Fishing vessels arriving at a port have a considerable waiting cost. They consider the berth service time to be the main determinant of the quality of the service provided. This quality, measured by the delay, is determined by the capacity of the port and by the demand. In this context, operations research methods and especially queuing theory are usually applied. Here, we adopt a strategic approach for the demand as well as the supply side of the model.

We assume the demand comes from a small number of big fishing vessels with strategic behaviour. More precisely, each vessel chooses ex ante a strategy based on its expected utility, taking into account the strategies of the other users.

On the supply side, the producers cannot directly control the quality of the port services but can control them indirectly, through two strategic variables, the capacity and the service price. We compare two models of organization:
- a monopoly model in which one actor chooses a capacity in the first place and a price in the second place,
- a decentralized model in which a capacity producer supplies a service producer who fixes the sale price.

It appears that the nature of the strategic demand has an important influence on the producer's strategies. On the other hand total profits do not depend on the organization of the production. Hence, the efficiency of the port facility seems to depend more on the nature of the demand than on organisational structure of the port.

key words: congestion effects, industrial organizations, quality choice, mixed strategies.
I  Introduction

A port can be considered as a mechanism for transforming land based goods into sea based goods and vice versa. It offers two types of service, handling ships and handling their cargo. Since ports provide services what they produce is by its very nature not storable and the amount that they can provide depends on their capacity which is considered as being the result of long term decisions. This supply is faced with a short term stochastic demand for which the delay before a vessel is handled and the time taken to off load its cargo determines the quality of the service provided. In the case of fishing vessels the situation is somewhat different. It is not the waiting time that is important but rather the price that will be achieved in the auctions once fish has been offloaded. Thus, by adding to the supply of fish currently available, a vessel will typically lower the price obtained for that fish. Formally, however, the analysis of this situation is very similar to that based on the theory of queueing and congestion. On the one hand, the quality of the service is measured in terms of those two features when ships arrive at random and on the other hand the quality is determined by the price which will be achieved, and this in turn is determined by the arrival process of fishing vessels.

In most economic models of the ports the costs of waiting are assimilated into the total cost function of the port. This type of model is that used for many of the simulations currently used by port authorities and is based on a very particular assumption about the objective function of ports. They propose a social welfare function in which the usres of port facilities are considered as an integral part of the facility that they are using.

The fact that the quality of the services provided is considered as being completely determined by technical situations and that actors with very different objectives are all integrated through one cost function which links both the providers of the service and its users means that it is not possible to take into account the strategic aspects of the behaviour of the port authority. Yet, in reality it is clear different port authorities have very different performances even though the technical constraints with which they are faced seem to be very similar.

In fact, in any case it is possible to simplify matters by considering the three intermediate products which are necessary to obtain the given volume of production. Each of these corresponds to a different time horizon and it determined by different decisions. In the short term the capital invested and the capacity of the port are fixed by long term decisions and these provide constraints on the level of overall production (we shall not consider here very long term considerations involving the actual establishment of a port).

Now, to turn to the nature of the short term production process consider the activity of a port handling containers or a port at which fish is landed. In this case, the level of activity of the container terminal will be measured in terms of the number of containers handled and this number will be conditioned by cranes and other handling facilities at the port. Similarly, the output of the fishing port can be measured in terms of the total weight of fish handled. This, activity not only involves a co-ordination of short term decisions but is also dependent on long
term decisions which determine the capacity of the port. An excess demand for the port facilities will result in waiting by those wishing to use the port. In the case of the container terminal there is an upper limit on the number of containers that can be handled at any one point in time. It should be observed that there are two specific features of this situation. On the one hand the quality of the service provided is determined both by the installed capacity and by the demand for the capacity and on the other hand the quality of the service provided also determines the level of demand.

Furthermore, for most ports the demand eminates from a small number of ship owners who are themselves producers and who have their own strategies. We propose here a simple model which brings out the strategic aspects of both the producers of port services and those of individuals who use those port services.

On the demand side, each ship owner takes an ex-ante decision on the basis of his expected utility but he includes in this calculation the behaviour of other ship owners. We will consider two types of demand: homogeneous and then heterogenous.

On the production side, the agents influence the quality of the service by controlling two strategic variables the ports capacity and the price that is charged for the service. We shall compare two models of different organisations.

- An integrated monopoly such as that which characterises the English port of Felix Stowe.

- A decentralised monopoly in which there is a hierarchical chain with a producer who determines the capacity of the port and after him a producer who provides the service and fixes the price of that service. This in terms of ordinary ports corresponds very much to the structure of certain ports, such as Bremen and it is commonly the case that for fishing ports the auction of fish and the price charged for participating in that auction is determined by some authorities such as the local chamber of commerce.

We show that the strategies of the producers of port services are particularly sensitive to the nature of the demand with which they are faced. In particular, some of the profits of the two producers in a decentralised monopoly is equal to the profit of the integrated monopolist. On the other hand, the level of that profit is very different depending on the type of demand with which the producer is faced.

We will present, in the next section, the assumptions which are generally made in the literature describing the production of services where there are congestion costs. This, will provide the justification for the choice of the decision variables in the model. In the third section, we shall propose a formal model of strategic demand. In sections four and five, we shall consider respectively, the organisational model of an integrated monopolist and then of a decentralised monopoly. We shall outline our results in terms of the demand structure are summarised and discussed in the conclusion.
2. General Assumptions

2.1 The Case of a Delay in Handling

In the standard approach to the choice of a product, demand is determined by the price and the quality of the product. These aspects of monopoly theory are discussed in a chapter of Tirole (1988). However, in many cases where services are produced, particularly in the case of port services, the quality can be measured in terms of the time for a cargo to be handled and this, in turn will depend on the level of demand. Stembaka and Tombak (1995) include the effect of congestion in the cost function. The length of time it takes to handle a cargo is thus the producer's only strategic variable.

However, when one looks at the production of port services, where the quality of the service provided is no longer completely under the control of the producer it is clear that one has to take congestion costs explicitly into account. The purpose of queuing theory is to take direct account of situations in which the quality of the service depends on the rate of arrival of the users of port facilities.

In general, in these models the stochastic process governing the arrival of users is assumed to satisfy the following two conditions.

1. The arrival rate of users at the port is described by a Poisson process with parameter $\lambda$.
2. The time taken for handling a cargo is a stochastic variable which has an exponential distribution with a parameter $\mu$ which can be thought of as the handling rate.

With these two assumptions, a standard result from queuing theory is that the expected waiting time $\theta$ is given by the expression,

$$\theta = \frac{1}{\mu - \lambda}$$

The quality of the service can be considered as given by the inverse of $\theta$ and this way of writing the congestion function shows clearly how the quality depends both on the current demand and on the service provided.

Naor (1969), Edelson (1971) and Knusen (1972) use results from queuing theory in the case of a monopoly and Luski (1976) and Reitman (1991) apply the same results in the case of an oligopoly in which price is the decision variable.
In these models quality is not directly a decision variable but the producer can nevertheless influence quality indirectly through the level of demand by choosing prices or can influence it directly by controlling the capacity of the handling facilities. In fact, as equation 2.1 shows the quality of service depends on the rate which is provided. That is, the number of vessels that can be handled per unit of time by the facilities that have been installed. One can make several assumptions as to the factors which determine this rate. In standard queuing models it is usually considered implicitly to be a parameter given by the technical characteristics of the port infrastructure. However, certain authors such as Reitman (1991) or Chappel (1990) consider the service rate as depending on the way in which the facilities are used and this is controled by the producer. Reitman, for example, sites the case of the opening of more or fewer check-outs in a supermarket to illustrate the idea that capacity can also vary in the short term. In this case the service rate can be considered as a decision variable even in the short term.

But whether or not it is a parameter of the system or a short term variable the service rate is still dependent on the long run decision as to the amount of infrastructure that is installed. We shall assume here that the service rate is fixed in the short term and that it depends on the handling capacity \( V \) which is controlled in the long run by the producer. Denoting by \( D \) the current level of demand we can rewrite the congestion function as:

\[
\theta = \frac{1}{V - D}
\]

We shall now analyse the behaviour of the producer in a two stage model in which he chooses, in the first stage, the capacity \( V \) to be installed and then fixes a price \( p \) in the second stage.

The producer is faced in the third stage with a level of demand. We will now explain how this is determined. We have already seen that one of the special features of the model is that demand reacts not only to the price but also to the quality of the service which was here defined as the delay in handling cargo. However, this quality is endogenous and is determined both by the capacity level and by the level or current demand. The level of demand and the quality level are therefore simultaneously determined in the third stage in which both capacity and the price of the service are already fixed.

The model therefore has the following structure,

Stage I: the producer chooses a capacity level \( V \)

Stage II: The producer chooses a price for the service \( p \)

Stage III: The current level of demand \( D \) and the quality of the service measured by the inverse \( \theta \) of the time spent in the system are determined simultaneously.

2.2 Characteristics and Behaviour of the Users of Port Facilities
In the literature discussed previously there are a number of standard assumptions concerning the structure of demand:

1. The basic service yields identical utility denoted by $R$ to each user.
2. Any waiting time before receiving this service, i.e., before a cargo is handled, generates a cost for users. This cost is generally assumed to be linear with respect to the waiting time.
3. When he arrives in the system each user has to decide between:
   - Taking his turn in the queue and accepting the cost.
   - Not being served.

The indirect utility function of a user depends on price $p$ and the handling time $\theta$. The utility that a user gets from the facility diminishes when this waiting time increases at a speed that depends on the value which the user attributes to time. For a user who attributes a value $V$ to a unit of time saved and for whom the cost involved is a linear function of the time spent in the port. The indirect utility can be written:

\begin{equation}
U(p, \theta) = R - p - v\theta.
\end{equation}

The models discussed previously can be separated depending on the way in which they treat or represent the value of time. In the models of Naor (1969) and Knusen (1972), the value of time is the same for all users. The utility that they get from the service provided by the port depends simply on the order in which they arrive. On the other hand, Luski (1976), Reitman (1991), Stembaka and Tombak (1995), consider models in which there are heterogeneous users. This heterogeneity in terms of the value of time has an effect on the behaviour of users and in particular on their decision as to whether or not to purchase the service provided by the port. In order to determine the level of demand one has to know the distribution of the values of time over users. Two basic assumptions are worth examining: either there is a continuum of users with a continuous distribution of time values or there are several types of user each type being identified by a particular time value and in this case the distribution function is discrete.

Luski (1976) or Stembaka and Tombak (1995), for example, construct models of demand which assume the existence of a continuous cumulative density function $F(v)$ of the time values and corresponding density $f(v)$.

They then define the "marginal user" who makes zero profit by buying the service provided by the port and who is thus characterised by a time value $v^*$ such that:

$$v^* = \frac{R - p}{\theta}.$$ 

The marginal user is then the user whose time value is the highest amongst all those users who do in fact purchase the service. If the length of service time $\theta$ is fixed then all those users whose time value $v < v^*$ get a positive profit from purchasing the service whilst all those users whose
time value \( v > v^* \), do not wish to buy the service since they would obtain a negative profit from it.

As is standard practice in this sort of model we will suppose that each user either buys or does not one unit of a service and that the time values are distributed on a segment \( [v, \bar{v}] \) with a density function \( f(v) \), so that the demand can be described by a function.

\[
D(p, \theta) = N \int_v^{\bar{v}} f(v) \, dv
\]

Where \( N \) denotes the size of the overall market.

If we assume that time values are distributed uniformly on the segment \([0,1]\), this demand function can then be written very simply as:

\[
D(p, \theta) = N \left[ \frac{v^* - v}{\bar{v} - v} \right] = N \left[ \frac{R - p}{\theta} \right]
\]

We have seen earlier that the congestion function described by equation (2.2) gives \( \theta \) as a function of capacity \( V \) and the level of demand. This is what is meant by saying that demand and quality mutually determine each other. One can then derive expression for the aggregate demand faced by a monopolist as a function only of the decision variables \( p \) and \( V \):

\[
D(p, V) = \frac{NV(R - p)}{N(R - p) + 1}
\]

This general equation introduces the idea of heterogeneity or differentiation which stems from the distribution of time values. Furthermore, the assumption of a continuum of users allows one to reason in terms of the marginal user. Reitman (1991) extends this approach by using discrete values to describe distribution of time values amongst users. In the case of port services the users are vessel or fleet owners and are themselves producers. They are not very numerous and it is thus difficult to conceive of them as being represented by a continuum. If one makes the assumption that all the users are identical or if one assumes that they are divided into different types it is then also difficult to use the concept of the behaviour of a marginal user. On the other hand, it does seem plausible in the framework of port services to suppose that the owner of the vessel decides on the port that he will use and in the case of a normal cargo vessel the freight handler ex-ante, on the basis of expected profit but once he has made this choice and reached the port whatever situations he finds he cannot reverse this decision. More precisely, we can argue
that each vessel owner chooses a mixed strategy which specifies the probabilities that he attributes to the decision to be served or not. The owner who decides not to be served is here considered to receive zero payment. Then the formal model is described and solved in the following three sections: as is usual in this approach we will argue in terms of backward induction and start by determining the level of demand.

3 Demand

The users are ship owners. In the case of a normal cargo port the length of time spent in the port represents a particularly high cost to the ship owner since during this period his ship is out of action. In this case, consider \( c \) the value attributed by the ship owner to diminishing the waiting time by one unit of time or equivalently the cost of waiting for one more time limit. We shall suppose here that this cost is a linear function of time. The income obtained by a ship in the course of one visit is evaluated as \( R \). The expected net profit obtained by the ship owner during one visit is then simply the difference between revenue and costs. The latter are determined as the sum of the cost of handling freight \( p \) and the cost of having the ship out of action which is taken to be a linear function of the expected waiting time of \( \theta \):

\[
\pi^s = R - p - c\theta
\]

(3.1)

Using the expression for \( \theta \) given by equation 2.2 we can rewrite the net profit as a function of the fixed capacity \( V \) and of the level of current demand.

\[
\pi^s = R - p - \frac{c}{V - D}
\]

Ship owners thus make their decision on the basis of their forecast of the level of current demand.

In the case of the fishing port the expression for profit will be determined by, again, the level of current demand since this influences the price level which in turn determines the level of profit.

3.1 Homogeneous Demand

\[\text{This is of course a considerable simplification since the owner will not simply abandon his cargo but will either wait or send his vessel to some other port.}\]
Assume to start with that all users are identical. Each user chooses a mixed strategy which specifies the probability $\beta$ with which he decides to be served and the probability $(1 - \beta)$ with which he chooses not to be served.

As has already been mentioned, the ship owner decides not to be served receives zero payment. On the other hand, if he does decide to be served his pay off will depend on the mixed strategies of the other ship owners whose choice will in turn determine the length of the queue. Since all of the ship owners are identical the proportion of owners in the queue is given by $\beta$. The ship owner $i$ when he is considering his expected profit will expect a level of demand equal to: $\beta (N - 1) + 1$ given the congestion function and considering the strategic behaviour of the user the expected profit from one visit to the port is then given by:

\[
\pi^*_i (\beta_i = 1) = R - p - \frac{v}{V - \beta(N - 1) + 1} \geq 0
\]

The mixed strategy is determined by the quality between the profit from a visit to the port and the payment that the ship owner will receive if he decides not to be served:

\[
R - p - \frac{c}{V - \beta(N - 1) + 1} = 0
\]

Solving this equation for $\beta$ gives the following expression:

\[
\beta = \frac{(R - p)(V - 1) - c}{(N - 1)(R - p)} \quad \text{with} \quad 0 \leq \beta \leq 1
\]

The total demand served by the monopolist is then given by:

\[
D^*(p, V) = \beta \cdot N = \frac{N}{(N - 1)} \left[\frac{V}{(V - 1) - \frac{c}{(R - p)}}\right]
\]

### 3.2 Heterogenous Demand
Assume now that there exists two types of user with time values which are different for each type. There are those who have a high unit cost of having their ships unused and these costs are given by $c_H$ and those for whom the unit cost is less and is given by $c_L$. The market is now made of $N_H$ and of $N_L$ users of type $L$.

\begin{equation}
N = N_H + N_L
\end{equation}

Let $\beta_L$ and $\beta_H$ be the proportions of users of each type. As previously these proportions correspond to the mixed strategies of the ship owners who are now divided into two groups. A user of $L$ who decides to be served evaluates his demand at $\beta_L (N_L - 1) + 1 + \beta_H N_H$.

The ship owner $i$ of type $L$ takes his decision on the basis of the equality between the expected payment when he uses the monopolist services and when he decides not to be served:

\begin{align*}
\pi^s_{Li}(\beta_L = 1) &= \pi^s_{Li}(\beta_L = 0) \\
R - p - \frac{c_L}{V - (\beta_L (N_L - 1) + 1 + \beta_H N_H)} &= 0
\end{align*}

In the same way, a ship owner of type $H$ makes his decision by equalising the expected pay-offs in the two cases.

\begin{align*}
\pi^s_{Hi}(\beta_H = 1) &= \pi^s_{Hi}(\beta_H = 0) \\
R - p - \frac{c_H}{V - (\beta_H (N_H - 1) + 1 + \beta_H N_H)} &= 0
\end{align*}

The solution of this system of two equations in two unknowns $\beta_L$ and $\beta_H$ is given by:

\begin{equation}
\beta_L = \frac{(V - 1)(R - P) + c_L (N_H - 1) - c_H \cdot N_H}{(N - 1)(R - p)} \quad \text{with } 0 \leq \beta_L \leq 1
\end{equation}
Comparing $\beta_L$ and $\beta_H$ leads to the following lemma:

**Lemma 1**  For given $p$ and $V$ the proportion of users of type $H$ who are served is always larger than the proportion of users of type $L$ who are served. This result is independent of the respective sizes of the two sub populations.

For the average time value,

$$\bar{c} = \frac{c_L \cdot N_L + c_H \cdot N_H}{N}$$

the total demand satisfied by the monopolist can be easily be calculated as

$$D^*(p, V) = \beta_L N_L + \beta_H N_H = \frac{N}{(N-1)} \left[ (V-1) - \frac{\bar{c}}{(R-p)} \right]$$

It should be noted that the aggregate demand has the same form as when the users are homogeneous simply be replacing the common time value by the average value in this case.
4. An Integrated Monopolist

We shall start by analysing the behaviour of a "integrated" monopolist by looking at a two stage model in the first stage of which the monopolist chooses his capacity and in a second stage of which he sets his price.

First Stage

\[
\max_{V} \pi^{I} = \max_{V} \left[ (p - \gamma) \cdot D(p, V) - k \cdot V \right]
\]

Second Stage

\[
\max_{p} \pi^{I} = \max_{p} \left[ (p - \gamma) \cdot D(p, V^*) - F \right]
\]

Assume that the production of port services generates two types of costs. The exploitation cost is proportional to the quantity of the service provided. The cost of production of a given level of quality is determined by investment in capacity. In both cases, the marginal costs are constant and the total cost function can be written as:

\[
CT = \gamma \cdot D(p, V) + k \cdot V
\]

The port activity undertaken by a single agent then generates an income which is defined as:

\[
\pi^{I} = [(p - \gamma) \cdot D(p, V) - k \cdot V]
\]

The determination of the level of demand allows one to define a demand function which depends on the average cost of having ships out of action whether or not demand is homogeneous.

In consequence, in stage two the monopolist chooses an equilibrium price which maximises the profit given by (4.3) when he is faced by the demand function given by equation (3.9). The first order condition for this maximisation problem is given by (4.4)
\[
\frac{\partial \pi^M}{\partial p} = \frac{N}{N-1} \left[ \left( V - 1 - \frac{c}{R - p} \right) \left( p - \gamma \right) \left( \frac{c}{(R - p)^2} \right) \right] = 0
\]

Hence, the equilibrium price is set at:

\[
p^* = R - \sqrt{\frac{c(R - \gamma)}{V - 1}}
\]

However, in stage 1 the results obtained depend on whether demand is homogenous or not. We shall therefore examine, firstly the case of homogenous demand and secondly, the case of heterogeneous demand.

### 4.1 An integrated monopolist faced with homogenous demand

Maximisation of the profits given by equation (4.1) has to take account of the constraint given by equation (3.4) which ensures that the proportion of users actually served falls in the interval of [0,1]. The constrain maximisation problem can be written as an lagrangin:

\[
L = (p^* - \gamma) \cdot D*(p^*, V) - k \cdot V + \lambda_0 \beta + \lambda_1 (1 - \beta)
\]

that is:

\[
L = \left( R - \sqrt{\frac{c(R - \gamma)}{V - 1}} \right) \cdot \left[ 1 - \sqrt{\frac{c}{(V - 1) \cdot (R - \gamma)}} \right] \cdot \frac{N(V - 1)}{N - 1} - k \cdot V
\]

\[+ \lambda_0 \left[ 1 - \frac{1}{\sqrt{(V - 1) \cdot (R - \gamma)}} \cdot \frac{V - 1}{N - 1} \right] + \lambda_1 \left[ 1 - \left( 1 - \sqrt{\frac{c}{(V - 1) \cdot (R - \gamma)}} \right) \cdot \frac{V - 1}{N - 1} \right]
\]

The two constraints of the lagrangin cannot be binding at the same time. Assume first that neither of the constraints is binding, that is, that \( \lambda = \lambda_1 = 0 \). In this case, maximising profit leads to the solution:
\[ V_{\min} = \frac{c(R-\gamma)N^2}{[N(R-\gamma)-k(N-1)]^2} \]

The second order condition shows that profit is a convex function of \( V \). Thus, \( V \) is the capacity which minimises this profit.

Since the two constraints can neither be binding nor non binding simultaneously the only interesting solution to examine is that when the producer serves all the demand. Suppose now that \( \lambda = 0 \) and \( \lambda > 0 \). The first order conditions for the Lagrangian are given by:

\[
\frac{\partial L}{\partial V} = 0
\]

\[
(4.8) \quad 1 - \frac{c}{\sqrt{(V-1)\cdot(R-\gamma)}} \cdot \frac{N(R-\gamma)}{N-1} - k - \frac{\lambda_1}{V-1} \left( \frac{N-1}{V-1} + \frac{1}{2} \sqrt{\frac{c}{(V-1)\cdot(R-\gamma)}} \right) = 0
\]

\[
(4.9) \quad \frac{\partial L}{\partial \lambda_1} = 1 - \frac{V-1}{N-1} \left( 1 - \frac{c}{\sqrt{(V-1)\cdot(R-\gamma)}} \right) = 0
\]

The solution for \( V \) from equation (4.9) is given by:

\[
(4.10) \quad V_{\sup} = N + \frac{\tilde{c} + \sqrt{\tilde{c}^2 + 4\tilde{c}(R-\gamma)(N-1)}}{2(R-\gamma)}
\]

For this capacity the quality provided is:

\[
(4.11) \quad \frac{1}{\theta} = \frac{\tilde{c} + \sqrt{\tilde{c}^2 + 4\tilde{c}(R-\gamma)(N-1)}}{2(R-\gamma)}
\]

It can also be seen that, using equation (4.5), a condition which guarantees that the Lagrangian multiplier is indeed strictly positive is given by:
Thus, for a marginal cost of investment in capacity which is "not too high" there exists an optimal capacity level $V$ which guarantees a positive profit to a monopolist who satisfies all of the demand with which he is faced. When the marginal cost is too high the monopolist provides no services. Profit is a convex function of $V$. $V$ is an increasing function of $\beta$. Thus, a monopolist who maximises is led; if he produces at all; to satisfy all of the demand.

**Proposition 1** When demand is homogenous the monopolist produces if the marginal cost of investment incapacity is not "too high" and in this case he serves the whole market.
4.2 An Integrated Monopolist faced with Heterogeneous Demand

When there are two types of user, given equations (3.7) and (3.8) and their respective constraints, the Langrangian is given by:

\[ L^T = \left( R - \sqrt{\frac{c \cdot (R-\gamma)}{V-1}} - \gamma \right) \left( 1 - \sqrt{\frac{-c}{(V-1) \cdot (R-\gamma)}} \right) \cdot N \cdot (V-1) - k \cdot V \]

\[ + \lambda_i^H \left( 1 - \frac{V-1}{N-1} \left( \frac{H}{\sqrt{c \cdot (V-1) \cdot (R-\gamma)}} \right) \right) \]

with

\[ H = N \cdot \tilde{c} - (N-1) \cdot c_H \]

The capacity level which maximises the monopolist's profit and the condition which guarantees that the multiplier is strictly positive can be worked out from the first order conditions.

The optimal capacity level is given by:

\[ V_{sup}^T = N + \frac{H \cdot (R-\gamma) (N-1)}{2(R-\gamma)} \]

At this capacity level the quality supplied is:

\[ \frac{1}{\theta^T} = N_L (1 - \beta_L) \cdot \frac{H \cdot (R-\gamma) (N-1)}{2(R-\gamma)} \]

The comparison between \( V_{sup} \) given by (4.7) and \( V_{sup}^T \) and between \( \frac{1}{\theta} \) and \( \frac{1}{\theta^T} \) shows that when \( c_H < c \cdot \left( \frac{N - \sqrt{c}}{N - 1} \right) \), the producer faced with heterogeneous demand chooses a higher capacity level than in the case where demand is homogeneous and furthermore he produces a higher level of quality.

The Lagrangian multiplier is strictly positive when:
(4.12) \[ k < \frac{R - \gamma}{V_{sup} - 1} \cdot (\beta L N_L + N_H) \]

This comparison between the two cases of homogeneous and heterogeneous demand in the case of the production of a service which is subject to congestion leads then to the following results:

**Proposition 2**  

i) When the marginal cost of the production of capacity is not "too high" the monopolist has a positive output level and:

- He does not satisfy all the demand but dies satisfy all the demand of those users with the highest waiting cost.
- He chooses a higher capacity level and quality than the monopolist faced with homogeneous demand.

ii) The constraint which guarantees that profit is positive is more restrictive than in the case of homogeneous demand. The monopolist is thus less likely to produce in this case.

5. Decentralised Monopoly

We shall now examine another type of organisation in which short and long term decisions are decentralised. To do this we introduce a new actor the "principal" who produces capacity in the long run and who sets its price. In this new model the actor in stages 1 and 2 does not produce capacity but buys it from the principal.

As in the case of the integrated monopoly just one monopolistic agent takes care of the exploitation of the capacity. It is, at this stage, the explicit consideration of fixed costs that makes the two situations different. In the case of the integrated monopolist the fixed costs are engendered by the level of capacity that he, himself, installed. In the decentralised case the fixed costs correspond to the payment for the exclusive right to use the capacity furnished by the firm who installed it. Moreover the setting of a price by the firm which transfers the right to use the capacity constitutes an additional stage in the model.

In the first stage the principal's problem consists of selecting that price function amongst all those under consideration that maximises his profit. We shall assume that the price function is linear in the capacity supplied. Profit can then be written as:

(5.1) \[ \pi^P = (\tau - k) \cdot V^* \]

The capacity \( V^* \) represents the demand that the agent directs to the principal and corresponds to the optimal capacity which the agent needs to satisfy the demand with which he is faced. It is derived from the first stage maximisation problem.
\(\max\pi^A \equiv \max_{\nu}(p^* - \gamma)D^*(p^*, V) - \nu V\)

Finally, at stage 2, the agent sets the price which maximises his profits which are the difference between his revenue and his variable costs since the capacity is fixed:

\(\max\pi^A \equiv \max_{p}(p - \gamma)D^*(p, V) - \nu V\)

The last two stages of this problem correspond to the integrated monopoly model with the rental of the capacity substituted for the cost of its production. Thus the solution for \(p\) is given by (4.5) and the solution for \(V\) is given by equations (4.7) in the case of homogeneous demand and by (4.11) in the case of heterogeneous demand. The monopolist produces when condition (4.9), (respectively 4.12) is satisfied with \(\tau\) replacing \(k\):

\[\tau \leq \frac{R - \gamma}{V_{\text{sup}} - 1} \cdot (N) = \tilde{\tau}\] homogeneous demand

\[\tau^T \leq \frac{R - \gamma}{V_{\text{sup}}^T - 1} \cdot (B_L \cdot N_L + N_H) = \tilde{\tau}^T\] heterogeneous demand

From inequalities (5.4) and (5.5) we obtain the following:

**Lemma 2:** Depending on the value of \(k\) the agent decides on whether or not to produce. If he decides to produce the capacity level is independent of \(k\). Consider the solution of the first stage of the problem. As long as the conditions (5.4) and (5.5) are not binding the agent's demand \(V_{\text{sup}}\) (respectively \(V_{\text{sup}}^T\)) which is transmitted to the principal does not depend on \(\tau\). But when these conditions are no longer satisfied demand is zero. With complete information the optimal strategy of the principal is only to produce if \(k < \tilde{\tau}\) (respectively \(k < \tilde{\tau}^T\)) and to set a price \(\tau = \tilde{\tau}\) (respectively \(\tau^T = \tilde{\tau}^T\)). In this way he obtains all of the surplus.

**Proposition 3:** By setting a linear pricing rule, the capacity producer obtains the whole surplus. The latter is identical to the profit obtained by the integrated monopolist.

6. **Conclusion**

In the example proposed here the efficiency of a port facility seems to depend more on whether demand is homogeneous or heterogeneous than on organisational structure of the port. However,
it is clear that these results are heavily dependent on the informational and competitive context that we have chosen. One could consider the decentralised structure with incomplete information. In particular the capacity producer may not know the marginal operating cost or the structure of the demand with which he has no direct contact. It is possible that the agent might be able to guarantee himself a non-zero profit by manipulating this information. Finally the analysis presented here lends itself naturally to the case of a duopoly. This sort of extension is the subject of research in progress.
References


