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The effects of decentralized capacity decisions for congested self-financed roads

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ABSTRACT

This paper studies the differences between centralized and decentralized decisions for capacity and road user charges on a congested self-financed road with local, national and international traffic. Road user charges are allowed only to cover the costs for providing the road with a specific capacity, and to cover external costs caused by traffic. The road is either provided by the nation, or else this responsibility is decentralized to the community.

The results of this paper show that it can matter significantly on what level such a decision is made. A decentralized decision leads to a total wellfare loss, and there is both a national and international interest for not decentralizing such decisions.

1. Introduction

Road user charges (henceforth referred to as RUC) in Europe has hitherto been developed along two different lines – urban road user charges with a focus on passenger cars and congestion problems (for instance Stockholm and London) and interurban road user charges with focus solely on Heavy goods vehicles pioneered by Switzerland (HVF) followed by Austria, Germany and other countries. However, in reality road traffic is a mixture of vehicles as well as a mix of urban, national and international transports. Implementing pricing and investment policies in transport networks with such a mix is complicated. There is a fear that transit traffic will be exploited via high RUC, it is also possible that a road supplier invests strategically in order to capture toll revenues. On the other hand, when RUC on transit traffic is not feasible, regions might be reluctant to invest in capacity that road users from outside the region benefit from, thereby supplying a capacity that is inefficient. One way to get around these problems is to allow RUC, but only when these are equal to the costs the region has for supplying the road, i.e. covering external costs (environmental costs, noise, health issues for people living close to the road, etc.), and costs directly connected to supplying the road with a certain capacity (financing, maintenance, etc.), i.e. the road is self-financed. The decision that the road supplier has to make is what capacity to offer.

The idea of self-financing roads is not new Mohring and Harwitz (1962) showed that under certain conditions, an optimally designed and priced road would generate toll revenues equal to the capital cost of the road. For a summary of research in this field see Verhoef and Mohring (2007). However, the "optimally designed and priced road" will differ depending on who provides the road, and the welfare function of this provider. In all the previous literature the road provider is assumed to care about all travelers, i.e. the consumer surplus of every traveler is included in the welfare function.

In most European nations decisions about road capacity is made on national level as well as on community level, since roads are supplied both by governmental funding as well as by communities. A community or nation providing a road will typically not include the consumer surplus of travelers from other regions in the welfare function. This gives rise to a number

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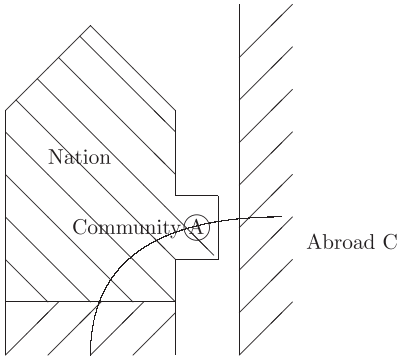

Fig. 1. Illustration of Model.

of questions. Does the strategic choice of capacity and toll for a self-financing road depend on whether the toll/capacity decision is made on national level or is decentralized to a community? How is international traffic effected depending on whether the decision is decentralized or not? What are the policy implications of such an approach?

This paper can bee seen as an extension of the existing literature on self-finacing roads by studying the difference in toll, capacity and welfare levels when the road is not "optimally designed" with respect to all users but with respect to the users of the road-providing region, i.e. the users of the community or the nation.

A simple model is introduced, where the he road in question is located in a community, and is used by three different types of users, local, national and international users. Each road user is charged with his/her own marginal cost plus a toll used to finance the supply of the road, thus making the road self-financing.

2. Model

The model used to study effects of decentralization of capacity decisions can be summarized as follows: One big road is going through a community in a nation. There are three types of traffic; local traffic in the community, national traffic passing through the community, and international transit traffic passing through the community. See Fig. 1. The figure can for instance be interpreted as the highway from Germany through Denmark and community Helsingör continuing to Sweden.

The traffic volumes are denoted by the strictly positive functions x^A for local traffic, x^B for national traffic, and x^C for international traffic.

The inverse demand functions are given by

$$p^i(x^i) = a^i - b^i x^i \quad \text{for all } i \in \{A, B, C\}$$

where the coefficients a^i and b^i are strictly positive real numbers. The reason to chose an inverse linear demand function is to simplify the further analysis.

For all $i \in \{A,B,C\}$, let m^i be the external cost experienced by the residents of the region supplying the road,[1] and r^i the maintenance cost caused by one vehicle of type i, i.e. local, national transit or international transit. These costs are assumed to be fixed for each traffic type.

The supplier of the road is allowed to charge a vehicle for all costs caused by this specific vehicle, plus a toll covering the costs for building and maintaining the chosen road capacity. This means that each vehicle of type $i \in \{A,B,C\}$ will be charged with $\tau + m^i + r^i$ for using the road, where $\tau \in \mathbb{R}^+$ is the toll. Since the toll incomes are used to finance capacity, deciding the toll also means deciding how much to invest in capacity per vehicle. The generalized user cost functions are given by

$$g^i = \alpha^i + \frac{\beta^i(x^A + x^B + x^C)}{R} + \tau \quad i \in \{A, B, C\}$$

The coefficients α^i and β^i are strictly positive real numbers for all $i \in \{A,B,C\}$. For simplicity the coefficients m^i and p^i are included in α^i for all $i \in \{A,B,C\}$. The coefficients β^i are measures on time value, i.e. the sensitivity of cost with relation to congestion, for all $i \in \{A,B,C\}$.

It is reasonable to assume that $\beta^A < \beta^B < \beta^C$, thus local trips have a lower time value than national trips, and national trips have a lower time value than international trips. This means that long trips has higher time value than short trips. For a reference for proportions between time values see for instance the SIKA rapport 2009:3.

The capacity is given by R, thus $(x^A + x^B + x^C)/R$ is the volume/capacity ratio, and $\frac{\beta^i(x^A+x^B+x^C)}{R}$ is the congestion cost.

[1] In reality the supplying region would need to give an account of these costs, irrespectively of whether the region takes measures to reduce the effects of external costs or not. This way one can make sure that the supplying region is fully compensated yet not overcompensated.