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Direction dependent prices in public transport: A good idea? The back haul pricing problem for a monopolistic public transport firm

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Abstract. Markets for transport are often characterised by unequal demand in both directions: every morning during peak hours the trains are crowded while moving towards the direction of large cities, whereas they may be almost empty in the other direction. In this paper we discuss the implications of these imbalances for price setting of transport firms. From the viewpoint of economic theory, two regimes can be distinguished: one where – owing to price discrimination – the flows are equal, and one where unequal flows are the result. Special attention is paid to the case where the transport firm does not apply price discrimination, as is the case with most railway firms in Europe. We find that in the case of substantial joint costs, the introduction of price discrimination not only leads to an increase of profits, but also to positive effects on consumer surplus. This result differs from the standard result in the literature on industrial economics. The standard result purports that with linear demand functions price discrimination has a negative impact on the welfare of the average consumer and that this negative impact dominates the positive effect on profits of the producer.

1. Introduction

Multiproduct firms often benefit from the fact that the production of several different goods in one firm is cheaper than outputs produced by separate monoproduct firms. A special example of multiproduct firms are transport companies: a transport company serving a certain market between points A and B will also produce services between B and A when the vehicles make the return journey. The structure of transport cost is such that once the capacity costs of the AB trip have been made, the additional costs of transporting passengers in the opposite direction are relatively small. An interesting feature of transport markets is that demand in both directions may be rather unbalanced. This holds true for both freight and passenger transport. This imbalance is one of the reasons why load factors in transport are often so low. In this paper we address the question to what extent differentiated prices can help to overcome this problem and explore the (possible) welfare implications.

To give an illustration of the magnitude of the problem we present data on a small sample of public transport links in the Netherlands during the morning peak (see Table 1.1).[1] Substantial differences in the number of passengers in both directions can be observed. These differences are especially large for bus transport (up to a factor of 20). An explanation of the difference between bus and train is the large share of school children travelling by bus from villages to cities where most of the schools for secondary education are located. Public transport operators can apply several strategies to accommodate this imbalance such as waiting until the afternoon peak for the return trip of some of the vehicles or using some of the vehicles on other links between the morning and the afternoon peak. In this paper we discuss the strategy of differentiated price setting to cope with the lack of balance.

In the economic literature various terms have been used for the phenomenon that production of one type of output implies that also other types of outputs are produced; for example; *joint products, joint costs or cost interdependence* (Gravelle & Rees 1992; Tirole 1988). The joint cost phenomenon is obviously related to the notion of *economies of scope*. A joint cost function is said to exhibit economies of scope when the costs of producing given amounts of two different outputs q_1 and q_2 are lower when it is done in an integrated firm compared with when it is done by two specialist firms, one producing only q_1 and the other one only q_2. In the context of the back-haul problem this condition is obviously satisfied.[2]

In the transport literature the joint cost phenomenon is known as *the back haul problem* (Felton 1981). The problem has received substantial attention in the older transport economics literature. See for example Locklin (1947), Ferguson (1972), Mohring (1976) and Felton (1981). The older literature on the back haul problem strongly focuses on freight transport in regulated markets. For example, in the USA, the Interstate Commerce Commission (ICC) had formulated rules for the rates to be charged in interstate trucking. These

Table 1.1. Number of daily public transport passengers in the Netherlands during the peak (weekdays) in both directions for a small sample of independent links.

Link	Mode	Number of passengers (high volume direction)	Number of passengers (low volume direction)
AB	Bus	391	16
CD	Bus	200	22
EF	Bus	1,595	83
GH	Train	8,954	2,986
IJ	Train	1,695	1,255
KL	Train	756	461

Source: NSR (train data), ZWN (bus data).

rules gave little scope for lower rates on transport markets characterised by spatial imbalances and therefore imply a shift of costs from shippers in one direction to shippers in the other direction. In addition the rate fixing rules had the effect of protecting small carriers against competition by large carriers and of giving carriers a stronger position against shippers (Felton 1981). Indeed, Locklin (1947) who mainly defends the protection oriented ICC rules cites the popular wisdom that "*one man's back haul is another man's living*." Similar policies of rate regulation are mentioned by Locklin for railways and aviation, both relating to freight transport.

In the more recent literature the back haul problem usually only receives brief attention (see for example Korver et al. 1992; Button 1993 and Blauwens et al. 1995). A possible explanation is that the practices of rate regulation have changed considerably during the past decades so that transport firms do not face such fare restrictions now. Nevertheless, the back haul problem in unbalanced markets still deserves attention in the analysis of transport firms. For example, it is one of the causes of the low load factors often observed in transport. The setting of direction-dependent rates is one of the means to improve them.

The older literature on the back haul problem usually takes the case of perfect competition as a bench-mark (see for example Felton 1981). However, also the case of monopolistic price setting deserves attention in this context. The reason is that the worldwide process of deregulation of transport did not lead to the disappearance of monopolists. There are many segments (specific links, specific periods) in the transport market where there are still monopolists. Also the practice of granting public transport suppliers long run concessions for the exploitation of certain networks has led to the emergence of firms with monopoly power given the duration of the concession.

In the context of monopolistic supply of transport services the back haul problem deserves special attention. Making transport rates direction-dependent has positive effects on total welfare in the context of perfect competition (as demonstrated by Felton 1981). In the case of monopolistic price setting such a beneficial effect may be questionable, however. The reason is that making prices direction-dependent is a form of price discrimination. Since price discrimination entails a shift of welfare from the traveller to the supplier with a usually negative effect on total welfare, one might argue against the use of direction dependent rates. Thus, a policy that is welfare enhacing with perfect competition might be counter productive with a monopolist.

The objective of this paper is to clarify this issue of the potential welfare effects of direction dependent prices for the monopoly case. The emphasis in the paper will be on analytical aspects. To clarify the model results, a numerical illustration will be presented. The paper starts with a micro-economic analysis of profit maximisation by a monopolist serving unbalanced markets

(Section 2). Based on this we will investigate two regimes: an equal quantity regime (where despite non-identical demand functions, one arrives at equal quantities transported) and an unequal quantity regime. In Section 3 we will investigate the consequences of a price setting strategy where the supplier adopts the constraint that *prices are equal* in both directions. Such a price setting strategy is typical in public transport firms in many countries. In Section 4 some numerical examples will be given for the case of the Netherlands Railways. Special attention will be given to the welfare effects of the price equality constraint: it certainly reduces profits of the monopolist, but what is its effect on consumer surplus of travellers in both directions and how does it affect total welfare?

2. Price setting in the presence of joint costs

This section gives the analytical formulation of a micro-economic model of a monopolist facing the back haul problem. Two possible regimes of outcomes will be discussed: one where the quantities consumed in both markets are equal and one where they are not equal. Factors having an impact on which of the two regimes will emerge are discussed. The analysis is followed by a broader discussion of the implications of congestion in the busy market on price setting.

Base model

Consider the case of a monopolist serving two markets (AB and BA) and having part of the production costs dependent on the maximum quantity sold in one of the two markets. For reasons of convenience demand on both markets is assumed to be independent. Thus we do not go into issues of the demand for return trips. This may seem more restrictive than it really is since the labelling of markets AB and BA as busy and non-busy during the morning peak simply carries over to the opposite labels during the afternoon peak. If all AB travelers during the morning peak would return as BA travellers during the afternoon peak (and the same pattern applies to the other travelers) this would keep the analysis completely intact. Of course, when part of the AB travelers during the morning peak would return outside the afternoon peak there would be a need to introduce interdependencies between demand on both markets. Given the aim of the paper to analyse the basic welfare effects of direction dependent prices we have decided to avoid the introduction of interdependent demand on the markets. In Section 3 more will be said about the nature of demand at both markets. The profit function of the monopolist can be expressed as:[3]

$$\Pi = p_{AB}q_{AB}(p_{AB}) + p_{BA}q_{BA}(p_{BA}) + C(Q) + c(q_{AB}) + c(q_{BA}) \tag{2.1}$$

where p are prices, $q(.)$ are demand functions, $C(.)$ and $c(.)$ are cost functions with standard properties. Furthermore:

$$
\begin{aligned}
Q &\geq q_{AB} \\
Q &\geq q_{BA}
\end{aligned}
\tag{2.2}
$$

If the monopolist can price-discriminate between the two markets, optimal prices would be determined on the basis of the following first-order conditions:

$$
\begin{aligned}
p_{AB} &= \left(1 - \frac{1}{\varepsilon_{AB}}\right)^{-1} [c'(q_{AB}) + \lambda_{AB}] \\
p_{BA} &= \left(1 - \frac{1}{\varepsilon_{BA}}\right)^{-1} [c'(q_{BA}) + \lambda_{BA}]
\end{aligned}
\tag{2.3a}
$$

$$
C'(Q) = \lambda_{AB} + \lambda_{BA} \tag{2.3b}
$$

$$
\begin{aligned}
&\lambda_{AB}(Q - q_{AB}) = 0 \quad \lambda_{AB} \geq 0 \quad Q - q_{AB} \geq 0 \\
&\lambda_{BA}(Q - q_{BA}) = 0 \quad \lambda_{BA} \geq 0 \quad Q - q_{BA} \geq 0
\end{aligned}
\tag{2.3c}
$$

Conditions (2.3a) are standard rules setting the price on the basis of a mark-up over marginal costs, where the mark-up is determined by the price elasticity of the demand in each market (ε). Here, however, marginal costs are given by two components: "direct" marginal costs $c'(.)$ and a Lagrange multiplier. From (2.3b) it can be seen that at least one of the two multipliers must be positive, which means that at least in one market the quantity q is equal to Q.

When only one multiplier is positive, marginal common costs $C'(Q)$ are completely assigned to the larger market, and the supplier acts as if it were in two separate markets in which marginal costs are higher in the larger market.

A more interesting case emerges when quantities q are equal (and equal to Q). Common costs are then shared, the multipliers are both positive and they are set in order to satisfy (2.3a). Clearly, nothing ensures that the multipliers expressing the share of common marginal costs allocated to the two markets are equal. This may be interpreted as a sort of cross-subsidisation between the two markets.

Thus the analysis indicates that two possible regimes may emerge. In the first regime the quantities consumed in both markets are unequal (UQ). Apparently the gap between demand in the two markets is so large that it cannot be closed by differentiated prices. In the second regime where equal quantities are consumed (EQ) price policies appear to be effective to get rid of the empty vehicle problem.

Graphical illustration

To better understand how a regime of equal quantities (EQ) may emerge from an unconstrained profit maximisation with joint costs, it may be useful to think about the problem of price setting as being composed of two stages: first, for each level of total quantity produced, the production is efficiently allocated in the two markets and, second, the optimal activity level is determined.

The first stage can be easily studied by means of isocost-isorevenue diagrams. An isocost function includes all the pairs (q_{AB}, q_{BA}) associated with the same level of total production costs. Analogously, an isorevenue curve identifies all the pairs associated with the same revenue level. Examples of isocost and isorevenue functions are depicted in Figures 2.1 and 2.2.

Isocost curves appear to be kinked here because of the presence of common costs, and in this case the kink is found where the quantities are equal. Higher common costs, relative to direct marginal costs, make isocost functions "more kinked".

Isorevenue functions are instead concentric circles with inner circles associated with higher revenue levels. The centre of the concentric curves is

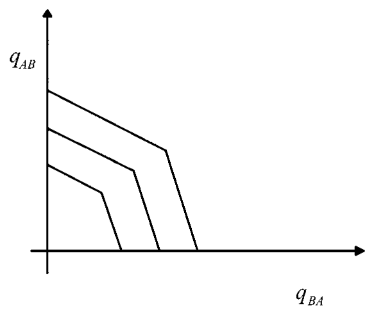

Figure 2.1. Isocost curves.

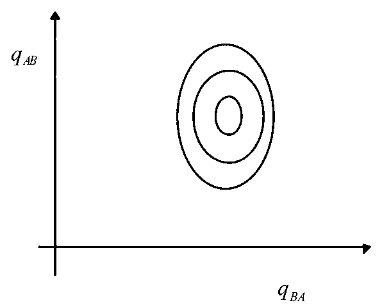

Figure 2.2. Isorevenue curves.

situated on the quantity pair that would be chosen in the absence of production costs.

It is straightforward to see that a necessary condition for profit maximisation is given by the tangency between an isorevenue and an isocost curve.[4] The set of all tangency points therefore defines an "optimal expansion path", a one-dimensional space along which total profits vary.[5] Since the profit maximising quantity pair is a point on the expansion path, the two possible outcomes of profit maximisation, equal (EQ) or unequal (UQ) quantities, appear as shown in Figures 2.3 and 2.4.

One might wonder whether similar results would be obtained in the case of a price-taking transport company. This case has been studied by Felton (1981). He demonstrates that also in the competitive case differentiated prices will be found, and that again two regimes (EQ and UQ) can be distinguished. The difference is of course that in our case the monopolist applies a mark up on the marginal costs, whereas such a mark up is not possible in the competitive case.

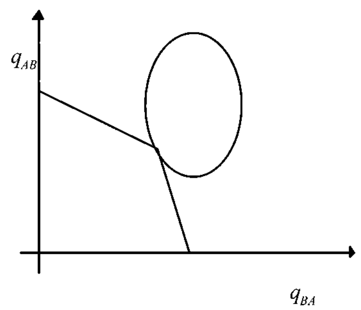

Figure 2.3. EQ case.

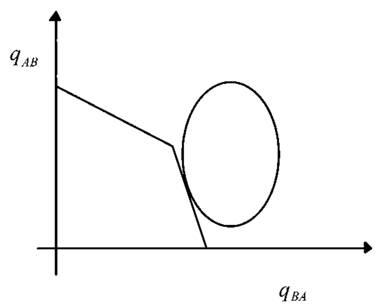

Figure 2.4. UQ case.

Comparison of EQ and UQ regime

One may wonder which factors determine whether the EQ regime will appear as opposed to the UQ regime. By looking at the two diagrams, it is immediately verifiable that the following conditions make the emergence of an EQ solution more likely:

a) relatively higher common costs, shifting the kink point above and rightward. A special example is given by the absence of direct marginal costs *c*(.), where isocost curves would be "squared";
b) market sizes relatively equal, where market size is defined as the maximum quantity associated with positive marginal revenue. Similar markets have the centre of isorevenue functions close to the line $q_{AB} = q_{BA}$;
c) relatively high price elasticity in one or both markets. High elasticities flatten the part of the isorevenue circle where the tangency point can be found. In the limit case of exogenously fixed prices, isorevenue functions would become downward sloping parallel lines.

The latter point suggests that it is straightforward to extend the analysis to non-monopolistic market structures. The demand function adopted in (2.1) could be re-interpreted as an individual demand function encountered by each competitor, on the basis of its conjectures about the competitors' behaviour. For example, in an oligopolistic market "à la Cournot", production volumes chosen by concurrent firms are taken as given, so that the individual demand curve is the residual of the market demand when the quantity produced by the competing firms is subtracted.

It is interesting to note that, in a monopolistic competition model, the price elasticity of the individual demand functions would be affected by the entry of new competitors. Since entry increases demand elasticity in a market for non-perfect substitute goods or services, market deregulation and increased competition may bring about the choice of an EQ price strategy.

Implications of congestion

In the analysis given above we did not pay explicit attention to the existence of *congestion externalities* in transport; yet, congestion may be quite relevant in an analysis of a "busy" versus a "non-busy" direction. Two types of congestion can be distinguished in this respect: external versus internal. In the first case congestion occurs in a competing mode (say road transport) implying a partial shift towards the public transport mode considered here. This would already be absorbed in the parameters of the demand function $q_{AB}(p_{AB})$ for public transport: the high level of demand for public transport in the busy direction may be partly due to travellers who want to avoid road congestion.

In the case of "internal" congestion the speed and/or comfort in the busy direction may be adversely affected by the number of travellers. When this leads to higher costs of producing the transport services this will be reflected by the pertaining cost function $c(q_{AB})$ which has the property of decreasing returns to scale. The analysis of Section 2 allows for such cost functions.

Internal congestion may also have an impact on the travellers, however. Slow or crowded public transport will discourage potential users during busy periods. To take this into account the demand function $q_{AB}(p_{AB})$ would have to be generalised so that it incorporates indicators of travel time t_{AB} and comfort v_{AB} (for example, the probability of getting a seat), which are themselves functions of travel demand q_{AB}. Note that the present formulation of the demand function $q_{AB} = q_{AB}(p_{AB})$ can be considered as a rewritten form of $q_{AB} = f[p_{AB}, t_{AB}(q_{AB}), v_{AB}(q_{AB})]$ so that congestion has been incorporated in an implicit way. Obviously, when the number of travellers has an impact on travel time and comfort this would have a dampening effect on demand in the busy direction. Given the externality involved, profit maximising public transport operators would apply an upward shift of the price in the busy direction to let the travellers pay for the external costs imposed on other travellers, similar to the case of congestion pricing on roads.

We conclude that the various forms of congestion considered here all tend to lead to a higher price set in the busy direction:

– congestion on the road makes public transport demand less price elastic (because the competing mode is less attractive) so that there are more opportunities for a mark-up (see 2.3a);
– introduction of congestion leads to higher marginal costs $c'(q_{AB})$ implying higher prices (see 2.3a);
– crowding and travel time losses among travellers induce congestion pricing strategies such that travellers in the busy direction pay a congestion charge to cover the disutility imposed on other travellers.

3. Discriminatory vs. uniform pricing: a welfare analysis

In this section the welfare implications of direction-dependent pricing will be discussed. Three types of actors will be distinguished for this purpose: people travelling from *A* to *B*, people travelling from *B* to *A*, and the public transport supplier. As a benchmark we will use the case where the monopolist imposes a uniform price on both markets.

The analysis conducted thus far has made clear that a network operator, if it is free to set prices in order to maximise profits, would not – in general – choose equal prices for two markets linked by cost interdependence. Yet, several examples can be found, especially in transportation markets, where prices are made dependent on distance but not on the direction, so that the same price applies to different markets. In this section, we shall consider the implications in terms of variations in profits and welfare of discriminatory (differentiated) and uniform pricing. To this end, we shall continue to assume that firms set prices according to profit maximisation, even in the presence of a constraint of price equalisation.

First of all, it is apparent that profits cannot increase if prices must be equalised. If a firm is free to set different prices, it can "at worst" replicate the outcome obtained under uniform pricing. Mathematically, a constrained maximisation cannot lead to better results than an unconstrained one.

Level of uniform price

On the other hand, the welfare of consumers in the two markets is affected by the direction of price changes. In this respect, it can be demonstrated under fairly general assumptions about demand and cost functions[6] that the single price, which would be chosen for both markets, must lie between the two prices chosen under discrimination.

To see this, consider the example of Figure 3.1, in which profit functions for the two markets are depicted in terms of price. The two functions are drawn under the assumption that common costs are considered as the production costs of the largest market.

We start with a discussion of the level of the uniform price in the UQ regime. If prices are allowed to differ and it is not optimal to sell equal quantities, prices are chosen to achieve, independently, the maximum profit in the two markets. If, instead, a uniform price has to be set, the firm maximises the sum of the two profit functions. By recalling that total profits are increasing (decreasing) where both profit functions are increasing (decreasing),[7] it is clear that the optimal uniform price can neither be found in regions X and X' nor

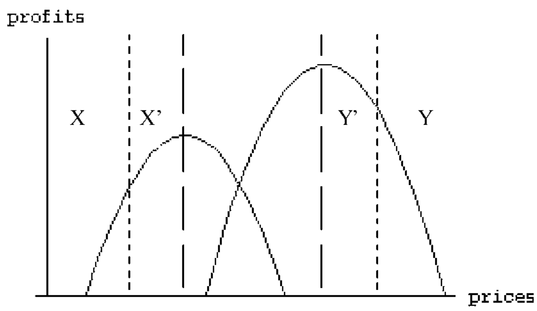

Figure 3.1. Profit functions in the two markets.

in regions Y and Y'. The price must therefore lie between the two differentiated prices. In turn, welfare of consumers in the large market increases with a single price, whereas consumers in the small market are made worse off.

Since the price in the small market tends to increase, it is also possible that the price would be too high to have a positive demand there. In this case, the small market would "disappear". In the large market the price and the consumer surplus would remain unchanged. In other words, price discrimination would lead to a Pareto improvement with gains for both the firm and the remaining consumers.

We continue with the EQ regime. When prices are set in the two markets so as to equalise the quantity sold, from (2.3) it can be noted that the marginal profit in the small market is positive in the optimum, whereas it is negative for the large market.[8] Prices are then set lower in the small market and higher in the large market, in comparison with the UQ case (thus the optimal price in the large market will be in the Y' zone; in the small market it will be in the X' zone). The argument applied above can be used here as well, so that the optimal uniform price can neither be found in region X nor in region Y.

A difference with the UQ regime emerges when the small market is not served under uniform pricing, because there would be no more need to equalise quantities, and this would make the price in the large market somewhat lower. Again we have here losses for consumers in the small market and gains for those in the large market, but with a different causal mechanism.

Welfare implications; who looses and who benefits

Who are the winners and loosers with the introduction of uniform pricing in unbalanced transport markets? First of all it is clear that the supplier is among the loosers: the price equality constraint implies a reduction in profits. Second. it appears that the consumers in the small market will also be loosers because they will have to pay a higher price. The reverse holds true for the consumers in the large market.

For an overall welfare assessment one would need to add the welfare and profit changes of the various actors. To make this a feasible exercise we have to make a number of simplifying assumptions. Therefore we consider a special case where demand functions are linear, there are no direct marginal costs,[9] and marginal common costs C are constant:

$$
\begin{aligned}
&q_{AB} = A - Bp_{AB} \\
&q_{BA} = a - bp_{BA} \\
&C(q_{AB}) = Cq_{AB} \\
&A > a \qquad A/B = a/b
\end{aligned}
\tag{3.1}
$$

It can be easily verified that optimal discriminatory and uniform prices are here determined as the following:[10]

$$p_{AB} = \frac{A + BC}{2B}\,; \quad p_{BA} = \frac{a}{2b}$$
$$\bar{p} = \frac{(A + a) + BC}{2(B + b)} \tag{3.2}$$

Furthermore, because demand functions are linear and there are constant returns to scale, it can be checked that the total quantity $q_{AB} + q_{BA}$ is the same under the two price regimes (Robinson 1933). This has important implications in terms of welfare. If the total quantity to be allocated is a given, the maximum total consumers' utility is achieved when the marginal utilities are equal. But in turn each consumer equates its marginal utility to the ratio of the price and the marginal utility of income; if the latter is not too different among the consumers,[11] the imposition of a single price means that welfare gains in the large market always exceed welfare losses in the small market, if the small market continues to be served.

Since profits are higher under discriminatory pricing, the variation in profits caused by the imposition of a uniform price is unambiguously negative:

$$\Delta\Pi = -\frac{(Ab - aB + bBC)^2}{4bB(b + B)} \tag{3.3}$$

Looking at (3.3), it is interesting to notice that:

- profit losses are higher the larger the difference in the size of the markets, expressed in terms of maximum willingness to pay, or in terms of maximum quantity. This is intuitively clear, as there should be more scope for setting different prices when the basic conditions are different;
- profit losses are higher the larger the common cost component C. In the case of a UQ discrimination, common costs are considered as production costs of the large market: their inclusion amplifies the asymmetry of the two markets. When an EQ solution emerges, there is an incentive to differentiate the prices even more to achieve the equalisation of quantities.

By charging discriminatory prices, the quantity sold in the large market decreases, making it possible to save on production costs. This "cost saving effect" is important because it overlaps with the fundamental motivation of price discrimination: the extraction of consumer surplus by the monopolist.

Consequently, there are two separate reasons why price discrimination is profitable for a monopolist. The standard case is that with different price elasticities, price discrimination serves to exploit a larger part of the consumer surplus. In addition, with joint costs, price discrimination helps to avoid high costs for the production on the large *AB* market.

What are the implications for total surplus, defined as the sum of profit and consumer surplus? The standard result has been formulated by Tirole (1988): with linear demand functions price discrimination is bad for total surplus as long as both markets are served. The introduction of joint costs makes the expression of variations in total surplus quite complex and difficult to analyse in general terms. However, following Tirole (1988), it is possible to compute lower and upper bounds for this variation. These are:

$$-C\Delta q_{AB} \leq \Delta W \leq (p_{AB} - C)\Delta q_{AB} + p_{BA}\Delta q_{BA}$$
$$-\frac{C[(Ab - aB) + bBC}{2(b + B)} \leq \Delta W \leq \frac{(Ab - aB)^2 - (bBC)^2}{4bB(b + B)} \tag{3.4}$$

Observe that if $C = 0$, total surplus would increase if a uniform price is imposed. This means that, if common costs are not very large, the gains for the consumers in the large market can compensate for the losses in profits for the firm and in surplus for the consumers of the small market. However, if C is sufficiently high, the "cost saving effect" may dominate, bringing about losses in profits so large that the variation in total surplus becomes negative. This can be seen in (3.4) because increases in C reduce both the lower and upper bounds. We conclude that the introduction of a uniform price in stead of price discrimination has two opposing effects on total surplus. Against the beneficial effect that monopolistic price discrimination is removed there is the adverse effect that potential cost savings of avoiding empty vehicles are not realised. Which of the two effects will dominate depends on the actual values of the parameters.

Thus, the welfare effects of uniform prices with a profit maximising monopolist cannot a priori be spelled out to be positive or negative. In the case of a price taking firm such an effect would be unambiguously positive (see Felton 1981) since the adverse welfare effects of price discrimination would not apply.

4. Numerical illustration: the Dutch railways

Given the indecisive result of our analysis that the welfare effect of uniform pricing on total surplus may be both negative and positive, a numerical illustration will be helpful to assess the size of the two countervailing forces. Railways are a good example of suppliers facing joint costs leading to the back haul problem. In this section we will give a short illustration of the consequences of joint costs on price setting for the Netherlands.

One may wonder to what extent it is appropriate to model the Dutch national railway company as a monopoly. A first point is that there is competition between public transport and the car. A more complete formulation of the demand functions would indeed indicate that the price of the competing mode (car) would be incorporated. However, one may consider the price of car use as exogenous in our model – there is no risk that some agent would adjust the price of car use as a consequence of price policies of the railway company – so that competition between car and railways can be safely ignored. A second question is to what extent competition on the Dutch railway tracks has to be considered. The Dutch railway system has been in a period of transition from a national state controlled company towards a system where some form of competition may be allowed. During a couple of years there has been a second supplier of services on the Dutch railways (Lovers Rail) versus the incumbent Netherlands Railways (NSR), but services provided by Lovers Rail were very insignificant in size and consumer response has been disappointing (a market share of less than 0.1%), so that Lovers Rail has decided to terminate its services in 1999. In the meantime the national government is changing its policy from stimulating competition towards franchising of regional networks based on competitive bidding. On the intercity network (the link *AB* analysed in the empirical case study being part of it) competition is not allowed according to the current rules. In a legal sense NSR is free to set its prices in order to maximise profits but it has been reluctant to do so because the Dutch public still considers NSR as a public company. For example, changes in the system of annual travel cards have led to a strong negative response in public discussions. The empirical study given here serves as an investigation of the consequences a profit-oriented differentiation of prices would have.

Base case with direction dependent prices

We take as an example the link between two medium sized cities (*A* and *B*),[12] where in the current situation of direction-independent prices in the morning peak, the daily number of travellers in one direction is about 35% higher than in the other direction.

The linearised demand equations for both directions are:

$$q_{AB} = 2460 - 60p_{AB},$$
$$q_{BA} = 1820 - 44p_{BA}$$

where monetary units are in dfl. The difference in scale in both markets is reflected by the difference in the constants in this demand function. The highest willingness to pay equals about dfl 41 in both markets (2460/60 and 1820/44). It is a coincidence that this value is equal for both markets. An implication is that for a given price, the price elasticity of demand is equal in both markets.

The cost function for the service between A and B and vice versa is assumed to be linear; the parameters have been estimated to be:

$$C = (0.86)(q_{AB} + q_{BA}) + (9.69)[\max(q_{AB}, q_{BA})] + \text{fixed costs.}$$

The cost factor 0.86 is the marginal cost of a passenger when we assume that there is sufficient capacity; this cost relates to passenger dependent services (such as ticket windows, train guards, etc.). The cost factor of 9.69 relates to the costs of moving seats (regardless of whether they are occupied or empty), plus the cost for the national railways of owning seats; it is assumed that additional seats are only used during the peak and that they do not generate receipts during the rest of the day.

Profit maximisation without imposing a price equality constraint leads to an optimum as follows:

$$p_{AB} = 25.78,\ q_{AB} = 913.2$$
$$p_{BA} = 21.11,\ q_{BA} = 891.2.$$

Note that the marginal cost in market *BA* is very low, so that the price is near the price level where marginal returns are zero ($p = 20.5$). The price paid by travellers in the low demand direction is only based on the marginal cost of 0.86 per passenger; the capacity costs are completely taken into account in the price charged to the passengers travelling in the opposite direction. The price differentiation clearly leads to a substantial convergence of volumes of travellers in both directions compared with the current situation. Actually, the optimum found in this case is quite close to the equal quantity regime discussed in Sections 2 and 3.

Price setting under the price equality constraint

Profit maximisation under the *price equality constraint* would result in:

$$p = 23.80, \quad q_{AB} = 1032, \quad q_{BA} = 772.6.$$

Under this constraint the difference in the number of travellers in both directions is substantial.[13]

What are the welfare consequences of the introduction of the equal price? For AB travellers welfare (measured by means of consumer surplus) increases owing to the price decrease (+1945). For BA travellers the opposite occurs: (–2246). Thus, the average consumer loses when the monopolist uses the self-imposed constraint that prices are equal in both directions. In addition, the profits of the railway company would decrease by an amount of 548. Thus, the change in total surplus when the price equality constraint is imposed is –849, the distribution being such that the firm and *BA* travellers are negatively affected and *AB* travellers are positively affected. This case underlines the importance of joint costs in the welfare analysis. Without joint costs the introduction of a uniform price would have a positive effect on total surplus (see Section 3).[14] But here the opposite is found: strong cost interdependence calls for differentiated prices from a social welfare perspective, even in the context of monopolistic price setting practices.

Sensitivity analysis

Of course this result depends on the specific parameters of demand and cost functions. Below we show the results of two other cases using different sets of parameters. In *case 1* a rather large difference exists between the *AB* and the *BA* market, both in terms of size of market and willingness to pay. The cost function remains unaltered:

$$q_{AB} = 2000 - 50p_{AB},$$
$$q_{BA} = 600 - 20p_{BA}$$
$$C = (0.86)(q_{AB} + q_{BA}) + (9.69)[\max(q_{AB}, q_{BA})] + \text{fixed costs.}$$

The results can be found in Table 4.1. A large difference in the number of passengers in both directions is observed. The quantity difference is substantially larger when the price equality constraint is imposed; this would lead to considerable positive welfare effects in market *AB*. The welfare loss of passengers in the other direction is smaller, therefore the average consumer benefits from the self-imposed price equality constraint. However, the sum of changes in consumer surpluses and profits is negative, since it appears that the advantage for the average consumer does not outweigh the decrease in profits for the supplier. When we compare the outcome of case 1 with that of the base case, we note that in both cases the introduction of a uniform price has a negative effect on profits, consumer surplus of travelers in the small market and on total surplus. The consumers in the busy market benefit in both cases. A difference between the two cases is that the average consumer benefits in the base case, whereas he loses in case 1.

In case 2 we use the same demand functions but drop the cost interdependence by using the cost function:

$$C = (0.86)(q_{AB} + q_{BA}) + \text{fixed costs.}$$

Table 4.1. Effects of profit maximisation under the price equality constraint, with and without cot interdependence.

	Case 1: With joint costs	Case 2: Without joint costs
Unconstrained profit maximisation:		
p_{AB}	24.4	20.4
p_{BA}	15.4	15.4
q_{AB}	780	980
q_{BA}	292	292
Profit maximisation with price equality constraint:		
p	21.8	18.97
q_{AB}	909.0	1,051.5
q_{BA}	163.6	220.6
Change in:		
Consumer surplus$_{AB}$	2,179	1,452
Consumer surplus$_{BA}$	–1,462	–915
Profit	–1,157	–357
Sum:	–440	180

In this case the imposition of the price equality constraint means that the benefits for the passengers in the large market exceed the disadvantages for the small market passengers and the transport company itself. This is a well-known result from the standard literature (see Section 3). It implies that in the absence of cost interdependencies and with the given linear specifications, a self-imposed constraint for a monopolist (which by definition leads to lower profits), leads to benefits for consumers that outweigh the profit decrease.

We conclude that the outcome of the welfare analysis strongly depends on the size of the cost interdependence. When the interdependence is low, the imposition of the price equality constraint leads to a smaller decrease in costs for the monopolist, compared with the case where the price interdependence is high. The reason is that price equality induces larger differences in flows in both directions which has a consequent strong cost impact via the cost interdependence term $c.[\max(q_{AB}, q_{BA})]$ when parameter c is large. Since in the case of transport firms the cost interdependence is usually substantial, we conclude that the self-imposed price equality constraint may not be expected to have positive effects on total surplus.

Two limitations have to be mentioned of the above analysis. First of all, they are based on parameters from confidential sources that have not been subjected to standard statistical tests. Therefore, the above computations only have the aim to illustrate the theoretical viewpoints presented in Section 3 but do not claim to be precise estimates of the effects of uniform versus direction dependent pricing strategies. Second, no attention is paid to other relevant aspects, one of them being the *costs of complexity*.[15] Public transport companies sometimes consider complex fare systems as a significant deterrant to travel. Therefore they tend to prefer uniform fares. It should be noted, however, that as electronic media become increasingly important as a source of information on fares, complexity cost may be expected to decrease. Thus, ICT developments tend to support the introduction of more refined pricing structures. Note also that in related markets such as aviation travelers have become used to rather complex fare structures. Also in high speed rail services fare structures have become more complex during the past period.

Given the positive effect of price discrimination on profits it is no surprise that several European railway companies are considering non-uniform pricing schemes where the prices are no longer simply based on the number of kilometres travelled, but where prices are time and direction dependent. The present paper demonstrates that given the issue of joint costs this price discrimination may also be beneficial for the average consumer. It should be emphasized that the direction dependent fare system discussed here is not identical to the time dependent fare system used by public transport companies in various countries. Such a time dependent fare system may for example mean that reduced fare tickets can only be used outside the peak periods. Note however, that on many public transport lines during the peak period vehicles are crowded in one direction but rather empty in the other (see also Table 1.1). Hence, a real application of direction dependent fares goes one step further since it would not only differentiate according to time of day, but also according to direction. For example trains running into the large cities during the morning peak would have higher fares than trains running in the opposite direction.

5. Concluding remarks

Joint costs in the situation of unbalanced markets pose a challenge to transport firms. In this paper we have investigated the implications for price strategies of transport firms. We find that two regimes may emerge when cost interdependence is present: an equal quantity regime (EQ), where despite the difference in demand in both markets, differentiated prices lead to equal quantities, and the UQ regime, where price differences will not be able to yield equal quantities. *Thus, equal flows in opposing directions are not necessarily a sign of balanced markets.*

The following conditions make the emergence of an EQ result more likely:

– a small difference in the dimension of both markets;
– high price elasticity in the large market;
– a high level of cost interdependence.

In many countries suppliers of transport services apply an equal price in both markets. This obviously has welfare implications, compared with the case that different prices are charged in different markets. *The imposition of equal prices will lead to lower profits, a higher consumer surplus in the large market, and a lower surplus in the small market.* An important question is of course what is the net result of the three effects.

A numerical illustration using Dutch railway data shows that *the net effect of the price equality constraint on total surplus may easily be negative*: for plausible values of the parameters we find a decrease in profits that is not off-set by an increase in the surplus of the average consumer. In the particular case considered, we even find that the loss of consumer welfare in the small market is larger than the increase in consumer welfare in the large market.

It is clear that the above results are based on a rather stylised model of transport markets. To bring the models formulated here closer to reality, we could introduce richer network structures (for example, people using the *AB* link in reality will travel from *A* to *C* via *B*). Travellers may express a dislike for crowding and accordingly have a different willingness-to-pay. The introduction of direction dependent prices implies the introduction of peak load pricing in public transport, and hence leads to the issue of choice of period of travel (peak versus off-peak). Other factors to be taken into account in future research are the costs of complexity related to complex fare systems and the disincentives these may have on total demand.

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Notes

1. Although we use abstract symbols like *A* and *B* to represent links between nodes, we want to emphasise that they represent real data about real cities; the links are independent. The reason we do not give the actual names is that the data concerned are confidential. Also the demand and cost function used in Section 4 are taken from applied models currently in use.
2. Note that there is still another form of economies of scope that is not related to joint costs: A firm producing complementary goods may have higher profits compared with supply of the products by separate firms, even when the costs would be independent.

3. We assume here that the cost function is separable and that the sub-functions related to the two markets are equal. Both assumptions, however, are not necessary to obtain the results illustrated in this section.
4. To see this, choose an isocost curve and find the highest revenue obtainable at the given cost level or, vice versa, minimise costs for each level of revenue.
5. Isocost-isorevenue diagrams can also be usefully employed to illustrate cases of constrained profit maximisation. For example, in this paper the case of uniform price setting is considered. For each single price level, the quantities sold in the two markets would then be exogenously determined. This defines an alternative "expansion path", along which profits can be maximised.
6. The assumptions needed regard the quasi-concavity of profit functions in the two markets. For example, this is ensured if demand and cost functions are both linear. We shall also assume here that the two demand curves do not intersect, so that for each price the market associated with the largest quantity remains the same.
7. Or, equivalently, one is increasing and the other is constant.
8. Recall that here the profit functions are computed by allocating all common costs to the large market.
9. This restriction is irrelevant if direct marginal costs are constant, because the parameters of the demand function can be normalised. To obtain results for the more general case, substitute parameters A and a in (3.2), (3.3), (3.4) with $A' + Bc$ and $a' + bc$, if c is the direct marginal cost (possibly different in the two markets).
10. We are assuming here that parameter values are consistent with the emergence of an UQ solution in the discriminatory regime.
11. We are not aware of systematic evidence on differing marginal utilities of income between passengers in busy versus non-busy directions. Note that these marginal utilities may also vary within the two groups; for example commuters and students, that are probably over-represented in the busy direction compared with travellers in the non-busy direction may have quite different marginal utilities of income, the latter group having a higher value than the former group possibly leading to an average value for the busy direction that is not far removed from the value in the opposite direction.
12. The parameters are based on confidential data provided by the Netherlands Railways (NSR).
13. Note that as already shown in Section 4, under the given specifications of the demand and cost functions, the imposition of the price equality constraint does not affect the sum of travelers in both directions.
14. As indicated in Section 3 this result holds with linear demand functions. It is contingent on the assumption that both markets are served. Both conditions are satisfied in this example.
15. The autors thank an anonymous referee for this point.

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