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On revenue recycling and the welfare effects of second-best congestion pricing in a monocentric city

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ABSTRACT

This paper examines congestion taxes in a monocentric city with pre-existing labor taxation. When road toll revenue is used to finance labor tax cuts, 35% of the optimal road tax in our numerical model does not reflect marginal external congestion costs, but rather functions as a *Ramsey–Mirrlees* tax, i.e. an efficiency enhancing mechanism allowing for an indirect spatial differentiation of the labor tax. This adds a quite different motivation to road pricing, since welfare gains can be produced even in absence of congestion. We find that the optimal road tax is non-monotonic across space, reflecting the different impacts of labor supply elasticity and marginal utility of income, which both vary over space. The relative efficiencies of some archetype second-best pricing schemes (cordon toll, flat kilometer tax) are high (84% and 70% respectively). When road toll revenue is recycled lump-sum, the optimal toll lies below its Pigouvian level. Extensions in a bimodal framework show that the optimality of using road toll revenue to subsidize public transport depends on the initial inefficiency in public transport pricing.

1. Introduction

This paper examines the design of congestion taxes in a monocentric city with pre-existing labor taxes. Labor taxation is highly relevant in this context, since it reduces labor supply, commuting flows and, therefore, the level of congestion externalities in the transport system. With a pre-existing tax on labor income, the traffic level in an untolled equilibrium might already lie below its optimal level, even when the absence of road charges makes the generalized price of a commuting trip fall short of its marginal social cost (Parry and Bento, 2001). Then, a policy intervention that introduces road tolls but leaves the labor tax unaffected (for example because the revenues are returned lump-sum) may be expected to produce a decline in social welfare rather than the increase that is hoped for.

This fundamental issue has received only limited attention in the transport economics literature, although similar questions have spawned several contributions in the literature of environmental economics (see, for example, Bovenberg and de Mooij, 1994; Parry, 1995; Goulder, 1995a; Bovenberg and Goulder, 1996; Parry and Bento, 2000). An exception is the paper by Parry and Bento (2001). They conclude that, in order to increase welfare, road toll revenues must be used to reduce the distortionary tax.[1] In that paper, as in a later contribution aiming to investigate other critical distortions within the transport system (Parry and Bento, 2002), commuting distance is assumed to be exogenous, since the model has no spatial dimension. Therefore, commuters react to the introduction of a road tax by adjusting their labor supply, but not their commuting distance. While this assumption might be realistic in the short run, one might question to what extent the above policy recommendation is valid in the long run, i.e. as commuters are able to relocate.

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[1] For a more general investigation of marginal tax reforms, see Mayeres and Proost (2001).

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More importantly, the lack of a spatial dimension implies that questions involving the differentiation of road taxes over space cannot be studied. This prevents the evaluation of second-best congestion pricing schemes such as the cordon toll (Mun et al., 2003, 2005) or a flat kilometer tax (Sullivan, 1983) which are more realistic in practice, but deviate from the first-best. Furthermore, it prevents one from analyzing optimal spatial differentiation of a revenue-raising labor tax. This issue is relevant since one expects that the optimal labor tax is not space-invariant; it varies over space because the labor supply elasticity, as well as the marginal utility of income vary over space. In addition, suboptimal pricing in public transport is ignored in Parry and Bento (2001). Thus, their model may understate the welfare gains of policies that use the road toll revenue to subsidize the providers of public transport when operating under increasing returns.

In this paper, we develop a monocentric city model in which household location is endogenous and both residential density and labor supply vary over space.[2] We combine the insights of the non-spatial labor supply model by Parry and Bento (2001) with the monocentric city model by Verhoef (2005), which allows city size and commuting distance to be endogenous. Our aim is to identify the optimal policy, i.e. a combination of a road toll scheme and a revenue recycling program, taking into account the equilibrium impacts of transport policies, as well as (in an extended model) the presence of a suboptimally priced public transport alternative.[3] To some extent, the model also resembles Bento et al. (2011), which is the only application of a double-dividend tax reform in a monocentric city that we are aware of. In that paper, an environmental policy motivated by sprawl-style externalities (a spatially-uniform development tax that increases open space) generates revenues in order to reduce the level of a preexisting spatially uniform property tax. However, in contrast to a spatially uniform development tax, this paper considers a continuous-in-space road tax, something that prevents us from deriving an analytic expression for the welfare change of a revenue-neutral tax swap in the way Bento et al. (2011) do.

To facilitate comparability of our numerical results with earlier work, we calibrate the model's parameters in line with Parry and Bento (2001) and Verhoef (2005). We compare the welfare gains (or losses) for a range of road toll schemes and revenue recycling programs. The welfare changes are reported in a relative manner, for instance as in Parry (2002), as well as in monetary terms, by computing the compensating variations for the representative household. Since the numerical results are likely to be sensitive to the model's parameterization, we perform sensitivity analyses with respect to the initial level of labor tax and the elasticity of substitution in consumption.

One of our main conclusions is that a *space-varying road tax* is not desirable as a congestion management policy only: with a tax-distorted labor market, it may be welfare improving to spatially differentiate taxes even in the absence of congestion. There are two reasons for this. The first is that the elasticity of labor supply exhibits variation over space, while the labor tax is independent of residential location. Bento et al. (2011) discusses a similar mechanism when deriving the marginal excess burden of a property tax in a monocentric city model. Thus, a space-varying road tax might improve the performance of an inefficient labor tax system by functioning as a *spatial correction* of a suboptimal labor tax, allowing it to vary with the elasticity of labor supply. This finding is in line with Parry and Bento (2000) and Bento and Jacobsen (2007), where an environmental tax is shown to be part of the optimal tax system, because it corrects failures of the existing tax system. Consequently, the optimal tax may be above the Pigouvian level.

The spatial differentiation of taxes is thus in line with the standard *Ramsey rule* for minimizing the distortionary impacts of taxes used to raise revenues. Our spatial setting, however, reveals a second reason to differentiate taxes by residential location. This concerns the *Mirrlees rule*, which states that taxes should be lower where the marginal utility of income is higher (Mirrlees, 1972; Wildasin, 1986). In our model (and probably in other spatial configurations as well), these two arguments appear to be working in opposite directions. Labor supply elasticity falls with commuting distance, as equilibrium labor supply falls; while the marginal utility of monetary income rises, as monetary income falls as well.[4] As a result, the *Ramsey–Mirrlees component*, which we define as the deviation of the optimal road tax from the marginal external cost of congestion (conditional on a given labor tax), can portray complex, even non-monotonic patterns over space.

Our paper is connected to two streams of literature. The first stream concerns the presence of various constraints (e.g. tolls on a subset of road links) or other sources of inefficiency *within* the transport system.[5] One such inefficiency regards suboptimal pricing in public transport, for instance average cost pricing combined with substantial fixed costs. To juxtapose labor tax cuts against public transport subsidies, we expand the base model to account for a public transit alternative, which operates with fixed costs. The numerical results show that the optimal type of revenue recycling depends on the degree of inefficiency in public transport pricing. For cities served by unsubsidized operators with significant fixed costs, it is optimal to return the road toll revenue in the form of a public transport subsidy, contrary to the results by Parry and Bento (2001).

At the same time, the paper contributes to the *double-dividend* stream of literature by focusing at a pre-existing source of inefficiency *outside* the transport system. In particular, this stream focuses on the occurrence of failures, most often tax-induced distortions accompanied by significant *marginal excess burdens* in markets that interact with the transport market to be regulated. The labor market is one such market: when it does not operate efficiently, there is a divergence between the (inverse) demand for commuting trips and the marginal social benefits.[6] In line with this, our results will show that optimal road charges fall short of the Pigouvian tolls when road toll revenues are recycled lump-sum. However, in our numerical model they remain strictly positive at least at some parts of the city, because the *tax-interaction effect* (i.e. the efficiency loss in the labor market caused by a marginal increase in the road toll) diminishes with distance from CBD and is outweighed by the *Pigouvian effect* (i.e. the welfare benefits from a marginal reduction of externality) for residents living at the more distant parts of the city. Therefore, even with lump-sum revenue recycling, welfare gains are possible through road pricing at the

[2] Throughout the paper, we assume that the labor market is competitive. For the impacts of congestion tolls in a wage bargaining model, see De Borger (2009).

[3] The present paper focuses on the efficiency gains of road pricing for a representative household in a monocentric city. Although revenue recycling is closely related to the various equity considerations of road pricing (Langmyhr, 1997), the distribution of the total gains among heterogeneous households in the context of a monocentric city is another future research challenge. See Ramjerdi et al. (2008) for an empirical approach of this issue.

[4] Note that the latter pattern may be reversed when income heterogeneity is introduced, with higher incomes locating further from the CBD (Brueckner et al., 1999).

[5] For instance, optimal tolls under unpriced alternative routes in the network have been investigated by Verhoef et al. (1996) and Small and Yan (2001). Kidokoro (2010) expanded the above work by considering revenue recycling *within* the transport system, i.e. capacity expansion and public transport subsidies.

[6] The other primary factors of production exhibit significant interactions with the transport market, and can play the role of labor as well. Furthermore, inefficiencies *outside* the transport system may include various regulations in the housing market: rent controls and density regulations (e.g. height restrictions and zoning), which may result in a suboptimal allocation of space across economic agents and activities (Glaeser and Luttmer, 2003). Road pricing affects the private and social benefits and costs of land use. Therefore, it can indirectly alter the magnitude of welfare losses in a distorted land/housing market.