Competition in Multi-Modal Transport Networks with Unpriced Roads: A Dynamic Approach

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1 Introduction

We analyze the behaviour of market participants in a multi-modal commuters network where roads are not priced. There is a substantial existing literature on road pricing, as well as on the effects of road pricing on public transport markets, and second-best pricing of roads in the presence of unpriced substitutes. In reality, road pricing is politically difficult to implement. It is therefore interesting to consider the converse, but common situation, in which roads are unpriced, but public transport has a usage fee, which may be be set while taking the effects on the roads into account.

As recent decades have seen a shift from governmental provision of public transport to provision by private firms, we test how different market structures influence public transport fares and social welfare, and how they compare with governmental provision. In particular, we analyse the difference between markets with a monopolistic public transport operator, which operates all public transport links, and markets in which separate operators own each public transport link.

2 Previous literature

Standard economic theory would predict that in normal markets, both Bertrand and Cournot competition lead to lower prices than a monopoly. Transport systems, however, usually consist of several interacting markets, and there are unpriced externalities associated with travel, so these standard results do not always apply. Previous studies [1] (see [2] for a transport application) have shown that, generally, parallel, or horizontal competition, where a number of competitors offer different possibilities to travel between two points, is beneficial, both to consumers and to society. Serial, or vertical competition, in which different operators own complementary links, has been shown to adversely affect consumers and social welfare. This result occurs only because travel demand is elastic. Each serial competitor exerts local market power, and is able to set a price above marginal cost. This has a negative effect on the patronage of other links, but this externality is disregard by the individual operators; a phenomenon that is comparable to the mechanism of double marginalisation.

However, these results have been obtained with static models; they disregard the fact that commuters can also choose the moment at which they travel. In most real-world applications, commuters do have this choice. We therefore use dynamic modelling techniques, and examine how this affects competition.

3 Methodology

We combine and extend the existing modelling literature to model a simple dynamic multi-modal many-to-one commuter network where transfers between modes are possible. In this way, we can capture the essence of serial competition, parallel competition, mode choice and departure time choice in one analytical framework, and study the efficiency of different types of market organisation. We assume that demand is fixed, such that we can clearly differentiate between dynamic interaction effects, and the effects of elastic demand that have been examined in the previous literature.

The network consists of three nodes (two origins and one destination), which are connected by two segments. Each segment consists of two congestable links, which represent the rail and road connections. Travellers treat the two modes as perfect substitutes, so that Wardropian equilibrium conditions apply for used alternatives [3]. We examine a typical morning commute, in which N commuters travel from node 1 to the destination, and a further N commuters from node 2 to the destination. Commuters from node 1 can transfer to a different mode at node 2, although, as we show, this assumption does not influence the results in an interior equilibrium. There is flow congestion on the roads, as in [4], and rail users face dynamic costs due to in-vehicle crowding.

4 Results and conclusions

Using this network model, we obtain a reduced form of the train operator’s optimal fare setting problem by assuming that the rail fare is constant over time. This reduced form is considerably simpler and easier to use than the original optimal control problem, and we can use it to show that in this dynamic model, even though the total travel demand is inelastic, serial Bertrand-Nash competition on the rail links leads to different fares than a serial monopoly. This results from the fact that trip timing decisions, and therefore the generalised prices of all commuters, are influenced by all train fares in the network. A monopolistic operator internalises the effect a price increase on one link has on the patronage of the other links, but a Bertrand-Nash operator disregards this, which leads to different fares. We also show that these results cannot be observed in a static model, where, in the absence of elastic demand, monopolistic and duopolistic fares are equal.

However, contrary to the results obtained in classic studies on vertical competition, the difference between duopolistic and monopolistic fares in the dynamic model is not necessarily positive. Indeed, numerical simulations show that, although monopolistic fares are usually lower, this is not always the case, especially when the value of approaches the value of schedule delay and when the unit cost of congestion is low.

The numerical simulations also show that model parameters such as the value of schedule delay and the cost of congestion have a significant effect on the fare difference between a monopoly and a duopoly, and on the relative efficiency of those two market structures. These parameters affect fares because they influence the amount of competition rail operators face from the unpriced parallel road, because they influence the total congestion costs commuters face, or both. These relationships are highly non-linear.

Hence, our models show that it is important to consider the effects of market structures in a situation where rail operators compete with an unpriced road, and to consider them in a dynamic setting. This introduces another reason for fare differences between different forms of competition, through the commuter's departure timing choices. As we have shown, although these effects often work in the same direction as the classic 'double marginalisation' that occurs when demand is elastic, there is a potential for it to work in the opposite direction. In any case, it should not be ignored, and we have shown how it can be modelled.

References

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