# A DIAGRAMMATIC ANALYSIS OF THE MARKET FOR CRUISING TAXIS

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## ABSTRACT

***In this paper a diagrammatic approach is developed to analyze the characteristics of the cruising taxi market. With this approach social optimum conditions, short and long run free market outputs and a second best solution with financial constraints (non-negative profits) are analyzed. Different system conditions are described in terms of number of taxis in operation, number of runs produced, fares charged, average production costs and generalized prices. Using system average production costs and demand functions expressed in terms of generalized prices, short and long run adjustment processes are described, to explain the market mechanisms that produce such system conditions. Thus, we derive short run and long run quasi-equilibrium conditions. We show that the maximum fleet size is obtained for free market conditions, and that the social optimum is characterized by producing the maximum number of runs with a fleet of taxis of lower size than those obtained with short and long run free market conditions. We show that price regulation allows to obtain a social optimum or a second best solution and that entry regulations are in such case redundant. On the contrary, entry regulations alone (without price regulation) that reduce fleet size, with respect to the free market case, produce worse system conditions than free market. Finally, we show that licensing policies can contribute to improve conditions generated by entry regulations, bringing them closer to the social optimum.***

## 1. Introduction

In most developing countries, cruising rather than dispatch taxi service is the norm[1]. Several authors have analyzed operating and economic characteristics of this market, which normally is considered subject to different imperfections: supply depends on demand, through waiting times (Beesley and Glaister, (1983); Manski and Wright (1976)), non-existance of equilibrium (Cairns and Liston-Heyes (1996)), production externalities (Paul (1982) and Yang and Wong (1998)) and supply-demand synchronization problems (Shreiber (1975,1977,1981)). Therefore, most of the studies recommend regulation policies to obtain second best solutions that maximize social welfare, subject to financial constraints: fare regulation (Douglas (1972), De Vany (1975) and Paul (1982)), entry regulation (De Vany (1975)), and both fare and entry regulation (Shreiber (1975,1977), Paul (1982) y Cairns and Liston-Heyes (1996)).

As Beesley and Glaister (1983) point out one of the main difficulties for the analysis of the cruising taxi market is that demand depends upon service quality which depends on both supply and demand. The scale of the industry influences the quality of service provided because as number of trips increases an economy is obtained in the inputs provided by consumers, through decreasing waiting times.

The objective of the paper is to provide a diagrammatic explanation for the economics of the operation of cruising services market. In the next section (2) the model used for the analysis is described. Then section 3 analyzes the characteristics of a free market equilibrium. Section 4 characterizes a social optimum solution for the operation of the industry. Section 5 uses the previous analysis to evaluate the results of the most common regulatory policies used in practice. Finally, section 6 summarizes the main conclusions and proposes some extensions.

## 2. The model

We adopt the approach proposed by Mohring (1976) for modeling the production of passenger transport services. The service offered by taxi operators is considered a quasi-service, which in order to become a real service must have the participation of the passenger, which contributes with two important production factors: the waiting time and travel time. Therefore, both taxi operators and passengers are taken as service producers. Accordingly, the number of taxi runs really produced is equal to the number consumed.

To handle the difficulty produced by the supply-demand dependencies mentioned in the literature (Cairns and Liston-Heyes (1996); Beesley and Glaister, (1983); Manski and Wright (1976)), we use a generalized price function formulation to define the demand function for taxi runs. This function is similar to that used by Beesley and Gleister (1983) and considers that the demand for taxi services does not only depend on the fare value, but also on the level of service experienced by passengers. Therefore prices reflect also service levels.

## 2.1 Main Assumptions

Some important assumptions made are the following

i. Only cruising services are considered. Taxis permanently run the streets looking for passengers. When a passenger is found he is driven to his destination after which the taxi resumes the search for a new passenger. The trip with a passenger is called a run.

ii. Taxis operate in a given geographical area, during a given time period, for which homogeneous operating conditions are assumed.

iii. It is assumed that each taxi operates independently without possibility of collusion[2]. The driver-owner and the vehicle constitute the individual taxi firm.

iv. Runs have an average length, and their duration is equal to a constant time, $t$[3].

v. All taxis make the same average number of runs per period, $q$. Therefore, if $N$ is the number of taxis and $Q$ is total number of runs produced by all taxis during the analysis period, $Q=N\cdot q$.

In addition we will use the following concepts: the individual capacity of a taxi is the maximum number of runs that it can produce per period, and is equal to the inverse of the average run duration, $1/t$. Therefore the industry capacity will be given by the sum of the individual capacities over the total number of taxi operators, $N/t$. The occupancy rate, is

[1] In Santiago, the chilean capital, a total of 50000 taxis were operating in 1999; 45000 of them providing cruising service.

[2] In most developing countries and especially in Chile, taxi operators are individuals who own one vehicle and operate independently.

equal to the ratio between the number of runs produced by a taxi during the analysis period and the individual capacity of the taxi, $\alpha(q) = q \cdot (1/t)^{-1} = q \cdot t$ with $q \leq 1/t$. Notice that also $\alpha(N,Q) = Q \cdot t/N$, with $Q < N/t$.

**2.2 Taxi Services Production Costs**

The costs incurred by the taxi operator include: fuel, lubricants, tires, variable maintenance, fix maintenance, driver time (salary), vehicle capital cost, license and taxes. The first four items correspond to direct operating costs related to the distance traveled, the other five are indirect or fix costs. Because cruising taxis are permanently running, (with or without passengers), and assuming that the effect of the passenger on the operating cost is negligible, previous authors have considered all the cost items mentioned above as fix, for a given length of the operating period (Douglas 1972; De Vany, 1975; Cairns and Liston-Heyes (1996)). Then the total cost incurred by a taxi during a given period (let us say an hour) can be expressed by:

$$TC_{taxi}(q) = c \qquad 0 \leq q < \frac{1}{t} \tag{1}$$

Therefore the average taxi cost, per run produced, can be expressed as:

$$AC_{taxi}(q) = \frac{c}{q} \qquad 0 \leq q < \frac{1}{t} \tag{2}$$

The maximum number of runs that can be produced in the period is equal to $1/t$, and therefore the cost functions are not defined for $q > 1/t$. Average cost per ride is hyperbolic and it achieves its minimum value when the maximum number of runs is produced ( $q = 1/t$, => $AC(1/t) = ct$) (Cairns and Liston-Heyes (1996)).

We define now the average industry cost (*AIC*). It is obtained by the horizontal addition of all average cost functions of taxi operators belonging to the industry. Therefore, considering a total of *N* identical operators, its expression is:

$$AIC(N,Q) = \frac{N \cdot c}{Q} \qquad 0 \leq Q < \frac{N}{t} \tag{3}$$

[3] Duration time t is a consequence of operating conditions and general congestion levels experienced on the streets of the area considered. In this paper the influence of taxis on general congestion is not considered. This analysis is made in a next paper.

The *AIC* function gives the minimum fare that taxi operators require, in order to completely finance all inputs used in taxi travel service production. Equivalently, it specifies, for each possible fare level, the minimum number of runs that the industry requires selling, to fully finance its operation.

Average travel time cost per passenger can be expressed as the product of the average run duration *t* and the passengers unitary value of travel time ($\phi$):

$$ATC = \phi \cdot t \qquad (4)$$

Because we do not consider the effect of taxis on streets flow congestion, this average travel cost has a constant value, determined by general traffic conditions. Therefore, corresponding marginal cost is also constant and has the same value:

$$MTC = \phi \cdot t \qquad (5)$$

Average waiting time experienced by an individual looking for a taxi, depends on the number of taxis in operation and the number of runs consumed, *w(N,Q)* (Cairns and Liston-Heyes,1996) or, in other words, "the delay distribution is a function of the density of vacant taxicabs in the area" (Douglas, 1972). Then, for a given a value of *N*, as the number of runs produced increases more taxis are busy and the probability of finding an empty taxi decreases. Therefore, based on the general expression derived by Douglas (1972), we assume the following average waiting time cost functional form:

$$AWC(N,Q) = \theta \cdot w(N,Q) = \frac{k}{N - Q \cdot t} \qquad 0 \leq Q < \frac{N}{t} \qquad (6)$$

where θ is the waiting time unitary value, $k$ is a calibration parameter[4] and *(N – Q·t)* corresponds to the average number of empty taxis available, in a given moment of the analysis period.

Therefore, from (6), when N is fixed a given increase in the number of runs (ΔQ) produces a more than proportional increase in the average waiting time cost. In other words, *AWC* is a convex function of *Q*. When no runs are produced (*Q=0*), the potential average waiting time cost that a passenger would experience is equal to *k/N*. On the other side, as the number of runs produced approaches the capacity (*N/t*), the average waiting

[4] As is mentioned in Douglas, (1972) the value of parameter k depends on the waiting time value ($\theta$), the size of the operating area considered and the average operating speed of taxis.

time cost asymptotically goes to infinity. Obviously, in such situation, the probability of finding an empty taxi goes to zero.

As it is well known, when a new run is produced in the short run, the average waiting time experienced by all consumers of taxi services increases, because the availability of empty taxis is reduced. Therefore, each consumer experiences the average waiting time but produces also a negative externality over the other consumers. The social waiting time cost produced by an additional passenger is explained by the marginal waiting time cost function. This is obtained derivating, with respect to $Q$, the total waiting time cost ($TWC = AWC \cdot Q$) experienced by the sum of all consumers $Q$. The corresponding expression is the following:

$$MWC(N,Q) = \frac{\partial[TWC(N,Q)]}{\partial Q} = \frac{k}{N - Q \cdot t} + \frac{k \cdot t \cdot Q}{(N - Q \cdot t)^2} \qquad 0 \le Q < \frac{N}{t} \tag{7}$$

Therefore, the negative externality can be readily obtained if we subtract the average to the marginal waiting time cost, as follows:

$$E(N,Q) = MWC(N,Q) - AWC(N,Q) = \frac{k \cdot t \cdot Q}{(N - Q \cdot t)^2} \qquad 0 \le Q < \frac{N}{t} \tag{8}$$

We now define the average and marginal passenger costs ($AC_{pas}(N,Q)$, $MC_{pas}(N.Q)$), adding the corresponding waiting and travel time cost functions defined above:

$$AC_{pas}(N,Q) = \phi t + \frac{k}{N - Q \cdot t} \qquad 0 \le Q < \frac{N}{t} \tag{9}$$

$$MC_{pas}(N,Q) = \phi t + \frac{k}{N - Q \cdot t} + \frac{k \cdot t \cdot Q}{(N - Q \cdot t)^2} \qquad 0 \le Q < \frac{N}{t} \tag{10}$$

These functions are represented in Figure 1(a).

Now we define the Average System production Cost function *(ASC(N,Q))*, which is obtained adding the Average Industry Cost (*AIC*) and the Average Passenger Cost functions ($AC_{pas}$):

$$\begin{aligned} ASC(N,Q) &= AIC(N,Q) + AC_{pas}(N,Q) \\ &= \frac{N \cdot c}{Q} + \phi \cdot t + \frac{k}{N - Q \cdot t} \qquad 0 \le Q < \frac{N}{t} \end{aligned} \tag{11}$$

*ASC* includes the costs corresponding to all inputs used (those provided by the operator and the service user) to produce a run. As we can see in Figure 1(b), it has a U form. For low values of $Q$, *ASC* is decreasing with $Q$ because it is dominated by the decreasing characteristic of the *AIC*. However, for high values of $Q$ it is increasing, because it is dominated by the effect of the waiting time cost, as production $Q$ approaches capacity ($Q \rightarrow N/t$). In the same figure the value of $Q$, for which the minimum value of the Average System Cost ($ASC(N,Q)$) is obtained, is represented by $Q_{min}(N)$[5].

The Marginal System production Cost function ($MSC(N,Q)$) is obtained taking the derivative, with respect to $Q$, of the total system production cost (Fig 1(b)):

$$MSC(N,Q) = \frac{\partial[ASC(N,Q)\cdot Q]}{\partial Q} = \phi t + \frac{k}{N\text{-}Qt} + \frac{k\cdot t\cdot Q}{(N-Qt)^2} = MC_{pas}(N,Q) \quad 0 < Q < \frac{N}{t} \qquad (12)$$

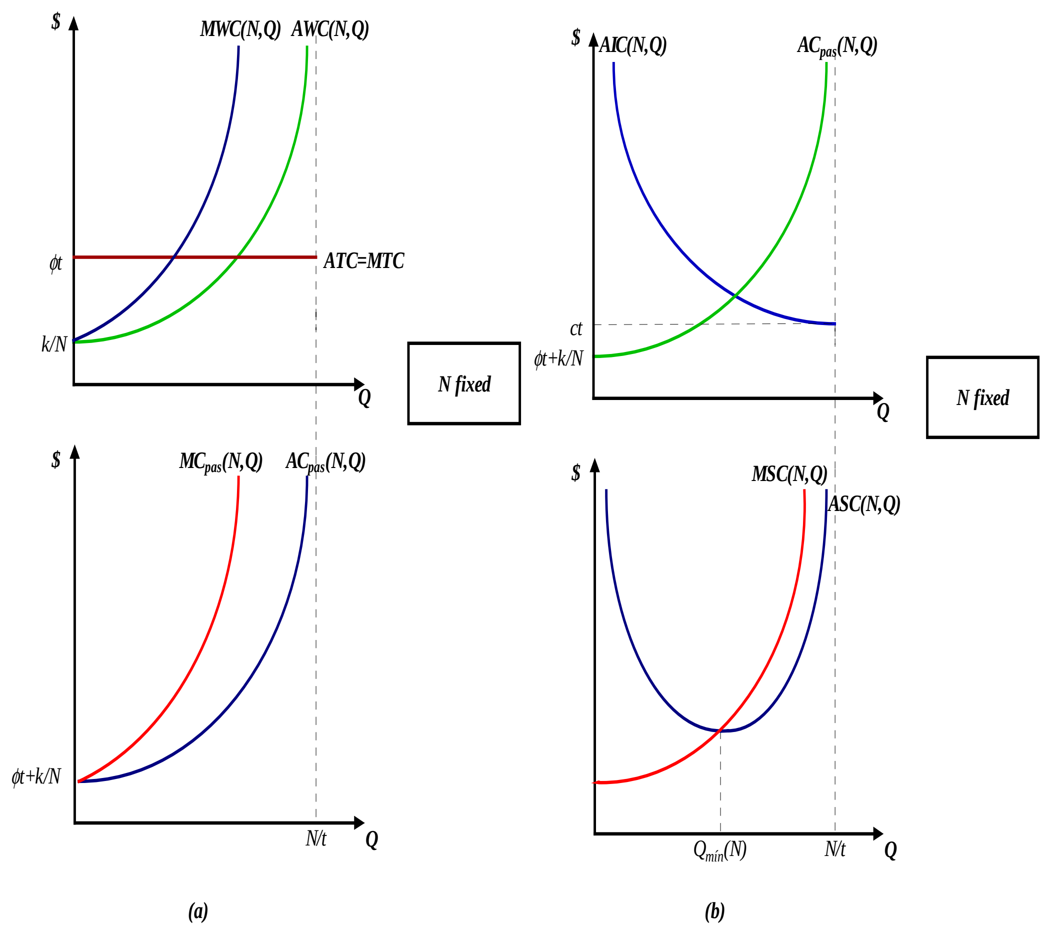

**FIGURE 1: Average and Marginal Costs: (a) Passenger and (b) System**

[5] The analytical expression that determines the value of $Q_{min}(N)$ is derived in Appendix A (see equation A.3).Notice that average and marginal cost functions in Fig 1(b), present one of the forms assumed by Mohring (1976) (Type IC) for schedules arising in transportation activities.

As we can observe, from (10) and (12), Marginal System Cost, *MSC*, is equal to Marginal passenger Cost, $MC_{pas}$, because taxi operating costs are fix.

It is interesting to analyze how the entry of new taxi operators to the market modifies the *ASC* function. The following effects are produced by the increase of *N*, from $N_1$ to $N_2$ (see Figure 2(a)): i) the industry production capacity increases from $N_1/t$ to $N_2/t$, ii) the *AIC* shifts to the right, because as the number of taxis in the market increases, the production of runs necessary to finance all the operators also increases; in other words, the average cost of producing a run increases, for any given level of production *Q*, iii) as new operators come into the market, the availability of taxis $(N - Qt)$ increases and therefore the average waiting time cost decreases, for any given value of *Q*. Then, the $AC_{pas}$ function shifts down and to the right, which means that the average passenger cost decreases as *N* increase, for any given value of *Q*.

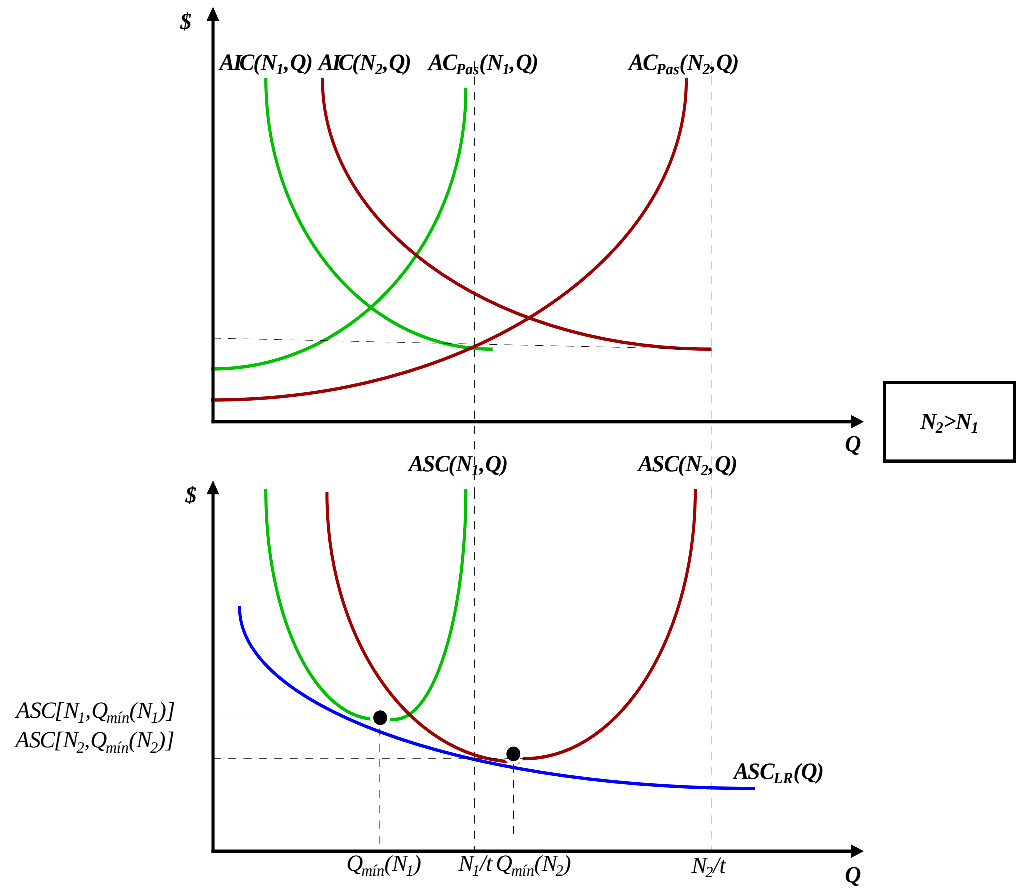


**FIGURE 2: Effect of the number of taxis on the Average System Cost**

Therefore, the following changes are produced in the Average System Cost function (*ASC*) as *N* increases (see Figure 2(b)): i) the function shifts to the right, ii) the distance between the left (decreasing) and right (increasing) branches of the function increases (the new function is wider), iii) the minimum point of the average passenger cost function decreases[6]:

$$\frac{d\left[ASC\left(N, Q_{\min}(N)\right)\right]}{dN} < 0 \tag{13}$$

[6] This characteristic, is obtained as a result of analyzing the slope of such trajectory, which is calculated in Appendix A (equations A4 and A5). This result is also consistent with the decreasing long run average system cost function shown in Figures 2 and 4.

Finally, it is easy to notice from (11), that a change in the value of taxi operating cost ***c*** will produce a vertical shift of functions *ASC(N,Q)*: up if ***c*** increases and down if ***c*** decreases. Therefore, a different family of such functions (one is shown in figure 2), as a function of *N*, will be obtained for each value of ***c***.

**2.3 Generalized Price and Demand Function.**

As several authors, (Douglas, 1972; De Vany, 1975; Morhing, 1976; Cairns and Liston-Heyes, 1996; Owen, 1984), we assume that the demand for taxi runs is not only a function of the fare *f* charged for the service (out of pocket cost). The total willingness to pay (of a regular informed user of taxi services) for a taxi run, includes the taxi fare plus the private economic value of the waiting and travel times experienced. Then, for a level of consumption *Q*, when waiting and/or travel time cost increases (or decreases), the net out of pocket willingness to pay decreases (or increases) in the same amount. We define a generalized price value that is a function of *N*, *Q* and *f*.

$$GP(N,Q,f) = f + AC_{pas}(N,Q) \tag{14}$$

In Figure 3, two *GP* functions are shown for $N_1$ and $N_2$ taxis, with $N_2 > N_1$.

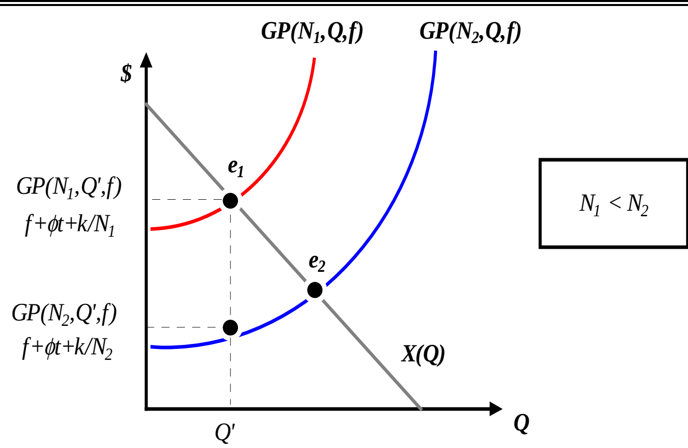


**FIGURE 3. Demand and Generalized Price Functions**

When the number of taxis N increases, from $N_1$ **to** $N_2$, the generalized price value (or total cost experienced by a user) decreases for any given values of *Q* and *f*. This is because when the same number of runs *Q* is produced by a higher number of taxis, passenger waiting times decrease, reducing the value of the average passenger cost. Figure 3 clearly shows a point raised by Cairns and Liston-Heyes, (1996): "for a fixed fare value *f* there are several possible equilibrium values of *Q* and *N*" (identified as $e_i$ in the figure). Actually, they correspond to different short run equilibriums, each of them for a different value of *N*.

However (a point not made by the mentioned authors) many of these, so called "equilibriums", can be unstable, or financially non feasible for taxi operators. We will analyze this in section 3.

## 3. Social Optimum and Second Best Solutions.

In this section we analyze the characteristics corresponding to a socially optimum system operation. According with basic microeconomic principles, the social optimum will be obtained in the intersection of the long run Marginal System Cost and Demand functions.

In Section 2.2 we defined the short run Average and Marginal System Cost functions, for fixed *N* (equations 11 and 12). The long run Average System Cost function will be equal to the envelope of the family of short run Average System Cost functions. In Appendix B, the following long run total, Average and Marginal cost functions, are obtained:

$$TSC_{LR}(Q) = 2\sqrt{k \cdot Q \cdot c} + Q \cdot t \cdot (c + \phi) \qquad (15)$$

$$ASC_{LR}(Q) = 2\sqrt{\frac{k \cdot c}{Q}} + t \cdot (c + \phi) \qquad (16)$$

$$MSC_{LR}(Q) = \sqrt{\frac{k \cdot c}{Q}} + t \cdot (c + \phi) \qquad (17)$$

As we can see from (16) and (17) that: i) the $ASC_{LR}$ is higher than the $MSC_{LR}$ for any value of *Q*, ii) both functions are decreasing with *Q*, iii) both functions tend to the asymptotic value $t(c + \phi)$ when *Q* goes to ∞.

In Figure 4, a demand function is also represented and the optimum solution is shown at point *O*, in the intersection of the long run marginal cost and demand functions. As we can see, it is obtained with $Q^*$ runs[7] and a generalized optimum price, $P^*$, equal to $\sqrt{k \cdot c/Q^*} + t \cdot (c + \phi)$. Subtracting from $P^*$, the corresponding, average passenger cost, $AC_{pas} = \phi \cdot t + \sqrt{k \cdot c/Q^*}$, the social optimum fare value obtained is, $f^* = t \cdot c$. Notice that this value is equal to the minimum average taxi cost per run, obtained when taxis occupancy rate is maximum, $q < 1/t$, (see equation 2). Therefore, for normal operating

[7] From equation (B.3) (see appendix B) we have that the corresponding optimum number of taxis:

conditions ($q < 1/t$) the social optimum fare does not fully cover taxi operating costs. If such fare value is imposed operators will perceive negative profits, represented by area $L$ in the figure. Notice that the lose per run, $\sqrt{k \cdot c/Q^*}$, is obtained subtracting (17) from (16) (evaluated at $Q = Q^*$). The value of $L$ can be then obtained multiplying by the number of runs performed, $Q^*$, $L = \sqrt{k \cdot Q^* \cdot c}$. This result is consistent with that obtained by Cairns and Liston-Heyes, (1996)[8].

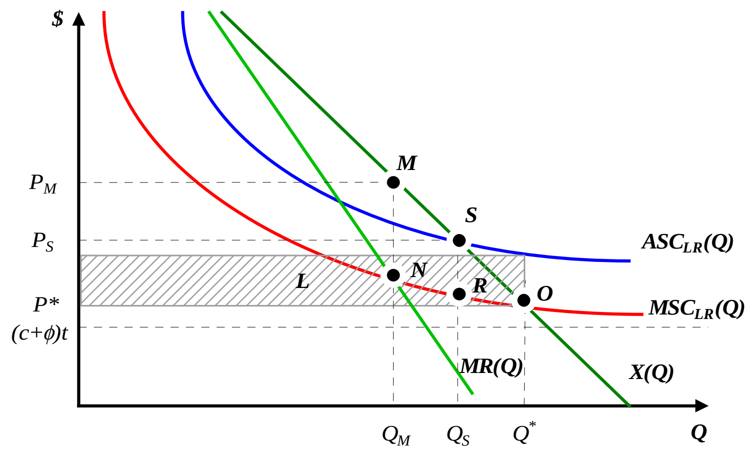


**FIGURE 4: Long Run Average and Marginal System Cost Functions**

To maximize the social welfare subject to non-negative profits point $S$ must be chosen, with ($P_S$, $Q_S$), determined by the intersection of the demand and average cost functions. At this point, fares cover exactly taxi operating costs. A social lose, represented by the area of triangle $SRO$, results with respect to the optimum social solution ($P^*$, $Q^*$). Therefore we will call second best solution to $S$. Its associated fleet size and fare are:

$$N_S = \sqrt{k \cdot Q_S / c} + Q_S \cdot t, \qquad f_S = \frac{N_S \cdot c}{Q_S} = \sqrt{k \cdot c / Q_S} + t \cdot c \tag{18}$$

As we can see from (18) the second best fare, $f_S$, exceeds the value of the optimum fare, $f^*$, in an amount equal to $\sqrt{k \cdot c/Q_S}$. This is equal to the difference between the long run average and marginal costs evaluated at $Q = Q_S$.

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$$N^* = N^*(Q^*) = \sqrt{\frac{k \cdot Q^*}{c}} + Q^* \cdot t$$

[8] They conclude that: “Running a private industry (at a social optimum) requires restricting $N$, so that profits are non negative”.

In figure 4 we also represent the marginal revenue function $MR$ and the monopolistic solution ($P_M$, $Q_M$). It is easy to observe that, depending on the slope of the linear demand function represented, the position of point $M$ will change. As the slope decreases, $M$ moves closer to point $O$[9]. Therefore, $P_M$ can be higher or lower than $P_S$, depending on the characteristics of the demand function. This also coincides with Cairns and Liston-Heyes, conclusions (1996) with respect to this point.

## 4. <u>Free Market Operation</u>

In order to analyze the possible outcomes of a free market operation, we will make the following assumptions: i) Taxi operators quote the fares, ii) Fares quoted may be freely changed but must be clearly displayed in the front of the taxi for the information of potential passengers[10].

### 4.1 Supply Demand Synchronization

An important characteristic of the operation of this market is that supply and demand are not simultaneously present in time-space. This is known as lack of supply-demand synchronization (Shreiber, 1975, 1977, and 1981). At any given time during the operating period, but at different locations in the geographical area, there are empty taxis looking for passengers and passengers waiting to find an empty taxi. Therefore, passengers must spend time waiting, although empty taxis exist. If the passenger does not like the fare charged by the first empty taxi arriving to the place where he is located, he must wait for the arrival of a new empty taxi, with the hope that it will charge a lower fare. Therefore, to have the option to choose a lower fare he must incur in an special cost, equal to the value of the additional waiting time. This constitutes an important market imperfection that gives to individual taxi operators some power over price determination. This special power would not exist in a perfect market, where all the supply options are simultaneously available and there is not special cost associated to the choice of supplier.

We will analyze now what is the influence of this market imperfection on the price formation process in the taxi market. To start, we will assume that all taxis are charging the

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[9] Actually, $M$ and $O$ will coincide if the demand function is horizontal

[10] These are the rules that apply in the case of the City of Santiago the Chile, where the taxi industry (cruising) operates with free fares and free entry.

same fare value $f$ for the service. Are there any incentives for individual operators to unilaterally modify the current price $f$?

Let us see first what would be the consequences of a fare reduction. Given the operating characteristics of cruising taxis, it is impossible for a waiting passenger to predict the location of empty taxis, at any given moment in time. Therefore, if any individual taxi unilaterally reduces the fare charged, below the current value $f$, none passenger will be incentived to wait for him, because the probability to find that taxi empty is for all practical purposes equal to zero[11]. Therefore, such operator will obtain the same number of passengers as if the fare charged were equal to the prevailing market value, and his income will be reduced proportionally to the unilateral fare reduction. The conclusion is that there is no economic incentive for a unilateral fare reduction[12].

On the contrary, is there any economic incentive for a unilateral fare increase? Let us assume that a given taxi operator unilaterally increases the fare charged from $f$ (prevailing value) to $f'$. Waiting passengers that meet such high fare taxi will reject it only if the fare difference, with respect to a normal fare, $f'-f$, is higher than the additional expected waiting cost, $2AWC(N,Q)=2\theta w$, incurred for having to wait a new (normal fare) taxi. Therefore, if the fare increase is lower than such value, the operator will get the same average number of passengers as a normal fare taxi, but his income will increase in the proportion of the unilateral fare increase[13]. In order to proceed to a new fare increase it is necessary however that other operators follow the initial fare increase establishing a new market fare $f'$.

From the point of view of the individual taxi operator, marginal revenue is not well defined because, as we saw above, price to charge (individual demand) is neither well defined[14]. Therefore, the usual price determination rule of "marginal revenue equal to marginal cost", can not be meaningfully applied. Individual operators will always have an

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[11] This assumes that all passengers know that such reduced fare taxi exists. However, in practice, the situation is still worse for such operator because for a very long time, only a few insignificant number of passengers (that are lucky to see him occasionally), would know of his existence.

[12] Obviously, this conclusion would change if a significant number of operators agree to reduce the fare. Then, the probability that a passenger finds an empty taxi of reduced fare becomes positive and increases with the number of taxis in the agreement. However, we do not consider such case because collusion is not included in our analysis and no big firms, with a large amount of cruising taxis, exist.

[13] A similar argument was used by Cairns and Liston-Heyes, (1996) to conclude that, "equilibrium does not exist".

[14] There is not a well defined demand function for the individual taxi operator.

incentive to rise fares by the small amounts indicated above. However, the analysis of this section must be completed taking into account the taxi operating (service supply) cost and its interaction with willingness to pay (demand) and levels of service. These factors are integrated in the next section to analyze the possible outcomes of a free taxi market.

**4.2 Short run Market Conditions**

Given that it is not possible to establish equilibrium conditions for individual taxi operators we will take a total system approach to make the analysis of the possible outcomes obtained from a free market operation. In Figure 6, short run market conditions (*N* fixed) are represented; a system average cost function, *ASC(N.Q)*, intersects with a demand function *X(Q)*, at points $E_1(N)$ and $E_2(N)$[15]. Region *R(N)* bounded by the mentioned functions represents the price-quantity combinations, [*Q*, *PG(N,Q,f)*] that are feasible under free market conditions. For all those combinations the generalized price paid by the passenger is lower (or equal) than the willingness to pay and higher (or equal) than the Average System Cost incurred.

$$X(Q) \geq GP(N,Q,f) \geq ASC(N,Q) \qquad \forall\, Q_{E1(N)} \leq Q \leq Q_{E2(N)} \tag{19}$$

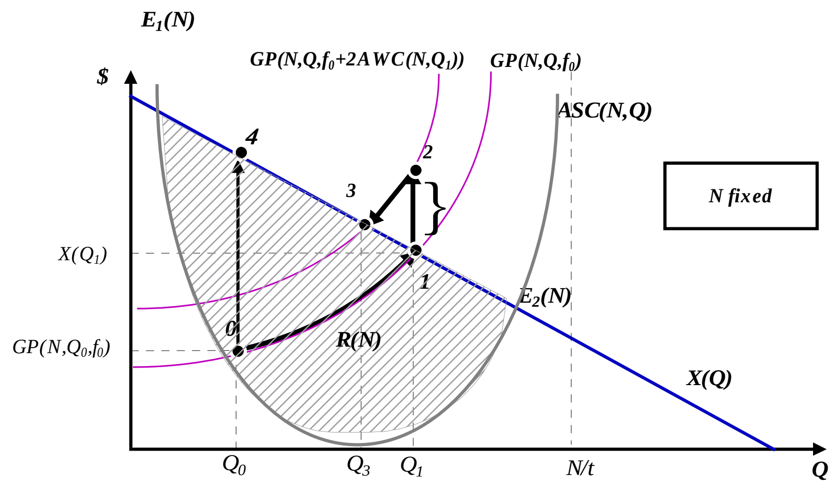


**FIGURE 5: Short Run Feasible Region and Market Adjustment Mechanisms**

From the first inequality in (19) we can obtain that:

[15] The case in which no intersection exists, corresponds to a situation where the production cost is higher than the willingness to pay for all values of Q, and therefore there is no feasible production of taxi services with free market conditions.

$$X(Q) \geq GP(N,Q,f) \Rightarrow X(Q) \geq f + AC_{pas}(N,Q) \qquad (20)$$

$$\Rightarrow X(Q) - AC_{pas}(N,Q) \geq f \quad \forall\, Q_{E1(N)} \leq Q \leq Q_{E2(N)}$$

which means that the fare value is lower than the net out of pocket willingness to pay. From the second inequality in (19) we obtain,

$$GP(N,Q,f) \geq ASC(N,Q) \Rightarrow f + AC_{pas}(N,Q) \geq AIC(N,Q) + AC_{pas}(N,Q) \qquad (21)$$

$$\Rightarrow f \geq AIC(N,Q) \qquad \forall\, Q_{E1(N)} \leq Q \leq Q_{E2(N}$$

which means that the fare value charged is higher than the average cost experienced by a typical taxi operator.

Every point in $R(N)$ is a possible outcome of the cruising taxi free market, with $N$ taxis. Therefore, in principle, they are all candidates for at least transitory existence in time[16]. Question is, are there among them some that are more probable to be observed? Points $E_1(N)$ and $E_2(N)$ are the only ones having the peculiarity that satisfy both (20) and (21) by equality: total willingness to pay equals the average system cost. Therefore, net willingness to pay (out of pocket) equals the fare value charged and this is equal to the industry average cost. They could therefore, be candidates for market equilibriums; however, there is still the question of their stability.

It is ease showing that $f_{E1(N)} > f_{E2(N)}$, $AC_{pas}(N,Q_{E1(N)}) < AC_{pas}(N,Q_{E2(N)})$ and that $\alpha(N,Q_{E1(N)}) < \alpha(N,Q_{E2(N)})$. Therefore, $E_1(N)$ corresponds to an operation with better level of service (lower waiting time) but with a more expensive fare, than $E_2(N)$.

### 4.3 Short run adjustments

To analyze the stability properties of different points in $R(N)$, we will analyze the existence of economic forces in the short run (keeping $N$ fixed). We consider two adjustment process in the short run.

Quantity adjustment. This is an adjustment of the number of taxi runs consumed by users, to maximize their utilities. We assume that the market demand function is obtained adding the individual demands and these are the output of rational decisions that maximize individual utilities. Therefore, starting from any point in $R(N)$ that is below the demand function, consumers will adjust the amount of taxi runs consumed, until a point on the demand function is reached.

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[16] Actually, we will see later that also some points outside $R(N)$could be transitorily observed. However, in such cases there will be always economic forces that will bring the market back to $R(N)$.

Let us assume that there are $N$ taxis in the market and we are in a feasible point like *0* in Figure 5. Passengers consume $Q_0$ runs, fare charged by operators is $f_0$ and the generalized price experienced is $GP(N,Q_0,f_0)$. However at that price, passengers are willing to increase their consumption which will take as to point *1*, where $Q_1$ runs are consumed ($Q_1 > Q_0$). $Q_1$ is obtained at the intersection of the market demand function with the generalized price function $GP(N,Q,f_0)$. The adjustment path from *0* to *1* corresponds to a segment of that generalized price function. Notice that, given that $N$ is fixed, the increase of $Q$ produces an increase of waiting times, which gradually increases the $GP$ value until point *1* is reached..

Fare adjustment. This is an adjustment undertaken by taxi operators, to maximize the profit obtained. As we saw above, taxi operators have economic incentives to unilaterally increase prices in a magnitude equal to $2AWC(N,Q)$, which depends on the magnitudes of the average passenger waiting time $w$ and the value of time $\theta$. These fare increases will be successful if they are validated by the passenger's willingness to pay, expressed by the demand function.

In Figure 5 this type of adjustment, will take the market from point *0* to point *4*, with successive small increases of fares, each of them smaller than $2w\theta$. A similar adjustment process can occur starting from any interior point of $R(N)$. However the fare adjustment can operate even if the point is on the demand function. This is graphically represented starting from point *1*; at this point the fare value is equal to $f_0$. If taxi operators rise the fare charged by the amount $2w\theta$, they will reach point *2*, which is not a feasible market solution, because, at the new fare value ($f_0 + 2w\theta$) passengers are willing to consume less than $Q_1$ runs. In this case the process is completed by an adjustment in quantity that takes the market from point *2* to point *3*. Point *3* corresponds to the intersection of the demand function and the generalized price function $GP(N,Q, f_0 + 2w\theta)$. Point *3* represents a new transitory short run market condition.

In principle, both types of short run adjustments defined are possible, starting from a situation represented by a point of the feasible region. A succession of these adjustments, will tend to bring the market towards point $E_1$. From the analysis made we can conclude that: i) point $E_2$ is unstable and ii) market forces will tend to take the market to the vicinity of point $E_1$. Although we can not say that point $E_1$ is an stable equilibrium, it seems reasonable to conclude however that, if short run conditions remain long enough, the most probable market conditions will be those described by a vicinity of point $E_1$. The size of this vicinity should be directly related to the value of $2w\theta$[17].

**4.4 Long run adjustments**

The adjustment mechanisms described above assume that the number of taxis *N* remains fix. Now we will analyze long run adjustments obtained when the number of taxis change.

A change in the number of taxis will be in general motivated by benefits or loses, experienced by the existing taxi operators. Benefits will be obtained if the market condition corresponds to a point inside the feasible region (*R(N)* in Figure 5) but above the average system cost function, *ASC(N,Q)*. In particular, benefits will be obtained if the market condition corresponds to any point on the segment of demand function located between the private market equilibriums $E_{1(N1)}$ and $E_{2(N1)}$.

[17] Notice that at point $E_1$ waiting time *w* has a very small value, because occupancy rates are low in comparison to other operating conditions (see end of 4.2).

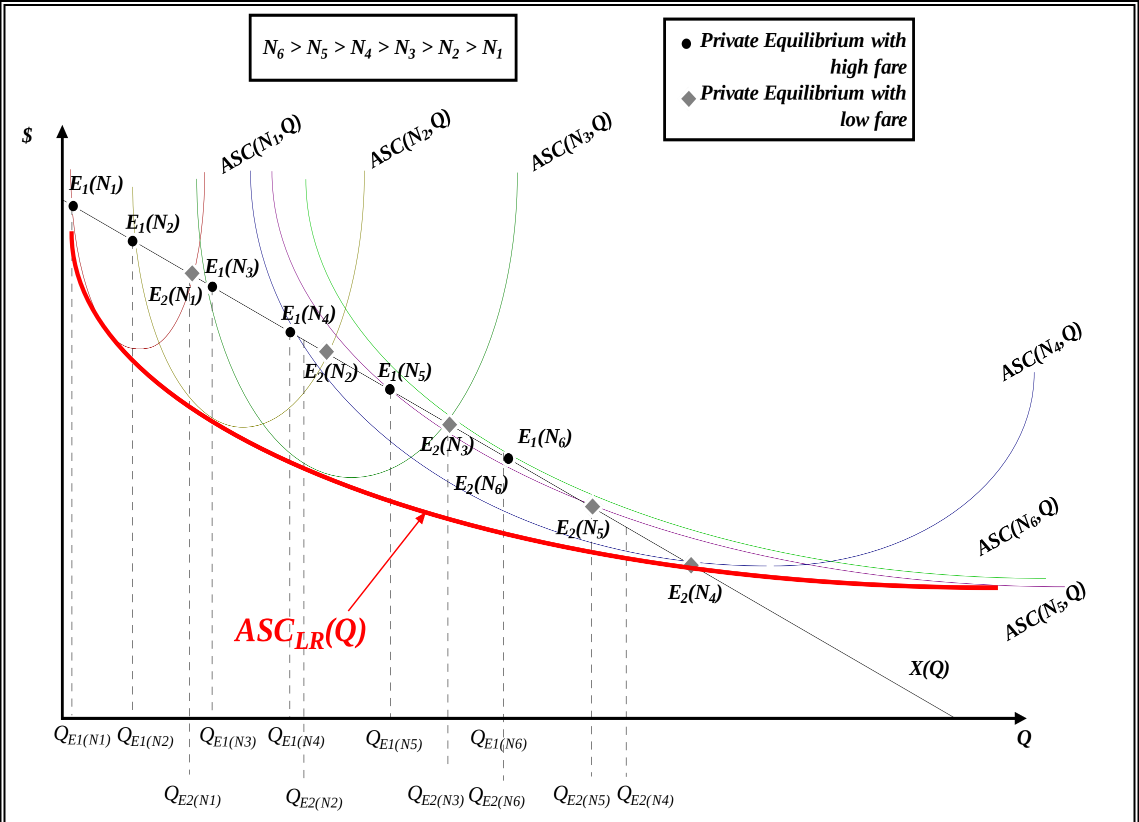


**FIGURE 6: Change of Market Conditions in the Long Run**

As we saw in section 3 the entry of additional taxis to the market produces a shift to the right of the *ASC* function (see Figure 2(b)). In Figure 6, a number of *ASC* functions are shown for different taxi fleet sizes ($N_1$ to $N_6$). We can see that when the number of taxis in the market increases, point $E_1$, moves down on the demand function (south-east in the figure); therefore, the number of runs, $Q_{E1}$, increases and the generalized prize decreases.

$$Q_{E1(N1)} < Q_{E1(N2)} < Q_{E1(N3)} < Q_{E1(N4)} < Q_{E1(N5)} < Q_{E1(N6)},$$

$$\text{and} \tag{22}$$

$$GP(E_1(N_1)) > GP(E_1(N_2)) > GP(E_1(N_3)) > GP(E_1(N_4)) > GP(E_1(N_5)) > GP(E_1(N_6))$$

The effect of the increase in $N$ over point $E_2$ is different, because, in this case the number of runs produced increases only till the number of taxis reaches $N_4$ and then decreases, while the number of taxis keeps increasing up to $N_6$. The contrary happens with the corresponding generalized price values:

$$Q_{E2(N1)} < Q_{E2(N2)} < Q_{E2(N3)} < Q_{E2(N4)} > Q_{E2(N5)} > Q_{E2(N6)}$$

$$\text{and} \tag{23}$$

$GP(E_2(N_1)) > GP(E_2(N_2)) > GP(E_2(N_3)) > GP(E_2(N_4)) < GP(E_2(N_5)) < GP(E_2(N_6))$

Notice that when the number of taxis is equal to $N_4$, point $E_2(N_4)$ corresponds to the minimum value of the total average system cost function for $N_4$ $(ASC(Q,N_4))$[18]. When the number of taxis is equal to $N_6$, the corresponding Average System Cost function, $ASC(N_6,Q)$, is tangent to the demand function $X(Q)$. Therefore, the short run feasible region $R(N_6)$ collapses into only one point. In the following figures the capital letter $T$, and the corresponding number of taxis, $N_T$, and runs, $Q_T$, will identify this tangency point. For values of $N$ higher than $N_T$ there is no intersection and therefore no feasible market solution exists. Then $N_T$ corresponds to the maximum number of taxis that can operate in the long run, under free market conditions[19].

$$ASC(N,Q) > X(Q), \quad \forall Q \quad if \quad N > N_T \tag{24}$$

Then, at point $T$, $(N_T,Q_T)$ the passengers willingness to pay is equal to the average system cost and therefore industry profits, $\pi_{Ind}(N_T,Q_T)$, are zero.

$$\pi_{Ind}(N_T,Q_T) = \{X(Q_T) - ASC(N_T,Q_T)\} \cdot Q_T = 0 \tag{25}$$

This, as we saw it also happens for points $E_1(N)$ and $E_2(N)$, corresponds to a situation where the net (out of pocket) passengers willingness to pay is equal to the equilibrium fare charged by the $N_T$ taxi operators, which is also equal to the average taxi cost.

Figure 7 shows a combination of short and long run market adjustments. Point *1* corresponds to a condition where $N_1$ taxis operate in the market obtaining positive benefits, represented by the shaded area $A_1$. Then, economic incentives will exist for new taxis to enter the market. As the number of taxis increases from $N_1$ to $N_2$, market conditions will be modified as follows:

i) The generalized price value decreases (see Figure 3) because passengers waiting time is reduced. In Figure 7, segment *1-2* represents this change, assuming that the number of runs $Q_1$ and the fare value $f_1$ stay temporarily constant.

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[18] Actually, $E_2(N_4)$ corresponds to the point where the demand function intersects with the trajectory formed by the minimum values of all the total average cost functions (see Figure 2(b)).

[19] Therefore there is no feasible region for $N > N_T$

ii) Simultaneously with the generalized price reduction, the average system cost function shifts to the right (see Figures 2-b and 6). In Figure 7, $ASC(N_2,Q)$ intersects the demand function at point *1*.

iii) As the *ASC* function shifts to the right, benefits obtained by operators (at points *1*and *2*) are reduced because the vertical distance with the average system cost decreases. When the number of taxis in the market gets to $N_2$, benefits are zero at point *1* and negative at point *2*. Notice that, there is a value of $N = N'$, with $N_1 < N' < N_2$, for what the $ASC(N',Q)$, goes through point *2*. Then for $N = N'$, benefits are zero for market conditions represented by point *2*, but positive for those represented by point *1*.

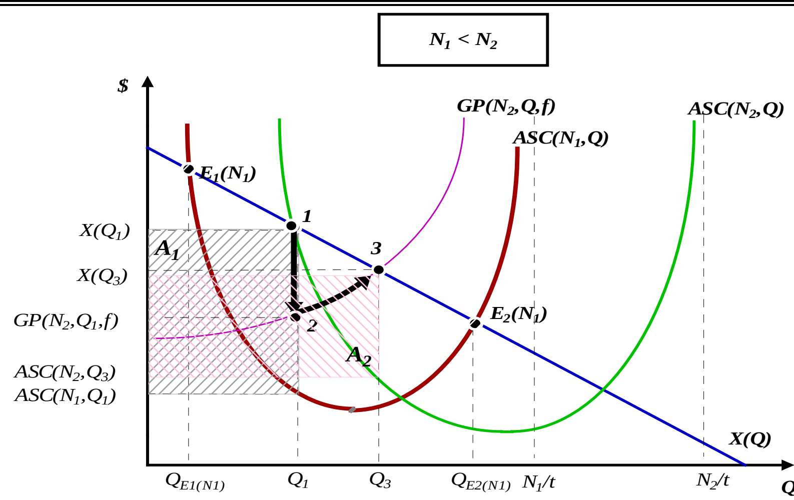


**FIGURE 7: Combination of Short and Long Run Market Adjustments**

However, depending on the length of time that takes new taxis to enter the market, at any intermediate point like *2*, (or for any point above it, on segment *1-2*) before total benefits are banished (before $N$ gets to $N_2$), short run adjustments could start to work in combination with the long run adjustment of $N$. For instance, segment *2-3* represents a short run quantity adjustment. Also a short run fare adjustment could start simultaneously to work, once an interior point of the feasible region is reached. These adjustments will tend to take market conditions back to a point on the demand function, located between the current points $E_1$ and $E_2$. An example, corresponds to point *3*, where if $N = N_2$ taxi operators obtain benefits represented by area $A_2$.

Therefore, all adjustment mechanisms described above will tend to get the market to the condition represented by the tangency point *T*. However, as was the case for $E_1$ and $E_2$, although point *T* is a candidate for a long run market equilibrium we can not guarantee that such conditions will remain without changes. The short and long run adjustment processes described above could transitorily take market conditions out of point *T*[20]; however the same economic forces analyzed will tend to drag market conditions back to point *T*, as long as demand and costs do not change. Then, long run market conditions will oscillate around point *T*. We will therefore call it: a long run "quasi-equilibrium".

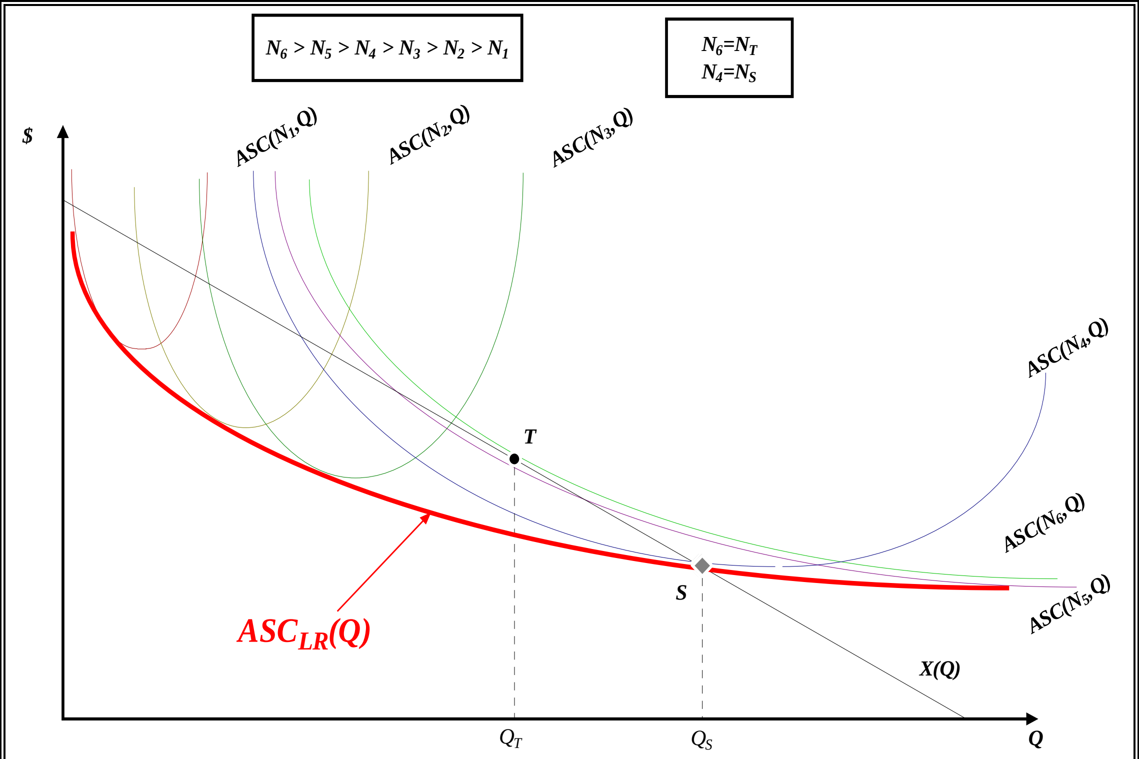


**FIGURE 8:** **Social Optimum (*S*) vs. Long Run Free Market Quasi-Equilibrium (*T*)**

**Comparing Private Equilibrium and Social Optimum Solutions.**

Characteristics of short run average system cost functions, allow us to conclude the following (see, Figure 8):

i) At a long run free market quasi-equilibrium *T*, the number of taxis in operation will be higher than at a second best solution *S*: $N_T > N_S$.

[20] This could happen because of the constant incentive to rise prices by individual operators, or as a consequence of imperfect information of potential operators, with respect to market profits.

ii) The number of runs produced and consumed is higher for the second best solution than for the private market equilibrium: $Q_S > Q_T$

iii) The average taxi occupancy rate is higher for the second best solution than for the private equilibrium[21]: $\alpha(N_T,Q_T) < \alpha(N_S,Q_S)$.

iv) Operators benefits are zero for both points *T* and *S*, but the fare charged by taxi operators is lower for the second best solution than for the private equilibrium[22]: $f_S < f_T$.

*v)* At the second best solution, average system cost is lower than at the quasi-equilibrium *T* : $ASC(N_S,Q_S)<ASC(N_T,Q_T)$.

*vi)* The generalize price is lower at *S* than at *T*: $GP(N_S,Q_S, f_S) < GP(N_T,Q_T, f_T)$.

From the characteristics analyzed it is obvious that the second best solution *S*, is socially preferred to the private equilibrium *T*. It produces a higher social benefit: consumer surplus plus operators profits (in this case profits are cero both at *T* and *S*).

## 7. Regulatory Policies

There has always been a general agreement among analysts that free market conditions do not produce a social optimum solution in the operation of a cruising taxi system. In particular, some authors have questioned that a market equilibrium can be obtained (Cairns and Liston-Heyes (1996)). Therefore different propositions have been made in the literature with respect to regulatory policies. In this section we analyze those of them most commonly proposed and used in practice.[23]

### Fare and Fleet Size Regulation

This policy has been recommended by several authors and widely used in taxi markets. Given that to obtain a social optimum *O*, the use of subsidies would be necessary, we will assume in the following that the objective of regulatory policies is obtaining a second best solution like *S* (see figure 4). According to the analysis made in section 4, a market condition *S* can be obtained if generalized price is set equal to a value given by

[21] Considering that $\alpha(N_T{\cdot},Q_T) = Q_T{\cdot}t/N_T$ and $\alpha(N_S{\cdot},Q_S) = Q_S{\cdot}t/N_S$, this is directly obtained from (i) and (ii) because: $(Q_S t/N_S) > (Q_T t/N_T)$

[22] Considering that $f_T=N_T{\cdot}c/Q_T$ and $f_S=N_S{\cdot}c/Q_S$, this is directly obtained from (i) and (ii) because: $(N_S c/Q_S) < (N_T c/Q_T)$

$GP(N_S,Q_S,f_S)$, that be equal to the Long Run Average System $ASC_{LR}(Q_S)$ (see Figure 4.). From (18) we have that:

$$f_S = \frac{N_S \cdot c}{Q_S} = \sqrt{k \cdot c / Q_S} + t \cdot c\,, \text{ with: } N_S = \sqrt{k \cdot Q_S / c} + Q_S \cdot t\,,$$

However, from (14), $GP(N_S, Q_S, f_S) = f_S + AC_{pas}(N_S, Q_S)$; therefore $S$ will be obtained only if, in addition to setting fares to $f_S$, passenger experience an average cost equal to (see, (9)):

$$AC_{pas}(N_S, Q_S) = \phi \cdot t + \frac{k}{N_S - Q_S \cdot t}$$

Therefore, to get $S$ it is necessary not only fixing $f = f_S$, but also that $N = N_S$. However, once $S$ is obtained, with $(f_S, N_S)$, the operating conditions will be stable, as long as $f_S$ is enforced. Given that at $S$ profits are zero, there will not be incentives to change the number of taxis $N$. Also, because fares are regulated, the fare adjustment mechanism analyzed in section 4.3, that tends to increase prices taking the market away from $S$ towards $E_1$, can not operate. Therefore, in order to stay at $S$ it is enough fixing fares at $f_S$.

Figure 9, shows how a market shift from $T$ to $S$ can be produced. Starting from $T$, with $(N_T,Q_T, f_T)$, if fare and fleet size are changed and fixed to $f_S$ and $N_S$, given by (18), a reduction of the generalized prize is experienced from $GP(N_T,Q_T,f_T)$, corresponding to point $T$, to $GP(N_S,Q_T,f_S)$[24], corresponding to point *1* in the figure. But for that value of $GP$, taxi users are willing to consume $Q_S$ runs instead of $Q_T$. Therefore a quantity adjustment represented by segment *1*-$S$ will occur taking market conditions to $S$, where they will stay as long as fare $f_S$ is enforced[25].

[23] The importance of obtaining S instead of T, will depend of the magnitude of the social lose. In a study of the Santiago (Chile) taxi system, it was found that loses associated to condition T, compared with S, were highly significant (43%).

[24] Notice that $GP(N_SQ_{,},f_S)$ goes through $S$, for $Q = Q_S$

[25] Notice that the average system cost function $ASC(N_S,Q)$ goes through point $S$, for $Q = Q_S$ and therefore zero profits are experienced at that point.

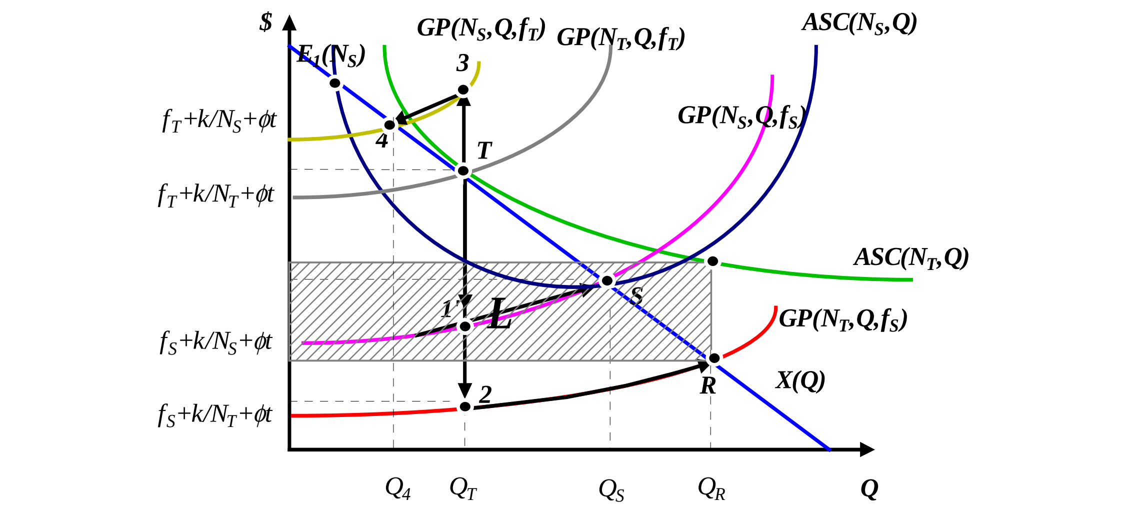


**FIGURE 9: Fare and Fleet Size Regulation**

Alternatively, if starting again from *T*, only the fare is changed to $f_S$, but fleet size remains equal to $N_T$, the generalized prize value will experience a reduction from $GP(N_T,Q_T, f_T)$, to $GP(N_T,Q_T, f_S)$[26], which corresponds to point *2* (below *1*). For the new value of *GP*, taxi users are willing to consume $Q_R$ instead of $Q_T$; therefore a quantity adjustment represented by segment *2-R* will occur, taking market conditions to *R*. However, at *R*, the $N_T$ taxis experience loses represented by shaded area *L*. Therefore, if by regulation fares are forced to remain equal to $f_S$, some taxis will exit the market until the increase in occupancy rate eliminates loses. As taxis exit the market, the reduction of fleet size, *N*, will make the average system cost function shift to the right from $ASC(N_T,Q)$ and the generalized price function will move up from $GP(N_T,Q,f_S)$. Loses will vanish (zero profits) when the average system cost function gets to $ASC(N_S,Q)$ and the generalized price gets to $GP(N_S,Q,f_S)$; both functions intersect at *S*. Therefore, it is not necessary to regulate fleet size to obtain second best conditions *S*; fare regulation can make the job, given that the loses produced at *R* will incentive some taxis to exit the market until the fleet size gets to $N_S$. This means that entry can be kept free, which can make the regulation policy easier to apply.

It is important noticing that taxi operating cost ***c*** is directly related to the quality of service offered: type of car used, driver qualifications, maintenance standards, etc. Also

[26] $GP(N_T,Q_T,f_s)$ is lower than $GP(N_S, ,Q_T, f_S)$, because given that $N_T>N_S$, waiting times are lower at point *2* that at point *1*.

notice that $ASC(N_S,Q)$ and the position of point $S$ are directly influenced by the value of $\boldsymbol{c}$ (see equations (11) and (16)). Therefore, practical implementation of fare regulation, requires setting up the service quality standards that are assumed in the value of $\boldsymbol{c}$ used to calculate the regulated fare. Otherwise, fare regulation will be meaningless, because operators can reduce $\boldsymbol{c}$**,** through service quality reductions.

**Fleet Size or Entry Regulation.**

If only entry or fleet size is regulated, it is easy to see that market conditions will never get to, neither stay at, $S$. Assume that we fix fleet size to $N_S$; then, unless fares are simultaneously fixed to $f_S$. market condition $S$ will not be obtained. Let us assume again that market conditions are initially at $T$; if fleet size is reduced to $N_S$, generalized price will increase from $GP(N_T,Q_T,f_T)$ to $GP(N_S,Q_T,f_T)$, because the fleet reduction will make increase passenger waiting times. Market conditions will then shift from $T$ to $3$ in Figure 9. However, for the generalized price value corresponding to point $3$, taxi users are only willing to consume $Q_4$ runs; therefore the corresponding quantity adjustment will take market conditions to point $4$, through segment $3$-$4$. Once condition $4$ is reached, successive fare increases (equal to $2\theta w$) and quantity adjustments (reductions of runs consumed) will take the market to the neighborhood of point $E_1(N_S)$[27].

Even starting at point $S$, if fares are not fixed to $f_S$, the same process of successive small fare increases, followed by quantity adjustments, will take the market to $E_1(N_S)$. Therefore, entry or fleet size regulation is not a good policy, because it always ends up with too low occupancy rates and too high fares, significantly reducing consumer surplus (and therefore social benefits[28]). It is easy to see in Figure 9 that, market conditions $T$, obtained as the result of free market policy (free fares and free entry) are socially better (generate more surplus) than market conditions $E_1(N_S)$ obtained when only fleet size is fixed equal to $N_S$. Therefore, fleet size regulations will in general be socially worse than free market policies.

**Licensing Policy.**

[27] The process is the same analyzed in section 4.3 (Figure 5).

[28] In a quantitative application made to the city of Santiago (Chile) it was found that the welfare loses, corresponding to point $E_1(N_S)$, were as high as 90%, with respect to $S$:

Two ways of implementing a licensing policy are the following: i) some authority (regulator) charges a license (a given yearly amount) to those taxis willing to enter the system, or ii) a licenses market is implemented as a complement of fleet size regulation.

For the first case let us assume a market quasi-equilibrium $T$, with $(N_T,Q_T)$, obtained assuming taxi operating costs $\boldsymbol{c}$ (figure 10). Adding the license cost increases taxi operating costs form $\boldsymbol{c}$ to $\boldsymbol{c'}$. This produces an upward shift of average system costs functions $ASC(N,Q)$ (see equation (11) and Figure 2) and generates a new family of relevant functions $ASC^L(N,Q)$, with operating costs $\boldsymbol{c'}$. Therefore, if no additional regulations are implemented, a new free market quasi-equilibrium $T^L$, will emerge at the tangency point between demand $X(Q)$ and the average system cost function $ASC^L(N_{TL},Q)$. At the new quasi-equilibrium $T^L$, fleet size $N_{TL}$ must be lower than $N_T$, because some taxis will exit the system induced by the loses produced in the short run (Figure 10), after the license introduction. The exit of taxis will take place until loses are eliminated. Given the negative slope of the demand function, the upward move of the average system cost functions from $ASC$ to $ASC^L$, produced by the license cost, and the shift to the left (from $ASC^L(N_T,Q)$ to $ASC^L(N_{TL},Q)$) produced by the fleet size reduction (see figure 2), the new number of runs $Q_{TL}$ will be also lower than the initial quasi-equilibrium value $Q_T$. It is important noticing that if the license value charged is too high (for the given value of $\boldsymbol{c}$) there could be no feasible tangency point $T^L$.

For the second case, let us assume that fleet size is regulated to $N_{TL}$, with $N_{TL}<N_T$. This is implemented by giving special operating permits (licenses) to $N_{TL}$ taxis. Then, each license will have an economic value equal to the present value of the profits obtained from the taxi operation. In order to make an efficient allocation of available licenses, among potential taxi operators, they can be made transferable, allowing a market of licenses. Maintaining a license will therefore have a financial cost for the operator, producing an operating cost increase. This will shift upwards the average system cost function $ASC(N_{TL},Q)$, until it becomes tangent to the demand function at a point $T^L$. $ASC^L(N_{TL},Q)$ is the average system cost function that includes the license cost and is tangent to the demand at $T^L$.

The main difference between the two licensing systems is that in the first case a surplus is produced for the government, equal to $LC$ in figure 10. In both cases the introduction of the license is consistent with a reduction of taxis in the system. However, for the second case analyzed, the introduction of negotiable licenses improves the market conditions with respect to those obtained when only fleet size is regulated (equal to $N_{TL}$), without licenses, because point $T_L$ is socially preferred to $E_1(N_{TL})$.

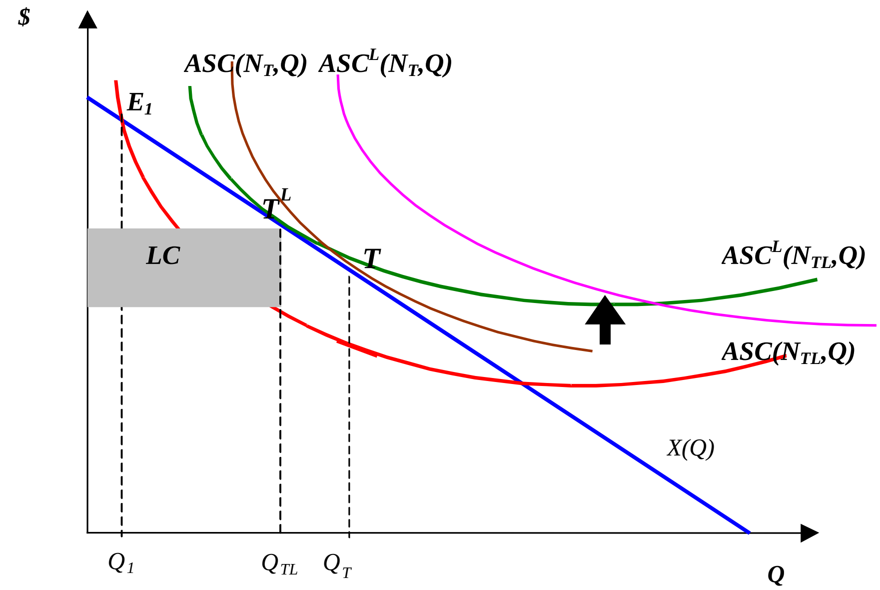


**Figure 10: Licensing Policies**

The change from $E_1(N_{TL})$ (fleet regulation without license values) to $T_L$ (fleet regulation with license values) implies a reduction of the generalized price perceived by taxi users, from $GP(N_{TL},Q_1,f_{E1})$ to $GP(N_{TL},Q_{TL},f_{TL})$. System conditions improve with such change. However, there are no decentralized mechanisms in the market to produce the move from quasi-equilibrium $E_1(N_{TL})$ to quasi-equilibrium $T_L$, with fleet size regulated. Such move requires a reduction of service fares from $f_{E1}$ to $f_{TL}$, in order to produce a decrease of the generalized price from $GP(N_{TL},Q_1,f_{E1})$ to $GP(N_{TL},Q_1,f_{TL})$. This will produce then an increase in the quantity of runs demanded from $Q_1$ to $Q_{TL}$. However the natural tendency of individual taxi operators will be to increase fares, as a consequence of the increase of operating costs produced by the licenses. Only an imposition of the new reduced fares $f_{TL}$ in addition to the fleet regulation at $N_{TL}$, could take the system from $E_1(N_{TL})$ to $T_L$.

The difference between the values of $ASC^L(N_{TL},Q_{TL})$ and $ASC(N_{TL},Q_{TL})$, multiplied by the number of runs $Q_{TL}$, corresponding to point $T^L$, represents the cost of financing the

$N_{TL}$ licenses for the operating period analyzed (*LC* in figure 10). The corresponding cost per license can be obtained dividing this value by $N_{TL}$. Notice that the indicated total financial cost is equal to the profits that the $N_{TL}$ operators would obtain if they produce and sell $Q_{TL}$ runs with an average system cost given by $ASC(N_{TL},Q_{TL})$; in other words with a zero license value ($\boldsymbol{c}' = \boldsymbol{c}$).

## 8. <u>Final Comments, Conclusions and Extensions</u>

A diagrammatic approach has been developed to analyze the characteristics of the cruising taxi market. This allows us to represent and analyze different operating conditions for the cruising taxi system: social optimum conditions and short and long run free market outputs. As in the social optimum taxi operators suffer loses, we introduce the consideration of a second best solution with financial constraints (non-negative profits). Different system conditions are described in terms of number of taxis in operation, number of runs produced, fares charged, average production costs and generalized prices. Short and long run adjustment processes are described to explain the market mechanisms that produce such system conditions.

We argue that producers of cruising taxi services do not perceive well defined individual demand functions and therefore the usual price determination rule, of marginal revenue equal marginal cost, can not be applied. To avoid this difficulty in the determination of free market conditions we take an industry approach, based on the use of the total system average cost and demand functions. Thus, we derive short run and long run quasi-equilibrium conditions. These are not normal supply-demand equilibriums, because they are not totally stable and some changes can be expected around the point describing its most probable conditions. These changes are produced by the existence of permanent incentives of individual operators to rise fares, derived from the inexistence of a well defined individual demand function[29].

We use the diagrammatic analysis to show the differences between free market quasi-equilibriums, social optimum conditions and the second best solution. The maximum

[29] This is different to the effect produced by lack of perfect information of potential taxi operators, which could enter the market wrongly assuming positive profits. This could happen in any market and has nothing special. What is special of this market and produces the instability mentioned is the permanent incentive of operators to rise fares, based on the choice cost (waiting time cost) faced by consumers of taxi services.

fleet size is obtained for free market conditions, and the maximum number of runs produced corresponds to the social optimum. Short run conditions ($E_1$), when the number of taxis in operation is lower than that corresponding to a long run free market quasi-equilibrium, leads in general to low number of runs, high generalized price and fares, with low occupancy rates.

In the final sections we analyze the most commonly used regulatory policies. We show that price regulation allows to obtain a social optimum or a second best solution and that entry regulations are in such case redundant. On the contrary, entry regulations alone (without price regulation) that reduce fleet size, with respect to the free market case, produce worse system conditions than free market. They are further away from the social optimum than free market outcomes. In the limit, they could be at most equal to those generated by free market, when the regulated fleet size is taken equal to the free market fleet size. In such case fleet regulation is obviously superfluous. Finally, we show that licensing can contribute to improve conditions generated by entry regulations, bringing them closer to the social optimum by modifying taxi operating costs. It is also argued that level of service regulation is in general necessary to fix taxi operating cost making meaningful the fare charged.

A logical extension of the analysis presented in the paper is the introduction of congestion, which will modify the cost functions considered. It would also be interesting to apply the analysis to other taxi operations modalities.

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**Appendix A**

Here we study the characteristics of the function that contains the minimum points of the short run Average System Cost functions. First we calculate the expression for the value of $Q = Q_{min}$, corresponding to the minimum value of *ASC(N,Q)*. For that we take de derivative of *ASC(N,Q)* with respect to $Q$ and make it equal to zero:

$$\frac{\partial ASC(N,Q)}{\partial Q} = \frac{\partial\left(\frac{Nc}{Q} + \phi t + \frac{k}{N - Qt}\right)}{\partial Q} = \frac{Nc}{Q^2} + \frac{kt}{(N - Qt)^2} = 0 \tag{A.1}$$

Then reordering terms we have:

$$\frac{kt}{Nc} = \frac{(N - Qt)^2}{Q^2} \tag{A.2}$$

Now taking square root to both terms and isolating $Q$ we obtain the expression $Q_{min}(N)$:

$$Q_{min}(N) = \frac{N}{\sqrt{\frac{kt}{Nc}} + t} \tag{A.3}$$

$Q_{min}(N)$ represents the number of runs that minimize the Average System Cost function corresponding to a fleet size N. If we now replace back expression (A3) into the expression of *ASC(N,Q)* we get:

$$ASC(N, Q_{\min}(N)) = 2c\sqrt{\frac{kt}{Nc}} + ct + \frac{k}{N} + \phi t \tag{A.4}$$

(A4) is the expression of the function that contains the minimum points of all short run average cost functions. Now we can take the derivative of this function with respect to $Q$:

$$\frac{\partial ASC(N, Q_{\min}(N))}{\partial N} = \frac{\partial\left(2c\sqrt{\frac{kt}{Nc}} + ct + \frac{k}{N} + \phi t\right)}{\partial N} = -\frac{kt}{\sqrt{\frac{kt}{Nc}}}\frac{1}{N^2} - \frac{k}{N^2} < 0 \tag{A.5}$$

We can observe from (A5) that, because all the variables involved in the expression have positive values and the two terms involved have a minus sign, then the value of the derivative is negative for all values of $N$. This indicates that the analyzed function is always decreasing with $N$. Therefore, the average cost corresponding to $Q_{min}(N)$ decreases as the number of taxis in the market increases.

**Appendix B**

We obtain here the expressions corresponding to the long run functions: Total System Cost $TSC_{LR}$, Average System Cost $ASC_{LR}$ and Marginal System Cost $MSC_{LR}$.

If we multiply the short run Average System Cost function (11) by $Q$ we obtain:

$$TSC(N,Q) = ASC(N,Q)\cdot Q = N\cdot c + \phi\cdot t\cdot Q + \frac{k\cdot Q}{N - Q\cdot t} \tag{B.1}$$

And derivating with respect to N:

$$\frac{\partial\big(TSC(N,Q)\big)}{\partial Q} = c - \frac{k\cdot Q}{(N - Q\cdot t)^2} = 0 \tag{B.2}$$

from where we obtain that the long run optimal relation between $N$ and $Q$ is equal to:

$$N^*(Q) = \sqrt{\frac{k\cdot Q}{c}} + Q\cdot t \tag{B.3}$$

Then, the Long Run Total Production Cost is:

$$\begin{aligned} TSC_{LR}(Q) &= TSC(N^*,Q) = N\cdot c + \phi\cdot t\cdot Q + \frac{k\cdot Q}{N - Q\cdot t} \\ &= 2\cdot\sqrt{k\cdot Q\cdot c} + Q\cdot t\cdot(c+\phi) \end{aligned} \tag{B.4}$$

Now, dividing by $Q$, we obtain the Long Run Average System Cost Function:

$$ASC_{LR}(Q) = \frac{TPC_{LR}(Q)}{Q} = \frac{2\cdot\sqrt{k\cdot Q\cdot c}}{Q} + t\cdot(c+\phi) \tag{B.5}$$

and derivating the $TSC_{LR}$, with respect to Q, we obtain the long run Marginal System Cost Function:

$$MSC_{LR}(Q) = \frac{\partial[TSC_{LR}(Q)]}{\partial Q} = \frac{\sqrt{k\cdot Q\cdot c}}{Q} + t\cdot(c+\phi) \tag{B.6}$$