A PRODUCT DIFFERENTIATION MODEL OF BUS DEREGULATION

By Norman J. Ireland*

1. INTRODUCTION

The example of bus deregulation is central to many debates on the desirability of subjecting economic agents to the discipline of the market. It is claimed that deregulation can induce cost economies which will benefit society in general, and that consumers in particular will benefit from lower prices and greater choice. On the other hand, a corollary of deregulation may well be the loss of any general direction and coordination of bus transport policy; and this suggests that improved welfare may not necessarily result. Much will depend on how the competitive market forces operate. Recent reports (Tyson, 1988, 1989) emphasise the range of outcomes that have been observed in the short period since bus deregulation occurred in the United Kingdom. Of course the deregulated bus industry cannot yet be assumed to have adjusted to long-run equilibrium, and it is probably too early to draw substantive empirical conclusions. However, there does seem to be a need for a theoretical analysis which will yield a calculus for assessing the costs and benefits of deregulation. This paper is intended as a modest contribution towards this.

Any theoretical or empirical analysis of bus deregulation is conditioned by the precise nature of the organisation of the industry both before and after deregulation. If the initial state was a profit-maximising monopoly, and “regulation” was simply the removal or limitation of competition, then more beneficial results might be expected from deregulation than if the initial state had involved only maximum price regulation. Similarly, if the regulated state involved substantial monopoly power as well as entry barriers, then less benefits might be expected than from a more competitive structure.

Our analysis will be based on precise, if arbitrary, descriptions of regulated and deregulated bus industries. It is assumed that the regulated industry is a monopoly which is protected from competition, but is required to minimise prices controlled

* Department of Economics, University of Warwick. An earlier version of this paper was presented to the Economic Theory Workshop of the University of Warwick. My thanks to participants and to a referee of this Journal for valuable comment.
for quality of service, and is subject to a non-negative profit constraint. The quality of service may reflect either the frequency of buses along a particular route or the number of routes. Thus the regulated monopoly chooses both prices and the number of routes/frequency of service, subject to a break-even constraint. The structure of the industry when deregulated is assumed to be competitive, with each route or bus service being operated by an independent profit-maximising firm. The number of firms, and thus the number of routes and frequency of service, are determined by a free-entry, zero-profit condition.

These descriptions of “ideal” scenarios approximate regimes (i) and (ii) in Evans (1987). With the addition of some simplifying assumptions on symmetry, they ensure that each route or service makes zero profit both before and after deregulation. The number of routes operated and prices charged will change with deregulation, however. Essentially, our model will focus on the argument that the equilibrium of the deregulated industry results from competition among the various routes and services, but that the regulated monopoly directs its attention to competition with rival forms of transport. In addition, there may be cost differences, as argued in the pre-deregulation literature (see for example Department of Transport, 1984) and reported in Tyson (1989); the deregulated industry may operate more efficiently, or pay lower factor prices, because of the need to survive in a more competitive environment.

The approach adopted here uses a model which combines, in a simple way, the concepts of both horizontal and vertical product differentiation. Horizontal product differentiation describes differences among the various bus services operated. Some consumers would use one route and others would choose another if both were offered at the same price. Relevant literature here is the address model of Hotelling (1929) and extensions developed by Salop (1979). In particular, a variant of Salop’s model has been applied to the bus deregulation issue by Evans (1987). Evans’s numerical simulations support Salop’s main result: that too many firms would enter an industry in a free-entry-zero-profit equilibrium. This allocative inefficiency arises because each entrant would reduce economies of scale enjoyed by incumbents. Entrants will not take this externality into account in their entry decisions, but a social welfare “orchestrator” would.

Vertical product differentiation is said to exist when all consumers choose the same product in preference to another if both are offered at the same price. We will assume that private car transport is vertically differentiated from bus transport, being of superior quality, so that bus transport has to be cheaper to be chosen by any consumers. Quality is taken as a superior good in the fashion of Gabszewicz and Thissé (1979, 1980) and Shaked and Sutton (1982, 1983), so that bus transport will be consumed by those individuals with lower incomes. We will abstract from the possibility of vertical product differentiation within the bus industry (but see Dodgson and Katsoulacos, 1988). Combining horizontal and vertical product differentiation within a single model proves to be a difficult task (see Ireland, 1987, chapter 5, and Neven and Thissé, 1988), and our analysis is facilitated by taking a sequential view of market decision-making: the consumer’s car/bus decision is long-run, and not related to the conduct of the bus industry as a whole. This reflects the view that an individual with no car has to make a number of different journeys,
or that he may not be able to predict the nature of his short-run demand for transport. Also the future characteristics of individual routes may be uncertain. For example, bus timetables may change. It is the combination of the consumer's long-run car/bus decision with his short-run "which bus" decision that is the principal innovative feature of the model.

Our principal objective is to examine the welfare effects of deregulation. The equilibria before and after deregulation are characterised in section 3, after the model has been fully described in section 2. The natural limit to our analysis is the unknown extent of cost reductions after deregulation. What we can attempt, however, is to give an indication of the level of cost reductions which would be sufficient to offset any allocative welfare loss from deregulation. Section 4 offers these indications, and gives a summary of our results and conclusions.

2. INTERNAL AND EXTERNAL COMPETITION

We assume that each bus service competes for custom with its nearest rivals, and that bus transport in the region as a whole competes with private cars. Individuals have potential discretionary income \( y \), which can be spent on transport or on other goods. Values of \( y \) vary among consumers and, for maximum simplicity, are defined by a uniform unit density on \((0, 1)\). For potential income to become actual income, a given amount of travelling is required. This amount is normalised to one journey. If the travelling is done by private car at a price \( p_c \), then utility for the consumer with income \( y \) is given by:

\[
U_c(y) = y - p_c
\]

(1)

If bus travel is chosen, a commitment to bus travel is made before the precise details of required routes and timings are known, though the consumer will have rational expectations concerning the number of routes which will exist and their frequencies. These notions may be formalised in the following way. Consider consumers wishing to travel at various times denoted by a 24-hour clock. Each consumer's "ideal" travelling time can be represented by a point on the unit-length circumference of a circle, and the location of this point can be considered as the consumer's "address". The density of consumers' addresses around the circle is assumed to be uniform, equal to unity, and independent of consumers' incomes. Each consumer is faced with the following decisions. First he must decide whether or not to buy a car. If he buys a car he obtains utility given by (1). If he decides not to buy a car, he must either take bus transport or lose his potential discretionary income \( y \). To take bus transport he must face the cost or inconvenience of taking a service which may be scheduled at a time different from his "ideal" time. Alternative interpretations of the model would include a spatial rather than temporal scenario.\(^1\)

\(^1\) Consider a population living in a suburban belt around a city centre. Bus services from the centre radiate out to the suburban belt, which takes the form of a unit circumference to a circle. The density of consumers of any given income \( y \) around the circumference is again assumed to be uniform and normalised to unity. To use bus transport, consumers have to suffer the inconvenience and cost of first reaching one of the radial bus services.
When deciding which bus service to use, the consumer chooses that service $i$ which maximises

$$U_b(y) = h(y - p_i - md_i)$$  \hspace{1cm} (2)$$

where $h$ is a constant parameter less than one, $p_i$ is the price charged by the $i$th bus service, $d_i$ is the difference in time of the $i$th service from the consumer’s ideal departure time ($d_i = \frac{1}{2}$ implies a 12-hour disparity), and $m$ is the “mismatch” cost of the inconvenience per unit difference in time.

When making the car/bus decision, the consumer can forecast average bus prices and the number of services $n$. He can thus expect an interval between services of $1/n$, but he cannot forecast when the precise departure times will be. On average, individuals will have to adjust by $\frac{1}{n}$ for the nearest bus departure time, and the symmetry of the model suggests an outcome with equally-priced services. At the time of the choice between car and bus travel, utility from bus transport is evaluated at

$$EU_b(y) = h(y - p_b - m/4n)$$  \hspace{1cm} (3)$$

where $p_b$ is the expected common price level of bus journeys. The parameter $h < 1$ is designed to capture a quality differential such that if $p_i = p_b + m/4n$ (so that there is no difference between the prices of bus and car transport, after allowance for the mismatch cost) all individuals would prefer to use cars. This formulation allows us to separate the demand effects of vertical product differentiation (external competition) from those of horizontal product differentiation (internal competition).

Consumers with potential incomes between $y^*$ and $p_b + m/4n$ will choose bus transport, where $y^*$ equates (1) and (3), and $y = p_b + m/4n$ equates (3) with zero. Individuals who can only achieve incomes less than $p_b + m/4n$ by taking a journey will take the long-run decision to opt out of acquiring income and to stay at home. Using (1) and (3), we find that $y^*$ is:

$$y^* = \{ p_c - h(p_b + m/4n) \} / (1 - h)$$  \hspace{1cm} (4)$$

so that the number of individuals deciding to use bus transport is:

$$D_b = y^* - (p_b + m/4n) = (p_c - p_b - m/4n) / (1 - h)$$  \hspace{1cm} (5)$$

Each consumer using bus transport and ideally wishing to travel at a time between services $i$ and $i+1$ will choose service $i$ if, from (2),

$$p_i + md_i < p_{i+1} + m(1/n - d_i)$$  \hspace{1cm} (6)$$

so that the marginal consumer has a mismatch of $d^*_i$ from service $i$, so that

$$d^*_i = (p_{i+1} - p_i + m/n) / 2m$$  \hspace{1cm} (7)$$

If $p_{i+1} = p_{i-1}$, then consumers within $d^*_i$ in either direction of the departure time of service $i$ will choose $i$, so that, given the uniform unit densities, the demand for service $i$ is $2d^*_i D_b$, which is:

$$D_i = (p_{i+1} - p_i + m/n)(p_c - p_b - m/4n) / (m(1 - h))$$  \hspace{1cm} (8)$$

Demand for an individual bus service is thus composed of the number of
consumers opting for bus transport multiplied by the proportion then opting for that particular bus service. The costs of providing bus services are assumed to be a fixed cost per service, $F$, plus a cost $v$ per passenger. Note that on this basis most costs are likely to be classified as fixed costs. The profit from an individual bus service is thus

$$\pi_t = D_t(p_t - v) - F$$

(9)

In the next section, we turn to the characterisation of equilibrium in the regulated and deregulated industry structures.

3. INDUSTRY EQUILIBRIUM

Consider first a regulated monopoly determining all bus prices and the number of services operated, but subject to a break-even constraint. A natural objective for such a firm is the minimisation of the “full cost” of bus transport for the average consumer. This maximises the average utility of users and permits more individuals to choose bus travel. Under the assumptions of this model, there is no reason to adopt different prices in different services; so the regulated industry has to choose the common price $p_b$, the number of services $n$ (and thus the interval between services 1/n), and the departure time of any one service. The departure time is arbitrary as far as the firm is concerned, so it cannot be predicted by consumers at the time of making their bus-versus-car or work-versus-no-work decisions. Prices and the number of services are determined as follows. Set $p_t = p_{t+1} = p_b$. Then (8) becomes

$$D_t = (p_c - p_b - m/4n)/n(1-h)$$

and the break-even constraint is

$$(p_b - v)(p_c - p_b - m/4n)/(n(1-h)) \geq F$$

(11)

Define the full cost of bus travel for the consumer as

$$z \equiv p_b + m/4n$$

(12)

Then (11) is

$$(z - m/4n - v)(p_c - z)/(n(1-h)) \geq F$$

(13)

Now minimise $z$ subject to (13) with respect to $p_b$ and $n$. Obviously this implies maximising the left-hand-side of (13) with respect to $n$, for any $z$. Hence the equilibrium number of services, $n'$, is

$$n' = m / \{2(z - v)\}$$

(14)

Substituting (14) back into (13) and rearranging yields

$$z \geq \{Fm(1-h)/(p_c - z)\}^{1/2} + v$$

(15)

The regulated industry’s optimal $z$ is the minimum $z$ such that (15) holds.
Figure 1 graphs both sides of (15) for the case of \( p_c > v \). The right-hand side function is denoted \( r \). If \( p_c \leq v \) bus transport will not be viable, as marginal costs exceed the cost of private cars. Even if \( p_c > v \), it may be that insufficient revenue can be generated to cover the fixed costs of any positive number of services. Remember that the existence of only very infrequent services will attract few customers away from car travel, and very frequent services will imply a small share of bus users for any one service. Where (15) is satisfied for some range of \( z \), as in Figure 1, then the minimum of that range is chosen. We denote this \( z' \).

It follows immediately from (15) as a binding constraint, or from Figure 1, that the following comparative statics results hold:

\[
\frac{dz'}{dF} > 0 \quad \frac{dz'}{dh} < 0 \quad \frac{dz'}{dm} > 0 \quad \frac{dz'}{dv} > 0 \quad \frac{dz'}{dp_c} < 0
\]

Thus the full cost of bus services increases with either cost parameter, increases with the mismatch cost \( m \), and decreases as the quality differential between cars and buses decreases (\( h \) increases towards unity). Of course the level of use of bus services responds in the opposite direction. Using (14) in the definition (12) yields

\[
z' = p_c + (z' - v)/2 \quad \text{or} \quad p_c = (z' + v)/2
\]

so that bus prices have the same qualitative comparative statics as \( z' \). Combining (14) and (15) also allows comparative static analysis of \( n' \), the equilibrium number of services. We find:

\[
\frac{dn'}{dF} < 0 \quad \frac{dn'}{dh} > 0 \quad \frac{dn'}{dm} = ? \quad \frac{dn'}{dv} < 0 \quad \frac{dn'}{dp_c} > 0
\]
A PRODUCT DIFFERENTIATION MODEL

The ambiguous response of the frequency of services to an increase in the customers' cost of "mismatch" is because, while consumers would be willing to pay more for more frequent services, there are fewer consumers as private car transport is relatively more attractive. This reduces the market's ability to support the current frequency of services.

Otherwise the effects of parameter changes are unambiguous. An increase in the price of private cars, or a reduction in their quality advantage, allows for more services and lower prices. An increase in fixed or variable costs leads to fewer services and higher prices.

Now consider the bus industry after deregulation. Each service is now assumed to be operated independently, and entry is assumed to occur until profit in each symmetrically located service is zero. The price $p_i$ of each service maximises (9). As we have taken the consumers' car/bus decisions to depend on the average bus price $p_0$, the aggregate number of consumers is little affected by a change in any one price. We will assume that this "little" effect can be ignored. Then $p^*_i$ will be that $p_i$ which satisfies:

$$-(p_i - v) + p_{i+1} - p_i + m/n = 0$$

(17)

With symmetric behaviour by all bus operators $p_i = p_{i+1} = p^*_n$, where $p^*_n$ is the unregulated common price of bus transport and is found from (17) to be given by

$$p^*_n = v + m/n$$

(18)

At prices $p^*_n$, the full cost of bus transport, $z$, is given by (12) as

$$z = v + 5m/4n$$

(19)

Using (19) to substitute out $n$ in the zero-profit condition ((13) as an equality) yields

$$z \geq (5/4) \left\{ Fm(1-h)/(p_c - z) \right\}^{1/2} + v$$

(20)

The form of (20) is very similar to that of (15). The coefficient $5/4$ implies that, for any value of $z$, the right-hand side of (20) is greater than that of (15). Thus the smaller positive root of (20), which will be denoted $z^\prime$, is greater than $z^\prime$. This is shown in Figure 1. $z^\prime$ characterises the zero-profit equilibrium of the deregulated bus industry. (It is selected rather than the other positive root of (20) by a stability argument.) The number of services, $n^\prime$, and the level of prices, $p^\prime_n$, at this equilibrium are given by (19) and (18) respectively. The comparative static responses to changes in the parameters $m, h, F, v$ and $p_c$ can be shown to be qualitatively the same as in the regulated industry.

4. RESULTS AND CONCLUSIONS

In the absence of cost differences, the regulated industry must serve customers better, since it minimises "full cost". There are two reasons why deregulation results in inferior welfare. First, entrants into the deregulated industry do not take proper account of the externality they cause to other operators by reducing their
economies of scale. This is the finding of Salop (1979). Secondly, individual operators do not have the incentive to reduce prices in order to attract more consumers away from the higher quality car transport. Together these factors cause bus prices \( p_b \) to be higher in the deregulated state. To show this result, use (18) and (19) to obtain

\[
p_b^* = (4/5)z'' + (1/5)v
\]

As \( z'' > v \), (21) implies that \( p_b^* > (z'' + v)/2 \), and as \( z'' > z' \), \( p_b^* > p_h^* \), using (16). It is not possible to show that \( n' \) is greater or smaller than \( n'' \): the excess frequency of services for the given number of customers in the deregulated case has to be weighed against the regulated industry's desire to gain customers, who would otherwise use cars, by increasing the frequency of services provided.

The principal argument for deregulation is that it leads to lower costs of supply. We can now ask to what extent costs must be lowered in order to cause deregulation to increase welfare (reduce the full cost, \( z \)). Either cost parameter can be considered. The simpler case is to assume that savings relate to the fixed cost of operating a service. This is also the more interesting case, since our concept of the fixed cost per service includes the provision of a bus and a driver, and is thus a large part of the total cost. Using (15) and (20), and distinguishing fixed costs pre- and post-regulation as \( F' \) and \( F'' \) respectively, we can say that \( z'' < z' \) if \( F'' < (16/25)F' \). If only if fixed costs are at least 36 per cent less after deregulation will welfare improve. Although no great significance can be read into a number from such a simple model, it is interesting to note that this exceeds the 20–30 per cent cost reductions (vehicle costs per mile) reported by Tyson (1989), Table 3.2

The case where cost reductions are made in variable cost is less clear. From (15) and (21) we know that, for \( z'' = z' \), \( v'' \) and \( v' \) must satisfy

\[
(4/5)(z' - v'') = z' - v'
\]

or

\[
4v'' = 5v' - z'
\]

and simplifying and using (14) yields

\[
v'' = v' - (z' - v')/4 = v' - m/8n'
\]

Equation (22) gives the lower bound of a variable cost reduction for deregulation to be welfare-improving as \( m/bn' \), or half the average mismatch cost in the regulated equilibrium. Also from (22), given our previous comparative static analysis of \( n' \), we can see that variable cost savings need to be greater to justify deregulation if \( F \) or \( v' \) is higher, or if \( p_c \) or \( h \) is lower.

---

2 Our formulation of costs does not allow a simple correspondence to the concept of vehicle operating costs per mile. However, what we have termed fixed costs is probably closer than variable costs, since neither vehicle operating costs nor fixed costs are much affected by passenger loading. One obvious exception to this is the move towards operating minibuses.
A PRODUCT DIFFERENTIATION MODEL

Precise numbers and expressions are only meaningful within our simple model. They do however illustrate that quite considerable cost savings may have to be made to make up for the lost coordination of a regulated industry. In particular, we have shown how a model, incorporating aspects of both vertical and horizontal product differentiation and stressing the long-run nature of the car/bus decision, highlights the significance of coordination. General reductions in bus prices or improved frequencies of services attract additional consumers into the market. However, the incentive for any individual supplier to cut his price does not encompass this argument for market expansion, since each would rather leave it to others to improve the overall image of the bus sector. Furthermore, the excess entry into a deregulated bus industry leads to high competitive prices, since economies of scale are not achieved. This detracts from the industry's ability to compete with private transport.

Of course models of the kind described above are merely illustrative of economic processes, and little weight should be placed on the detailed results. Nevertheless, it would appear that models which neglect the presence of external competition, and how this reacts with the overall state of the bus industry, omit an essential ingredient in the issue of bus deregulation. Finally, it is interesting to note that some evidence of the effects of bus deregulation in the UK conurbations appears to give broad support to the predictions of our model. Tyson (1989) reports that fares have risen steeply (27.5 per cent more than inflation) while the volume of services has increased by a more modest amount (12 per cent). Overall bus use has fallen very considerably; but of course the continuation of past trends would suggest that some fall would have occurred even without bus deregulation (see Tyson, 1989, pp. 34—41) and it is also necessary to take into account the simultaneous reduction in subsidies.

Date of receipt of final typescript: May 1990.

REFERENCES


161