# WORKING PAPERS

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**Selection Effects in Regulated Markets**

July 2008

Working Paper No: 0810

# DEPARTMENT OF ECONOMICS

# UNIVERSITY OF VIENNA

# Selection Effects in Regulated Markets

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July 16, 2008

**Abstract**

This paper analyzes dynamic selection effects that arise in a regulated market where price structures are determined by a regulator or central management. Consumers come in different types where each type requires a different service or treatment. We show that for a large class of price structures some group of customers is refused the service. Equilibria with selection are welfare inferior to equilibria without selection. We also characterize the class of price structures for which selection does not arise. As the number of customers increases or agents become more patient the class of selection-free price structures shrinks and in the limit it is unique. Moreover, all other price structures induce selection. The general model can be applied to a variety of markets, including health care and taxi markets.

**JEL-codes: I11, L51, R48**

**Key Words: Selection, Regulated Markets, Fare regulation, Taxi Markets**

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# 1 Introduction

Consider yourself arriving after a long trip at the railway station of your final destination. You know it is not too far to your hotel, but you want to take a taxi because of your luggage and because of the fatigue. Taxis are standing in line and have regulated non-negotiable fees. You walk up to the first taxi waiting in line and after hearing where you want to be taken, the driver tells you that you better walk because he refuses to take on passengers for such a short distance. As an economist, you may wonder: is this rational behaviour on the part of the taxi driver? If so, what is the role of the fare structure and does a fare structure exists where potential passengers are not refused? Can it be socially optimal that potential passengers are refused?

There are a certain number of elements that are crucial to the above example. First, consumers arrive sequentially to demand some service and come in different treatment times or "complexities". In the taxi example: different passengers have different travel destinations and thus require different travel time. Second, the fare structure (how price depends on treatment time or "complexity") is fixed by a regulating authority or central company management. In the taxi example: in different countries around the world, taxi drivers are not free to determine their own fare structure, but the fare structure is centrally programmed in the taxi meter. Third, agents who actually provide the service can either accept or reject customers based on comparison of benefits and costs. In the taxi example: taxi drivers are "free" to tell potential clients that they do not take them.[1] It is optimal for a taxi driver to refuse a passenger if the expected discounted revenue of waiting for the next passenger (the chance of getting " big fish") is larger than the revenue of taking the current passenger and waiting before a next passenger can be taken on. This, of course, assumes that the taxi driver receives at least a part of the revenue of the ride.

The taxi market is not the only market where these features are present. In many countries, many parts of the medical sector also satisfy the main features outlined above. First, patients demanding some treatment enter a hospital or private clinic sequentially. Second, medical doctors are not free to set their own fees, but instead the fees per treatment are set by government authorities. Finally, medical doctors can refuse to take on patients and send them to other hospitals sometimes giving the argument that other doctors are better equipped to provide the proper treatment. Instead of selection, one may also observe what is called demand inducement in health care markets where medical doctors provide either more or a different treatment than what would be socially optimal for a patient with a particular disease. The phenomenon of demand inducement is of the same nature as the selection that appears in taxi markets: it exists because the provider prefers to deal with a different type of customer than the one they actually face. Though taxi drivers cannot induce demand (there is no possibility of bringing the customer to some other location), for medical doctors it is possible to provider some unnecessary treatment. Since demand

[1] A more official way to say this is that it is very difficult to enforce a system where taxi drivers have to take all passengers.

inducement by its nature is similar to selection, it can also be studied as part of our general framework. Other markets that have features that are described above include the market for social attorneys[2] and some repair markets (shoes, electronics) where prices for standard repairs are set at the central management level and franchise holders bear the revenues and costs.

In this paper we analyze markets that are characterized by the three features mentioned above. We show that for a large class of price schedules, selection (or demand inducement) is a crucial aspect of the equilibrium in these markets: depending on the price schedule either consumers with a low level of complexity or consumers with a high level of complexity are refused. We then characterize the (class of) price structures for which selection does not arise. As the number of customers increases or agents become more patient this class of selection-free price structures shrinks and in the limit it is unique. We also show that selection is always bad from a welfare point of view in the sense that for any price structure that gives rise to selection, there exists another price structure without selection that generates a higher total surplus.

To the best of our knowledge there are relatively few papers on selection effects in regulated markets. There is, however, some literature on demand inducement in health care markets, where the modeling and measurement of induced demand is one of the main topics. This literature started with Evans (1974) who studied "supply-induced demand". McGuire and Pauly (1991) studied the demand inducement problem under regulated fees in a static setup and they characterized possible demand inducement based on physician's utility function (where intrinsic motivation also plays a role). They studied physicians responses to changes in fees as well. The model is static, although time is taken into account through the physician's preference for leisure. Gruber and Owings (1996) extended the model by introducing a parameter capturing overall demand and supply conditions. Wright (2007) described selection of the patients between public and private hospitals based on different fee structures. To the best of our knowledge no paper in this literature studies the optimal price structure avoiding demand inducement and they also do not provide a dynamic analysis of selection or demand inducement.

On taxi markets, there is some literature on the desirability of entry and price regulation. Tullock (1975) and Williams (1980), among others, have argued in favour of deregulation, basically using standard arguments on the welfare effects of perfect competition. Proponents of regulation (such as Beesley (1973, 1979) and Teal and Berglund (1987) have argued that due to the pecularities of the taxi market, some form of regulation may be necessary for a proper functioning of the market. Cairnes and Heyes (1996) also mention the rather mixed success with experimentation with deregulation in some US cities in the 1980s leading those cities to back away from the deregulation policy. Whatever one's views on the (theoretical) desirability of regulating the taxi market, fact is that most taxi

[2] In quite a few countries, low income families can apply for legal aid (attorneys) at a regulated fee. The fee structure has been modified recently in The Netherlands and this has lead to selection effects as attorneys argued the fee structure is such that they cannot provide legal aid to certain clients.

markets around the globe are heavily regulated. Cities as diverse in nature as New York, London, Tokyo, Amsterdam, Shanghai and Singapore all have price structures which are regulated (see, e.g., Yang et al. 2005). Although every city has a structure with an initial charge and a distance-based charge, the precise nature of the price structure differs from city to city.[3] What is striking is that certainly for smaller distances, almost all price structures are linear in distance. In some cities the price proportional to distance becomes lower, if distance is beyond a certain threshold. In this paper we show that such price structures always lead to selection of some customers.

The rest of the paper is structured as follows. The next section describes in detail the general model of selection we are analyzing in some detail. Section 3 presents the main results for generic price structures. Section 4 extends the analysis to study demand inducement effects where suppliers have the possibility of giving consumers a treatment that is different from the socially most optimal treatment given their complexity. Section 5 briefly analyzes the case where the arrival rate of customers follows a Poisson process. Section 6 concludes.

## 2 General Model

Consider a market where a consumer arrives and demands some service in each certain time interval $\Delta t$. Assume each consumer is characterized by a level of complexity $\theta$ which is randomly distributed over the interval $[\theta_{\min}, \theta_{\max}]$, with distribution $F(\theta)$. A customer of complexity $\theta$ derives a utility $u(\theta)$ from a service and a customer's reservation utility is normalized to 0. The market is (centrally) regulated, which means that the price structure per unit $g(\theta)$ is fixed by a central authority or by central management. Note, that the central authority does not observe the complexity $\theta$ of a particular customer; it just sets up a complete price structure for any $\theta$. There are $N$ (sufficiently large to meet the demand) agents who provide the service and in the basic model they simply decide whether or not to accept a customer on the basis of expected costs and benefits. This decision takes place after the customer reveals the information about his complexity $\theta$. Sometimes it is more beneficial for the agent not to take the first customer, but to wait for the next one. For simplicity, agents have infinite planning horizons and maximize the expected present value of future cash flows. Payment is made just at the moment when the customer is accepted. It is not possible for agents to influence the price structure. There are material costs per $c(\theta)$ and the time to treat a consumer of complexity $\theta$ is given by $t(\theta)$. The time cost implies that when a consumer is accepted no other consumer can be treated during the time period $t(\theta)$. We define $f(\theta) = g(\theta) - c(\theta)$ to be the net price. We assume that for any $\theta \in [\theta_{\min}, \theta_{\max}]$ $f(\theta) > 0$ to exclude trivial selection cases.

Obviously for some price structures it can be the case that it is more profitable to refuse a customer now, and to wait for the next one. In general it

[3] In addition, the fare may depend on delay-based charges, and additional week-end or night charges.

is possible that multiple groups of customers are excluded due to selection, but there is a subcase that is of particular interest, namely where selection is monotone. We say that selection is monotone if it is not the case that a customer with complexity $\theta_1$ is accepted and both customers with $\theta_0 < \theta_1$ and $\theta_2 > \theta_1$ are not accepted. Though the analysis below is applicable to the more general case where selection is not monotone, monotone selection allows us to simplify notation as it can be characterized by a unique cut-off level $\theta_a$ for which either all customers with smaller or larger complexities are not accepted (so we can parameterize selection). In case of low-$\theta$ selection, we get that the support of $\Phi(\theta;\theta_a)$ is $[\theta_a;\theta_{\max}]$, where $\theta_a$ is the lowest accepted complexity and $\Phi(\theta;\theta_a) = \frac{F(\theta)-F(\theta_a)}{1-F(\theta_a)}$. For high-$\theta$ selection, we obtain that the support of $\Phi(\theta;\theta_a)$ is $[\theta_{\min};\theta_a]$, where $\theta_a$ is the highest accepted complexity and $\Phi(\theta;\theta_a) = \frac{F(\theta)}{F(\theta_a)}$.

If there is selection, the probability that an agent faces an acceptable customer each period is $p(\theta_a)$ which is equal $1 - F(\theta_a)$ for the low-selection case and $F(\theta_a)$ for the high-selection case.

We assume that the objective function of agents is their discounted *expected* value of future cash flows *conditional on* $\theta$: $v(\theta)$.[4] The *unconditional* expected value of future cash flows we denote by $V$. It is important to emphasize that the value of $V$, which is the value prior to the moment when an agent knows the complexity of a particular customer, should be distinguished from the value of the process after this complexity is revealed. This latter value is $v(\theta)$ and can be either larger or smaller than $V$. The discount factor $\delta$ is assumed to be the same for all agents. As the model horizon is infinite and each time the agent has to make a decision whether or not to take a customer he faces the same situation, $V$ has to be constant over time.

In case of monotone selection, the agent's decision-making problem can be presented as in the tree below.

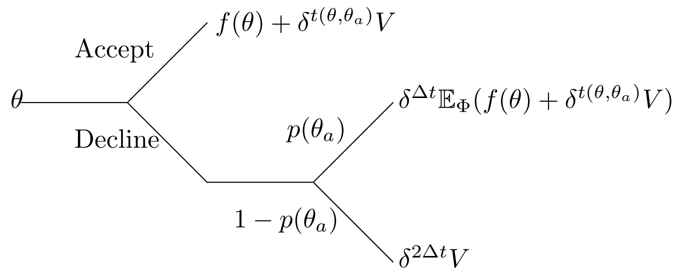
Once the agent knows the particular $\theta$ of a customer, he can either accept or reject the customer. If he accepts, he receives the price $f(\theta)$ from the customer and some expected continuation value. If he rejects the customer, he faces an acceptable customer with probability $p(\theta_a)$ in the next period, or he has to wait until the next period after that which gives him discounted value $V$. In an equilibrium with selection, the agent compares the value of accepting a customer now $f(\theta) + \delta^{t(\theta,\theta_a)}V$ with the expected value of waiting, which equals

$$p(\theta_a)\left[\delta^{\Delta t}\mathbb{E}_{\Phi}(f(\theta) + \delta^{t(\theta,\theta_a)}V)\right] + (1 - p(\theta_a))\,\delta^{2\Delta t}V.$$

If the pricing structure is such that every consumer is provided the service, then the agent should at least weakly better off by taking the consumers. As we will see, this invokes some restrictions on the parameters of the model.

[4]We abstract from discussions whether providers are also lead by different considerations, such as the health of their patients or the socially optimal level of service. We only say that if the provider is indifferent between providing any type of service, he will choose to provide the optimal service.

Figure 1: The decision tree of the service provider




# 3 Analysis

We are now ready to proceed with the analysis of the model. We first consider situations where every consumer is provided the service and then consider the case when selection may occur.

## 3.1 Full participation case

We now first characterize the (class of) price structure(s) that is such that all customers participate in equilibrium. Note, that in case of full participation $p(\theta_a) = 1$ so that the continuation value $V$ is defined by:

$$V = \mathbb{E}(f(\theta) + \delta^{t(\theta,\emptyset)}V), \tag{3.1}$$

where $t(\theta, \emptyset)$ is just a $t(\theta, \theta_a)$ in case there is no selection.

Full participation means that agents have no incentives to reject customers. Therefore, for any $\theta$ from the support of $F(\theta)$ we must have:

$$f(\theta) + \delta^{t(\theta,\emptyset)}V \geq \delta^{\Delta t}V \tag{3.2}$$

where $V$ is defined above.

Thus, we can formulate the following proposition:

**Proposition 3.1.** *A price structure $f(\theta)$ insures full participation of customers if and only if equations* (3.1),(3.2) *hold for $f(\theta)$.*

In general for a given price structure $f(\theta)$, agents may still prefer one type of customer to another even if all customers are taken. But since $\Delta t$ is some finite number, the agents still have no incentives to reject any consumer as the customer with the least profitable $\theta$ now is better than a costumer with an average $\theta$ later.

A particular case of an optimal price structure is when agents are purely indifferent between the customers, which means that even if $\Delta t$ goes to 0, selection does not arise in a market equilibrium. We define this particular price structure in the following proposition.

**Proposition 3.2.** *The tariff structure that makes agents indifferent between customers and thereby eliminating selection is defined by:*

$$f^*(\theta) = V(1 - \delta^{t(\theta,\emptyset)}) \tag{3.3}$$

*where $V$ is continuation value.*

*Proof.* Since agents are indifferent among the customers, the value must be constant in $\theta$ and equal to the expected value $V$. Thus, the equation

$$V = f^*(\theta) + \delta^{t(\theta,\emptyset)}V \tag{3.4}$$

must hold for any $\theta$ as an identity. Therefore,

$$f^*(\theta) = V(1 - \delta^{t(\theta,\emptyset)}). \tag{3.5}$$

Now we need to check conditions (3.1) and (3.2). For (3.1) we obtain:

$$V = \mathbb{E}\left(V(1 - \delta^{t(\theta,\emptyset)}) + \delta^{t(\theta,\emptyset)}V\right) = V \tag{3.6}$$

For (3.2) we obtain:

$$V(1 - \delta^{t(\theta,\emptyset)}) + \delta^{t(\theta,\emptyset)}V = V > \delta^{\Delta t}V \tag{3.7}$$

which completes the proof.

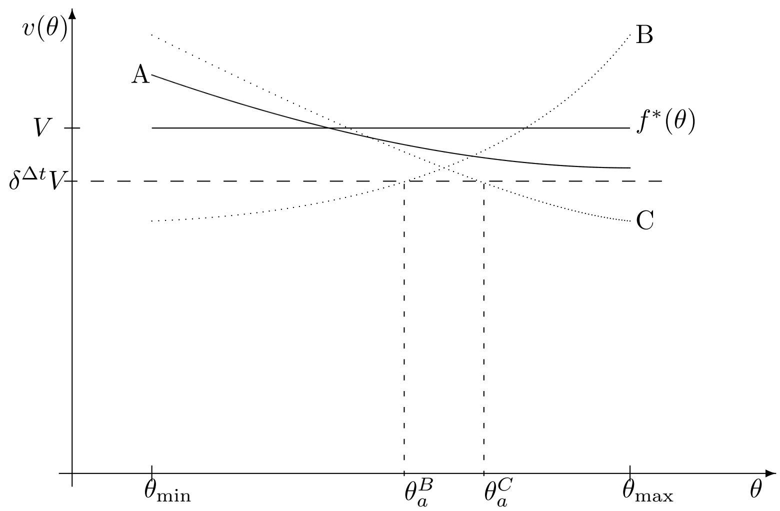
□

Note that the value of $V$ is not determined here – it is a free parameter determining the level of prices in the model and we can assign any arbitrary value to it.

We summarize our results so far by means of the following graph (see figure 2).

The expectation of $v(\theta)$ for all prices must be equal to $V$. For the price structure $f^*(\theta)$ we have that $v(\theta)$ is a constant, i.e., $v(\theta) = V$. Price structure A does not imply a constant value: agents prefer customers with lower complexity. But given the waiting time $\Delta t$ it is still optimal to accept all the customers. If the arrival frequency of customers increases this price can induce high-complexity selection. Price structure B induces low-complexity selection: customers with $\theta$ lower than $\theta_a^B$ are not accepted. price structure C leads to selection from the top, all customers with complexity higher than $\theta_a^C$ are not accepted.

Figure 2: Agent's pay-off under different price structures




## 3.2 Dynamic Selection at busy places: general case

A natural question to ask is what will happen at busy places, where the time that elapses between consecutive customers arriving is very small. Analytically, we analyze situations where $\Delta t$ is arbitrarily small. We will show that in this case, all selection-free price structures are sufficiently close to $f^*(\theta)$, i.e., price structures that are significantly different from the price structure where agents are indifferent between any of the customers lead to selection.

To this end, we first introduce the class of selection-free price structures. Since the value $V$ determines the level of prices, we consider structures with the same $V$. Let $\mathcal{F}_V(\delta, \Delta t)$ be the class of all price structures such that the following three requirements are met:

- for any $f(\theta) \in \mathcal{F}_V(\delta, \Delta t)$ there is full participation in the market, i.e. condition (3.2) is satisfied for all $\theta$ in the support of the distribution;
- any $f(\theta) \in \mathcal{F}_V(\delta, \Delta t)$ gives to the agent the expected value $V$;
- for any $f(\theta) \in \mathcal{F}_V(\delta, \Delta t)$ and all $\theta$ $u(\theta) > f(\theta)$.

We assume that for all customers the utility derived from a service is large enough so that at least $f^*(\theta)$ is in $\mathcal{F}_V(\delta, \Delta t)$, and hence, so that $\mathcal{F}_V(\delta, \Delta t)$ is not empty. With this definition, we can state the following proposition.[5]

[5]A similar proposition can be proven for the case where the discount factor $\delta$ goes to 1. To economize on space, this proposition is not included in the text.

**Proposition 3.3.** *For any $\epsilon > 0$ there is a $\Delta t^*$ such that for any $\Delta t^< \Delta t^*$ all selection-free price structures defined on $[\theta_{\min}, \theta_{\max}]$ are $\epsilon$-close to the optimal one, i.e. satisfy the following two conditions:*

1. $f^*(\theta) - f(\theta) < \epsilon$;
2. $\int_{\theta_{\min}}^{\theta_{\max}} |f^*(\theta) - f(\theta)| dF(\theta) < 2\epsilon(\theta_{\max} - \theta_{\min})$.

*Proof.* 1. Recall, that by definition

$$f^*(\theta) + \delta^{t(\theta,\emptyset)} V = V$$

for all $\theta$ in the support of $F(\theta)$. Also note, that since $f(\theta) \in \mathcal{F}_V(\delta, \Delta t)$ we have that for all $\theta$

$$f(\theta) + \delta^{t(\theta,\emptyset)} V \geq \delta^{\Delta t} V.$$

By taking difference we obtain

$$f^*(\theta) - f(\theta) \leq (1 - \delta^{\Delta t}) V$$

then by choosing $\Delta t^* = \frac{\ln(1-\frac{\epsilon}{V})}{\ln \delta}$ for any $\Delta t < \Delta t^*$ we get that

$$f^*(\theta) - f(\theta) < \epsilon$$

which proves the first part of the proposition.

2. To prove the second part recall, that since both price structures belong to $\mathcal{F}_V(\delta, \Delta t)$ we have

$$\mathbb{E} f^*(\theta) + V \mathbb{E} \delta^{t(\theta,\emptyset)} = V$$
$$\mathbb{E} f(\theta) + V \mathbb{E} \delta^{t(\theta,\emptyset)} = V$$

and therefore

$$\int_{\theta_{\min}}^{\theta_{\max}} [f^*(\theta) - f(\theta)] dF(\theta) = 0 \tag{3.8}$$

Let $A^+$ be a set of all $\theta$ in the support of distribution, such that $f^*(\theta) \geq f(\theta)$, and $A^-$ be a set such that $f^*(\theta) < f(\theta)$, $A^+ \bigcup A^- = [\theta_{\min}, \theta_{\max}]$. Then

$$\int_{\theta_{\min}}^{\theta_{\max}} |f^*(\theta) - f(\theta)| dF(\theta) = \int_{A^+} [f^*(\theta) - f(\theta)] dF(\theta) - \int_{A^-} [f^*(\theta) - f(\theta)] dF(\theta)$$

From (3.8) we get

$$0 = \int_{A^+} [f^*(\theta) - f(\theta)] dF(\theta) + \int_{A^-} [f^*(\theta) - f(\theta)] dF(\theta)$$

Therefore, by taking the difference and using the first part of the proposition we obtain:

$$\int_{\theta_{\min}}^{\theta_{\max}} |f^*(\theta) - f(\theta)| dF(\theta) = 2 \int_{A^+} [f^*(\theta) - f(\theta)] dF(\theta) < 2\epsilon(\theta_{\max} - \theta_{\min})$$

□

Intuitively, when $\Delta t$ becomes arbitrarily small, the cost of waiting for the next customer vanishes as well and waiting gives you the expected continuation pay-off. In this case, the only price structure that does not give rise to selection is the one where every complexity yields (approximately) the same revenue (which is equal to the expected value). This is exactly how the price structure $f^*(\theta)$ is characterized.

It is interesting to next investigate the welfare issues arising from selection. Our analysis shows that from the point of view of social welfare price structures with full participation are better than structures inducing selection.

We define social welfare as the sum of consumer and producer (agents) surplus. Producer surplus is simply equal to the discounted value of future pay-offs for the agents multiplied by the number of agents in the market. Each consumer has a utility of $u(\theta) - f(\theta)$ per service taken, which is his or her surplus. Integrating over all consumers (or over all services taken by consumers) that are accepted in equilibrium we arrive at the expected consumer surplus. So social welfare conditional on $V$ is given by:

$$SW(V) = N \cdot V + M \int_{S_\Phi} (u(\theta) - f(\theta)) dF(\theta) \tag{3.9}$$

where $S_\Phi$ is the support of the distribution under selection and $M$ is some weighting parameter. Integration over $S_\Phi$ implies that we calculate surplus only for the customers who are accepted in equilibrium, since the others receive their reservation utility, which is zero.

**Proposition 3.4.** *Consider a tariff structure $g(\theta)$ which induces selection, and delivers value $V$ to the agents. Then any $f(\theta) \in \mathcal{F}_V(\delta, \Delta t)$ yields social welfare that is larger than under $g(\theta)$.*

*Proof.* Consider some $f(\theta) \in \mathcal{F}_V(\delta, \Delta t)$. Since both fare structures $g(\theta)$ and $f(\theta)$ deliver value $V$ to the agents, producer surplus equals $NV$ in both cases. On the other hand, under fare structure $g(\theta)$ less customers participate in the market. Therefore to provide the same $V$ they must pay on average more:

$$\int_{S_\Phi} f(\theta)dF(\theta) < \int_{S_\Phi} g(\theta)dF(\theta). \tag{3.10}$$

Let $W$ be consumer surplus. Then, using (3.10) we obtain:

$$\begin{aligned} W(f(\theta)) = \int_{\theta_{\min}}^{\theta_{\max}} (u(\theta) - f(\theta))dF(\theta) > \int_{S_\Phi} (u(\theta) - f(\theta))dF(\theta) > \\ > \int_{S_\Phi} (u(\theta) - g(\theta))dF(\theta) = W(g(\theta)) \end{aligned}. \tag{3.11}$$

Since agents' surplus is constant, it follows that social welfare is larger in the full participation case for any positive value of $M$. $\square$

Whether or not the socially optimal price is necessarily also a Pareto-improvement depends on the consumers processing time function. Indeed, for the optimal price structure $f^*(\theta)$ we have:

$$f^*(\theta) = (1 - \delta^{t(\theta,\emptyset)})V. \tag{3.12}$$

For a price structure with selection at $\theta_a$ we have:

$$g(\theta_a) = (\delta^{\Delta t} - \delta^{t(\theta,\theta_a)})V. \tag{3.13}$$

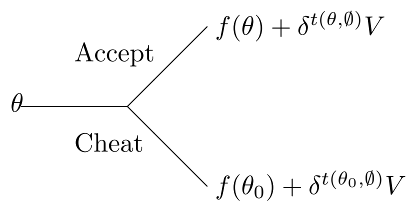
Note, that if $t(\theta, \emptyset)$ is quite close to $t(\theta, \theta_a)$ (e.g. when consumer processing time is exogenous) customers with $\theta$ close to $\theta_a$ are better off under $g(\theta)$. Thus, if each customer has a fixed level of service complexity $\theta$, then the optimal price structure may not be Pareto-optimal. However, if consumers' complexities vary in time so that each customer is interested in expected surplus rather than surplus generated for a particular value of $\theta$, then the price that maximizes social welfare is also Pareto-improving.

# 4 Demand Inducement

The framework developed so far also allows us to analyze the demand inducement (or moral hazard) problem which can arise in health care markets. A medical doctor is, in principle, able to provide a customer of complexity $\theta$ with some other service $\theta_0$ as no one apart from him knows the exact value of $\theta$. This problem of "demand inducement" can be analyzed in our framework as follows.

Assume the agent, say a medical doctor, can provide the customer with the level of service which is not required by his complexity. For example, he can prescribe some extra (unnecessary) treatment. If the customer (and the regulator who determines the price structure) does not know the true level of complexity, payment for this (unnecessary) treatment is made. We assume that pure fraud (reporting that a certain treatment is given while this is actually not the case) is not possible: if the true value is $\theta$ and the agent decides to provide

Figure 3: Decision tree under demand inducement




service with level of complexity $\theta_0$, then the required treatment time is $t(\theta_0, \theta_a)$ and the payment to the service provider is given by the net price $f(\theta_0)$. Thus, the agent can substitute the true $\theta$ with $\theta_0$ but then it is necessary to perform the treatment that is required by $\theta_0$ and he is payed for that.

It is clear that if there is a possibility for moral hazard the option "do not accept" is no longer relevant to the agent: a medical doctor can always treat the customer as the *best customer from his perspective*. We denote the level of complexity of this best customer as $\theta_0 \in \mathrm{Argmax}_\theta(f(\theta) + \delta^{t(\theta,\emptyset)}V)$. Then, the decision tree of the agent looks like:

Thus, the agent can either accept the customer and treat him truthfully or cheat (we skip non-optimal ways of cheating since they are dominated by $\theta_0$). Note, that the processing time is $t(\theta, \emptyset)$ or $t(\theta_0, \emptyset)$ which indicates that in the equilibrium of the model with the possibility of demand inducement the equilibrium level of selection is zero as the agents can always take on the costumer and provide a treatment that yields the highest possible pay-off.

The next Proposition argues that under the optimal price structure, the agent does not have an incentive to induce extra demand.

**Proposition 4.1.** *Under the optimal price structure 3.3 there is no pair* $(\theta, \theta_0)$ *from the support of* $F(\theta)$ *such that* $\theta_0$ *is better for the agents than* $\theta$.

*Proof.* Recall, that the optimal fare structure is defined by

$$f^*(\theta) = V(1 - \delta^{t(\theta,\emptyset)})$$

Then the expected value of the service process for any $\theta$ after it has been observed is defined by:

$$f^*(\theta) + \delta^{t(\theta,\emptyset)}V = (1 - \delta^{t(\theta,\emptyset)})V + \delta^{t(\theta,\emptyset)}V = V = f^*(\theta_0) + \delta^{t(\theta_0,\emptyset)}V \tag{4.1}$$

□

Thus, the optimal price structure $f^*(\theta)$ we characterize allows to avoid both selection and moral hazard (demand inducement) problems in regulated markets. Given the optimal price structure, service providers are indifferent between providing (and getting paid for) any possible treatment and so they do not have an incentive to cheat. If they have a slight preference for given the optimal socially efficient treatment they will do so.

# 5 Stochastic arrival process

So far, we have studied the case where in any given time interval, only one potential costumer arrives. In this section we show that our results are robust to the case where customers arrive according to a Poisson process instead of having one customer arriving at a particular moment in time. To this end, assume $\Delta t$ is now distributed according to an exponential distribution with parameter $\lambda$. Self-selection of customers leads to a decrease in the intensity of the Poisson process: if $p(\theta_a)$ is the fraction of customers that is taken in a selection equilibrium, then the intensity parameter of the arrival process equals $\lambda(\theta_a) = \lambda p(\tau_a)$. This means that the average waiting time until the next customer comes is $\frac{1}{\lambda p(\theta_a)}$.

Taxi drivers form expectations concerning the arrival time of the next customer. To derive the optimal decision-making rule for drivers we need the following result.

**Lemma 5.1.** *If $x$ is exponentially distributed, then*

$$\mathbb{E}\delta^{ax} = \frac{\lambda}{\lambda - a\ln\delta} \tag{5.1}$$

*Proof.* Indeed,

$$\mathbb{E} = \delta^{ax} = \int_0^\infty \lambda\delta^{at}e^{-\lambda t}dt = \int_0^\infty \lambda e^{(a\ln\delta - \lambda)t}dt = \frac{\lambda}{\lambda - a\ln\delta} \tag{5.2}$$

□

Now we can apply this result to all previous sections. To do so we just need to replace a predetermined discount factor $\delta^{a\Delta t}$ by the expected discount factor $\frac{\lambda}{\lambda - a\ln\delta}$. Then we can formulate the following proposition.

**Proposition 5.2.** *The price structure $f^*(\theta)$ ensures full participation of customers if and only if:*

$$V = \mathbb{E}(f(\theta) + \delta^{t(\theta,\emptyset)}V) \tag{5.3}$$

*and*

$$f(\theta) + \delta^{t(\theta,\emptyset)}V \geq \frac{\lambda}{\lambda - \ln\delta}V. \tag{5.4}$$

The optimal price structure is not affected by changing the arrival process, therefore Proposition 3.2 still holds, and the price structure which ensures full participation for any value of the intensity $\lambda$ is given by:

$$f^*(\theta) = V(1 - \delta^{t(\theta,\emptyset)}).$$

For an arbitrary net price structure $f(\theta)$, which leads to selection, the lowest (highest) accepted type is defined by the following equation:

$$\begin{aligned} f(\theta_a) + \delta^{t(\theta,\theta_a)}V = p(\theta_a)\frac{\lambda}{\lambda - \ln\delta}\mathbb{E}_\Phi(f(\theta) + \delta^{t(\theta,\theta_a)}V) + \\ +(1 - p(\theta_a))\frac{\lambda}{\lambda - 2\ln\delta}V \end{aligned}, \tag{5.5}$$

which corresponds to (3.2) (put as equality) in the non-stochastic case.

Finally, since the proof of proposition 3.4 is invariant with respect to the nature of $\Delta t$ the price structure (3.3) is still socially optimal under stochastic customer arrival conditions.

# 6 Conclusions

In this paper we have analyzed dynamic selection effects that arise in some regulated markets. Our framework applies when three core conditions are satisfied: (*i*) consumers arrive sequentially at some moments of time (a stochastic arrival process is also possible) and differ in their types (complexity of service required); (*ii*) price structures, with price depending on the level of complexity of a costumer, are fixed by a regulator or another authority or by central management and (*iii*) agents (providers of the service) can either accept or reject the customers based on a comparison of benefits and costs (or, in an extension, can decide to give a different treatment).

We have shown that for a large class of fare structures customers with a low level of complexity or customers with a high level of complexity are refused the service. Equilibria with selection are welfare inferior to equilibria without selection. We have characterized the class of price structures for which selection does not arise. For markets with very many customers, this price structure is unique up to a scaling factor. The optimal price structure also prevents moral hazard to arise if service providers can induce demand (as in the medical sector).

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