Optimal road pricing and revenue recycling in urban networks with distorted land and labor markets: a model tailored for the area of Randstad.

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The Randstad area is a polycentric urban conglomeration in western Netherlands, which comprises the country's four largest cities (Amsterdam, Rotterdam, the Hague and Utrecht). The region is of considerable economic significance; while it covers only 20 percent of the country's land area, at least 40 percent of the population resides there, and half of the national income is generated within its boundaries. Despite being a prosperous region, it has, for a series of years, experienced a lower productivity growth[1] compared to other regions in the Netherlands and Europe.

The territorial review by OECD (2007) places *heavy congestion* and the *incoherency of public transport system* as the first and second most important drivers of this sluggish growth. Regarding congestion, roughly 80 percent of the traffic jams in the Netherlands in 2005 occurred in Randstad. The problem is deteriorated because the regional public transport is relatively fragmented, i.e. the coherence between the multiple operators and facilities is limited, resulting in a suboptimal use of the public transport system. Other identified factors include distortions originating from the labor and, especially, the housing market, where a series of land-use practices (e.g. density regulations) add burden to the social cost of public transport provision. Given this complex reality, the natural question arising is whether there are road pricing policies which can simultaneously address congestion and mitigate distortions elsewhere in the economy.

To study this in a coherent framework, this paper presents a stylized *general equilibrium network* model that is tailored to capture the various distortions enumerated above, occurring simultaneously in the markets for transport, housing and labor in Randstad. The model is used as a tool for the evaluation of pricing schemes (road pricing, parking, public transport) and intelligent revenue recycling programs at a federal level,

[1] annually 1.7 percent over the period $1995 - 2005$.

which in modeling terms means that the role of municipalities is restricted to the collection of parking fees.[2]

Some earlier contributions in the first and second-best literature have derived rules for optimal road pricing in a generic static network. For instance, Verhoef (2002a;2002b) offers a general analytical solution for the second-best problem where not all links of a congested transportation network can be charged; an algorithm based on this analytical solution is then tested on a medium size network. Also, van Dender (2004) shows that constraints in network pricing can cause the optimal toll to deviate in a complex way from the marginal external cost of congestion. The above contributions assume that both the residence and job location, i.e. the OD pair of the commuter, is fixed.

The point of departure for this paper is the previous work of Anas and Kim (1996) and Anas and Liu (2007). The latter developed a polycentric model for the wider metropolitan area of Chicago, and a recent application of the model in order to evaluate the potential welfare effects of a cordon toll in the area (Anas and Hiramatsu, 2012). The interactions of transport with the housing and labor market are captured in a detailed way, since the residence and job locations are endogenous. However, the distortions generated in the respective markets are not considered. Subsequently, the marginal social benefit of road use may be understated or overstated, depending on the relative conditions in these markets (taxes, subsidies, regulations). Furthermore, public transport is not modeled in a way that facilitates the analysis of policies involving changes in the public transport system.

Our model accounts explicitly for labor income and land rent taxes, as well as subsidies to public transport agencies (urban and intercity) which operate above the break-even level. The model is calibrated to fit a series of stylized facts characterizing the Randstad region: the general spatial lay-out and network, the observed differences in average wage across locations, household expenditure shares, relative land rents and densities, average commuting times by car and public transport and the relative flows in the different parts of the network.

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[2] This implies that the focus of the paper lies on the optimality, rather than the public acceptability, of an arbitrary policy; a companion paper will investigate the relative efficiency of programs of higher public acceptance, in which the involvement of municipality in revenue recycling is stronger.

We compute the welfare gains of the optimal second-best policy (i.e. the welfare maximizing charge and type of revenue recycling at each link) and the relative efficiency of policies which are subject to specific constraints (with respect to the pricing scheme or revenue recycling). The main results are accompanied by an extensive sensitivity analysis regarding the relative efficiency of these constrained policies.

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