Deregulating Taxi Services

A Word of Caution

By Jonas Häckner and Sten Nyberg*

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 (1995) we examine the role of firm types, private vs cooperative, in determining the market outcomes.

In most countries the taxi-cab 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 transport available at times when demand is low and in areas where population is dispersed. For example, 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.1

The poor performance of regulated industries in general initiated a wave of deregulation during the 1980s. Whether deregulating a taxi market improves its performance depends on many factors. One of the most important factors is the presence or absence of inherent market failures that give rise to inefficiencies in the absence of regulation.2 Essentially, two types of distortion have been discussed in the literature, one arising from

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1 When deciding on the appropriate number of licences, 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.
2 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, taxi-cab productivity declined, resulting in lower earnings for taxi drivers.
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 analysing the market for street-hailed cabs where price information is more likely to be incomplete.\footnote{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) criticise Schreiber's analysis, noting that it is confined to the market for cruising cabs while 70-80 per cent of the US taxi demand consists of telephone-ordered trips for which price comparisons are relatively easy. Furthermore, most taxi firms have large fleets making price advertising worthwhile. Finally, on the cruising cab market, the presence of cab-stands facilitates price comparisons, further reducing search costs.} In this paper we focus on markets for telephone-ordered taxi-cabs, where price information is easier to obtain and where waiting time is, presumably, an important determinant of product quality.

The externality argument was first brought up by Orr (1969)\footnote{Assuming price-taking behaviour, Orr characterised 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 an extent that profits per cab increase.} 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, excessively low prices.

Although several authors have stressed the interdependence between demand, price and capacity, the economic implications have not been thoroughly analysed. 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 because when firms set prices they 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.\footnote{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).} Other things being equal, the externality may in fact help firms to sustain a higher profit level than otherwise would 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 proceeds as follows. The basic model is presented in Section 2 and some results concerning price-setting behaviour 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 generalised 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.
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 its taxi fleet. The fleets are initially assumed to be of equal size and are normalised 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, for example, 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 a representative consumer patronising firm 1 is given by

\[
U_1 = y_1 + (w - \alpha q_1)q_1 - \beta Q_1 q_1,
\]

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 parameterised by \( \alpha \) and \( \beta \) respectively.\(^6\) Waiting time is assumed to become more important, the more taxi trips consumed, thus affecting marginal utility and individual demand. Furthermore, consumers disregard the effect of their own demand on the price-setting behaviour of firms. The demand for taxi services by a single consumer patronising firm 1 is derived from the individual consumer’s utility maximisation subject to the budget constraint, \( I = y_1 + p_1 q_1 \), where the price of the composite good is normalised to one. That is,

\[
q_1 = \frac{w - p_1 - \beta Q_1}{2\alpha}.
\]

The aggregate demand of firm 1, normalising the number of consumers to unity, is simply \( Q_1 = q_1 m \), where \( m \) is firm 1’s market share. Consumers will choose to ride with the firm offering the best price/waiting time trade-off. If both firms have positive market shares, customers must be indifferent between them in equilibrium, that is, 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

\[
p_1 + \beta Q_1 = p_2 + \beta Q_2.
\]

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

\[
m = \frac{2\alpha(p_2 - p_1) + \beta(w - p_1)}{\beta(2w - p_1 - p_2)}
\]

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

\(^6\) \( \beta \) can actually be given two structurally indistinguishable interpretations. The first, and most obvious, interpretation is that it reflects consumers’ aversion towards spending time waiting. However, it may also be thought of as a technology parameter that relates capacity to waiting time.
\[ Q_1 = \frac{2\alpha(p_2 - p_1) + \beta(w - p_1)}{\beta(4\alpha + \beta)}. \] (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

\[ \pi_1 = (p_1 - c_1)Q_1. \] (6)

The best-response function for firm 1 is obtained by differentiating profits with respect to \( p_1 \):

\[ \phi_1(p_2) = \frac{1}{2} \left( c_1 + \frac{2\alpha p_2 + \beta w}{2\alpha + \beta} \right). \] (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

\[ p^* = c + \frac{\beta(w - c)}{2(\alpha + \beta)}. \] (8)

This equilibrium is derived under the assumption that both firms face a strictly positive demand. While this is not true for all price vectors it can be shown that \( p^* \) remains the unique equilibrium also when taking bounded demand into account.\(^7\)

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 \( \beta \) approaches infinity prices are close to the monopoly level, \((c+w)/2\). Equilibrium profits are, however, highest for intermediate values of \( \beta \). For low \( \beta \)s, the market will be fairly competitive and for high \( \beta \)s 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 (a similar result can be found in Schotter, 1985).\(^8\) Moreover, while the socially efficient price in 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

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\(^7\) To see that the equilibrium candidate \( p^* \) is unique, note that (i) in any equilibrium \( p_j > c \ \forall \ j \) and (ii) that all firms must have positive market shares in equilibrium since any firm facing a zero demand could do better by charging the same price as one of the firms with positive demand. Finally, for price vectors satisfying (i) and (ii) the "local" best responses are given by (7). Thus, the only feasible equilibrium candidate is given by (8). Furthermore, the complete reaction functions, defined over the unit price cube, can be shown to be continuous and thus Brouwer's fixed point theorem ensures existence. For a more rigorous discussion and proof, covering the case of different costs (which if differences are large may yield sets of equilibria), see Häckner and Nyberg (1995).

\(^8\) In fact, it suffices for a fraction of all consumers to have an aversion towards waiting time for all firms profitably to 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 transport but a large queue aversion, and "ordinary people" with a low willingness to pay for transport and a moderate queue aversion.
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\[ p^{**} = c + \frac{\beta(w - c)}{2\alpha + \beta} \]  \hspace{1cm} (9)

where \( p^{**} \) approaches marginal cost as \( \beta \) approaches zero.\(^9\) This holds true for \( p^* \) as well. Hence, if \( \beta \) can be made arbitrarily small, efficiency losses will also become arbitrarily small (Häckner and Nyberg, 1995). As will be discussed in Section 3, an inflow of new cabs can be interpreted precisely as a reduction in \( \beta \).

3. Entry

The findings in Section 2 suggest that price competition alone may not suffice to ensure efficient pricing in the market for taxi services. However, the results were derived under the assumption of fixed capacity. Insofar as 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-licence. 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. However, this also 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.\(^10\) First, office staff, marketing costs and equipment costs are more or less independent of scale. Furthermore, it is inconvenient for a consumer to memorise 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 with fleet size even if demand per cab is kept constant. This is because the geographical distance between a (randomly located) customer and the nearest taxi can be expected to decrease with 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.

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\(^9\) \( p^{**} \) is derived from maximising the representative consumer's indirect utility function minus production costs.

\(^10\) The airline industry may serve as an interesting comparison. Airline business was widely held to be essentially contestable for many of the same reasons put forward in the discussion about the taxi industry. The experience following airline deregulation in the US was, however, somewhat disappointing in that factors like gate access and computerised booking systems tended to impede entry, 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 computerised booking systems. Although in the case of taxi-cabs high fixed costs \textit{per se} do not constitute entry barriers in a strict sense, they do limit the number of firms that can coexist in the market without running at 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.
Assuming that entry is most likely to occur on the cab level, we now analyse the effects of entry, keeping the number of RDSs fixed. This is done by introducing an initial stage in which RDSs decide on capacities by taking into account the effect on equilibrium prices in the subsequent stage. Technically speaking, we solve for the subgame perfect Nash equilibrium of a two-stage game. Fleet sizes, equilibrium prices and quantities are compared under two different assumptions regarding the organisational 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 organisational 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) as benefits the majority of the members. Hence, RDSs choose fleet size to maximise per cab profits. In regime II, RDSs are privately owned enterprises choosing connection fees to maximise firm profits.

In this section, fleet sizes are firm specific. Waiting time is approximated by $Q/f$, where $Q_i$ measures the number of trips demanded and $f_i$ is the number of taxi-cabs available to an RDS, that is, the fleet size. In Section 2, fleet sizes were normalised to unity so the congestion term in the utility function was equal to $Q/D$. Allowing for asymmetric fleet sizes, the congestion term becomes $b(Q/f)Q_i$, where $b$ now reflects the aversion towards waiting time.\(^{11}\) Replacing $\beta$ with $\beta_i = b/f_i$ in equation (3) and proceeding as in Section 2, the demand facing firm 1 becomes

$$Q_1 = \frac{f_i(2\alpha f_i(p_2 - p_1) + b(w - p_1))}{b(2\alpha f_i + f_1) + b}$$

as long as demand for both firms is positive. Straightforward differentiation implies that the gross equilibrium profit of RDS 1 is

$$\pi_1 = \frac{bf_i(w - c)^2(b + 2\alpha f_i)(b + \alpha(2f_i + f_1))^2}{4[3\alpha^2 f_i f_1 + 2\alpha b(f_i + f_1) + b^2(2\alpha f_i + f_1) + b]}.$$

It can be checked 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 subsequent units.

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

\(^{11}\) There are no absolute capacity constraints in the model. A small fleet size translates into a long waiting time and a low willingness to pay, but all consumers who decide to call an RDS are served eventually.

\(^{12}\) $K_c$ could include wages, marketing costs and capital costs while $K_r$ could include leasing fees, and the driver's opportunity cost of working in the cab industry.

\(^{13}\) The net RDS profit function can be shown to be single-peaked for positive fleet sizes. Using equation (11) they can be written in the form: $\pi_1(f_i) - f_iK_c - K_r = f_i(\pi_1(f_i) - K_r)$, where $\pi_1(f_i)$ is decreasing in fleet size. It follows that profits per cab are also single-peaked.
3.1 The fleet size equilibria
Cooperatives simply maximise profits per cab, \( \pi_i = \pi_i/f_i - \bar{K}(f_i) \), with respect to fleet size. Privately owned RDSs maximise total profits, that is, 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 will maximise \( \pi_{II} = {f_i} \pi_i = f_i[\pi_i/f_i - \bar{K}(f_i)] \) 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.

\(^{14}\) In Figure 1 maximal profit 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 normalising the total number of consumers to one.
The proof of this is as follows. Both $\pi_{\text{ff}}$ and $\bar{K}(f)$ are decreasing and strictly convex in $f$. If fixed costs are very large, no fleet size will yield a positive profit. For lower, but strictly positive, fixed costs, $\pi_{\text{ff}}$ and $\bar{K}(f)$ will intersect twice. This follows from two observations:

(i) $\bar{K}(f)$ approaches infinity for small $f$s while $\pi_{\text{ff}}$ does not.
(ii) $\pi_{\text{ff}}$ approaches zero for large $f$s while $\bar{K}(f)$ does not.

Consequently, profits per cab, $\pi_1$, is at least quasiconcave in $f$. It is obvious that $\pi_{\text{II}}$ 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 $\pi_1$ ($\pi_{\text{II}}$) with respect to 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, $\pi_{\text{ff}}$, become more robust to changes in $f_1$. Under regime I, firm 1 can therefore increase its fleet size, spreading the fixed cost, $K$, over a larger number of cabs, incurring only a small loss in terms of $\pi_{\text{ff}}$. Conversely, under regime II, firm 1 can reduce its fixed cost payments, $f_1K + K$, by reducing its fleet size, without affecting $\pi_1$ very much.

**Proposition 1**
Under both regimes, there exists a unique and symmetric equilibrium in fleet sizes.\(^{15}\)

The proof of this is as follows. The reaction functions, $f_1(f_2)$, are identical. For finite fleet sizes, they are strictly concave and upward sloping under regime I (by strategic complementarity). Under regime II they are downward sloping (by strategic substitutability).

**Proposition 2**
Under regime I:

(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, $K$, increases $f_i$ given any $f_j$, resulting in lower prices and larger equilibrium quantities. The fixed cost per cab, $K$, does not affect fleet sizes.

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

The direct effect of an increase in $w$ is a rise in both price and quantity. However, firms benefit from cutting back on capacity, which increases prices and reduces quantities.

\(^{15}\) Since equilibrium taxi fleets are symmetric under all regimes, the assumption of identical RDSs in Section 2 can in fact be rationalised.
Hence, only the effect on price is clear. Similarly, when $c$ increases, the direct effect is a rise in price and a reduction in quantity. As capacity increases, prices go down and quantities go up, 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 lump sum tax on RDSs which is a somewhat paradoxical result. Raising the fixed cost per cab, $K_c$, does not affect the maximisation problem.

**Proposition 3**

Under regime II:

(i) If consumers are patient, that is, when $b$ is small, the equilibrium fleet size decreases in consumers' valuation of taxi services, $w$, and increases in marginal cost, $c$. If consumers are impatient, that is, when $b$ is large, the opposite is true.

(ii) For small $b$, increases in $w$ raise prices while the effect on quantity is ambiguous. Increased costs, $c$, have indeterminate effects on price and quantity. When $b$ is large, $w$ has a positive effect on quantity while the effect on price is ambiguous. Increases in marginal cost raise prices and reduce quantity.

(iii) An increase in per-cab fixed costs, $K^r$, reduces $f$, given any $f$. This raises prices and reduces quantity. The RDS fixed cost, $K^r$, has no effect on capacities.

The proof of this is shown in the Appendix. If consumers have a large aversion towards waiting, the willingness to pay for a reduction in waiting time will increase greatly when $w$ increases, in which case it is 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, let us assume that $b$ is large. The direct effect of an increase in $w$ is a rise in both price and quantity. But since firms increase capacity, which tends to reduce price and increase quantity, the only clear effect is on quantity. When $c$ increases, on the other hand, the direct effect is a price rise and a reduction in quantity. In this case, firms cut back on capacity, which tends to raise prices and reduce quantity so the effect in this case is unambiguous.

Finally, when the fixed cost of taxi-cabs, $K_c$, 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 subsidise the fixed cost of entrant cabs. Raising the fixed cost of an RDS, $K_r$, does not affect the maximisation problem.

From a welfare perspective, it is interesting to compare the equilibrium fleet sizes. In Figure 1, which is drawn for an arbitrary $f_r$, we can see that the equilibrium fleet size in regime II, $f_{II}$, is larger than that of regime I, $f_I$. Indeed, given any $f_r$ 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.\footnote{The two major firms on the Stockholm taxi-cab market are organised in this manner.} Assume that the market initially is in a regime I equilibrium. Then one
firm, say firm 2, is reorganised 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 at the new intersection both firms will have larger fleet sizes 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
From the previous section we know that market profits are positive despite "free" entry of taxi-cabs. The reason is the endogenous entry barrier, in the form of high connection fees and exclusion, created by the RDSs.

If the fixed cost of entrant cabs, $K_e$, is low, it would be socially desirable to reduce entry barriers to a minimum since a large number of new cabs would drive $\beta$ towards zero, without incurring a great cost to society. 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 almost no externalities. Clearly, the market outcome will not be efficient in this case, but regime II will be relatively more efficient than regime I. If the industry could be costlessly re-regulated, one therefore might want to prevent the RDSs from refusing to hook up new entrants. 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.

4. Conclusions
The sunk cost of an entrant cab is likely to be small since cabs can be leased and there exist well-functioning markets for second-hand taxi equipment. Also, the fixed costs are likely to be moderate, consisting mainly of a leasing fee and perhaps the opportunity cost of working in the industry. All this together makes for a strong case for deregulation. However, price competition alone does not ensure efficiency. Cooperatively-run RDSs will be relatively less efficient 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. In such a case, the costs of regulation must of course be taken explicitly into account. Specifically, information asymmetries may make it difficult to induce cost efficiency.
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References


Appendix

\[ p^* = \frac{6a^2 c f_w + \alpha b(c(2f_w + 3f) + w(2f_h + f)) + b^{-2}(c + w)}{2[3a^2 f_h + 2\alpha b(f_h + f) + b^{-2}]} \]  

\[ Q^* = \frac{b(w - c)(2a^2 f_h^2 + f) + \alpha b(2f_h + 3f) + b^{-2})}{2[3a^2 f_h^2 + 2\alpha b(f_h + f) + b^{-2}][2a(f_h + f) + b]} \]  

Proof of Proposition 2:

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

\[ \frac{\partial^2 \pi_f}{\partial f \partial w} < 0, \frac{\partial^2 \pi_f}{\partial f \partial c} > 0. \]

(ii) Differentiating equilibrium price, equation (A1), with respect to \( w \) yields

\[ \frac{dp^*}{dw} = \frac{\partial p}{\partial f} \frac{df}{dw} + \frac{\partial p}{\partial f} \frac{df}{dw} + \frac{\partial p}{\partial f} \frac{df}{dw} \]
where fleet size affects price negatively. As \( w \) has a negative effect on fleet size and the direct effect of \( w \) is to increase prices, the total effect must be positive.

Differentiating equilibrium price, equation (A1), with respect to \( c \) yields

\[
\frac{\partial p^*}{\partial c} = \frac{\partial p}{\partial f} \frac{\partial f}{\partial c} + \frac{\partial p}{\partial f} \frac{\partial f}{\partial c} + \frac{\partial p}{\partial c},
\]

where fleet size affects price negatively. As \( c \) has a positive effect on fleet size and the direct effect of \( c \) is to increase prices, the total effect is indeterminate.

Differentiating equilibrium quantity, equation (A2), with respect to \( w \) yields

\[
\frac{\partial Q^*}{\partial w} = \frac{\partial Q}{\partial f} \frac{\partial f}{\partial w} + \frac{\partial Q}{\partial f} \frac{\partial f}{\partial w} + \frac{\partial Q}{\partial w},
\]

where fleet size affects quantity positively. As \( w \) has a negative effect on fleet size and the direct effect of \( w \) is to increase prices, the total effect is indeterminate.

Differentiating equilibrium quantity, equation (A2), with respect to \( c \) yields

\[
\frac{\partial Q^*}{\partial c} = \frac{\partial Q}{\partial f} \frac{\partial f}{\partial c} + \frac{\partial Q}{\partial f} \frac{\partial f}{\partial c} + \frac{\partial Q}{\partial c},
\]

where fleet size affects quantity positively. As \( c \) has a positive effect on fleet size and the direct effect of \( c \) is to reduce quantity, the total effect is indeterminate.

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

\[
\frac{\partial^2 \pi_f}{\partial f \partial K_c} = 0, \quad \frac{\partial^2 \pi_f}{\partial f \partial K_r} > 0.
\]

Fleet size, in turn, affects 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

\[
\frac{\partial^2 \pi_f}{\partial f \partial w} < 0, \quad \frac{\partial^2 \pi_f}{\partial f \partial c} > 0,
\]

when \( b \) is small and

\[
\frac{\partial^2 \pi_f}{\partial f \partial w} > 0, \quad \frac{\partial^2 \pi_f}{\partial f \partial c} < 0,
\]

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), with respect to \( w \) yields

\[
\frac{\partial p^*}{\partial w} = \frac{\partial p}{\partial f} \frac{\partial f}{\partial w} + \frac{\partial p}{\partial f} \frac{\partial f}{\partial w} + \frac{\partial p}{\partial w},
\]

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

Differentiating equilibrium price, equation (A1), with respect to $c$ yields
\[
\frac{dp^*}{dc} = \frac{dp}{df} \frac{df}{dc} + \frac{dp}{dc} + \frac{dp}{dc},
\]
where fleet size affects price negatively. As $c$ has a negative effect on fleet size and the direct effect of $c$ is to increase prices, the total effect must be positive.

Differentiating equilibrium quantity, equation (A2), with respect to $w$ yields
\[
\frac{dQ^*}{dw} = \frac{dQ}{df} \frac{df}{dw} + \frac{dQ}{dc} \frac{dc}{dw} + \frac{dQ}{dw},
\]
where fleet size affects quantity positively. As $w$ has a positive effect on fleet size and the direct effect of $w$ is to increase prices, the total effect must be positive.

Differentiating equilibrium quantity, equation (A2), with respect to $c$ yields
\[
\frac{dQ^*}{dc} = \frac{dQ}{df} \frac{df}{dc} + \frac{dQ}{dc} \frac{dc}{dc} + \frac{dQ}{dc},
\]
where fleet size affects quantity positively. As $c$ has a negative effect on fleet size and the direct effect of $c$ is to reduce quantity, the total effect must be negative.

(iii) The effect of fixed costs on fleet size is derived by applying the implicit function theorem to the first-order condition, noting that
\[
\frac{\partial^2 \pi_{II}}{\partial f \partial K_c} < 0, \quad \frac{\partial^2 \pi_{II}}{\partial f \partial K_r} = 0.
\]
Fleet size, in turn, affects the equilibrium price negatively and the equilibrium quantity positively. This follows trivially from differentiating (A1) and (A2).

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