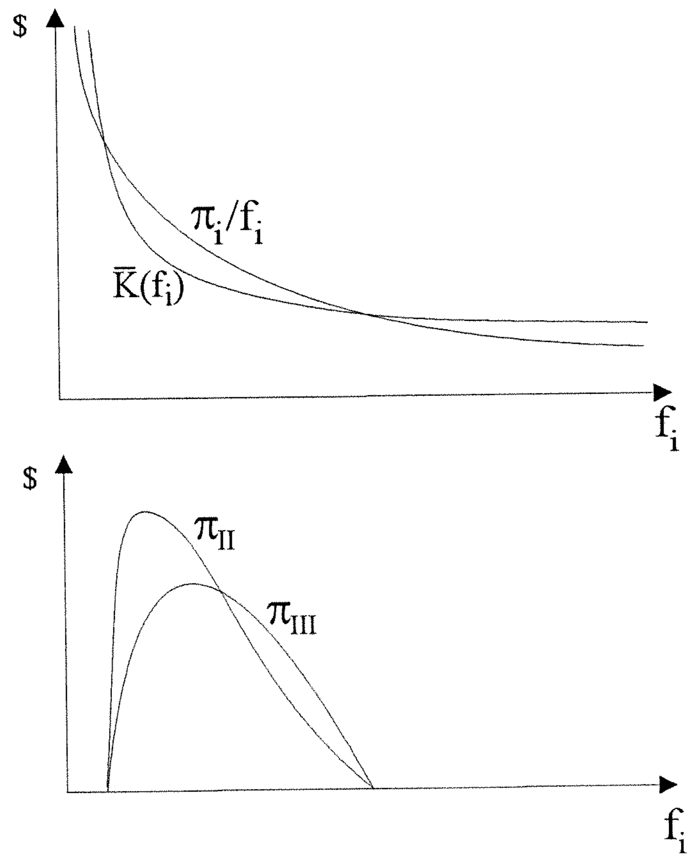


Figure 1