A joint internalization model for congestion and air pollution externalities: Is marginal cost pricing enough to comply with the EU CO_2 reduction targets?

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April 10, 2015

Extended Abstract

Introduction

Congestion, vehicle emissions, accidents and noise are major contributors to the total external costs in the transport sector (Maibach et al., 2008; Parry and Small, 2005). These costs are 'external' to the transport market since they are not considered in the behavioral decision making process of individuals as there is no compensating market mechanism in place. This yields travel demand beyond the economic optimum which, in turn, results in social welfare losses. Several contributions in the literature investigated the interrelationship between different negative externalities such as congestion and vehicle emissions, and found them to be positively correlated (see, e.g., Beamon and Griffin, 1999; Namdeo and Mitchell, 2008). Despite this correlation, most studies focus on finding optimal pricing strategies to internalize one isolated externality, and examine the impacts on the other externality (Daniel and Bekka, 2000; Beevers and Carslaw, 2005; Kickhöfer and Nagel, 2013). There is only a limited number of studies that aim at combined pricing schemes for both externalities (see, e.g., Wang et al., 2014; Proost and van Dender, 2001).

An internalization of local externalities (congestion, air pollution, etc.) is also advised by European Commission (2011). According to European Union's directive 2008/101/EC, a target is set to reduce global greenhouse gas emissions in the transport sector by at least 20% until 2020 with respect to 1990 levels. Such approach is known as 'backcasting' in the literature (Geurs and van Wee, 2000, 2004; IWW et al., 1998). The questions therefore arise (i) to what extend the internalization of externalities could contribute to this goal, and (ii) how (additional) prices would need to be set in order to reach the above target.

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Clearly, improvements in vehicle and fuel technology are to be considered in this context. However, most estimates indicate that these innovations are only able to stabilize transport-related emissions (IEA, 2014), since the (possible) reduction in generalized costs, and thus higher demand, neutralizes the impact of technological improvements (Divjak, 2009).

In a first step, the present study continues the existing line of research by investigating the effect of congestion internalization on emissions levels and vice versa for a real-world scenario of the Munich metropolitan area in Germany. In a second step, and going beyond existing studies, a joint internalization of congestion *and* emission costs is proposed for an agent-based simulation which is based on dynamic traffic flows and activity-based demand, and which is applicable for large-scale scenarios (Agarwal and Kickhöfer, 2015). The results of the three pricing schemes are compared in terms of changes in emission and congestion externalities at aggregated and highly disaggregated levels. In a third step, the paper attempts to identify the necessary additional prices, as multiples of the original damage cost estimates, in order to reach the EU 2020 CO_2 reduction targets.

Model

The paper starts with the internalization of congestion effects using a marginal congestion pricing approach by Kaddoura and Kickhöfer (2014). This approach calculates link-based delays and identifies the causing agent(s). They are charged with the equivalent monetary amount of the delays they caused for other agents. In order to internalize emission effects, emissions are calculated using an approach by Kickhöfer et al. (2013). The resulting costs are internalized using a marginal emission pricing approach by Kickhöfer and Nagel (2013). Both approaches consider heterogeneity in individual attributes and choice behavior. In consequence, the resulting toll levels are highly differentiated. Subsequently, a simultaneous pricing scheme is applied which accounts for both external effects under consideration. In an iterative process, travelers learn how to adapt their route and mode choice decisions in presence of this combined toll. In the last part of the paper, price corrections are introduced in order to reach the EU 2020 CO_2 reduction targets (i.e. an overall reduction by 20%). The idea is to increase the unit cost factors of Maibach et al. (2008) in parametric simulation runs.

The simulation is applied to a real-world scenario of the Munich metropolitan area in Germany. Changes in travel behavior resulting from the different pricing schemes are analyzed for different subpopulations with different activity patterns, namely urban travelers, commuters, reverse commuters, and freight traffic (see Fig. 1).

Results

For the status quo, Fig. 1 shows the number of individuals, emission and, experienced and caused congestion costs for each user group. Even though freight only contributes to less than 10% of the total trips, it causes most of emission costs. The numerous urban travelers produce only little emissions, but highest level of caused and experienced congestion. Presumably, this happens since urban travelers travel on multiple congested links inside Munich and therefore shows highest delay per car trip. Congestion costs are, as expected, significantly higher than emission costs – with the exception of freight traffic.

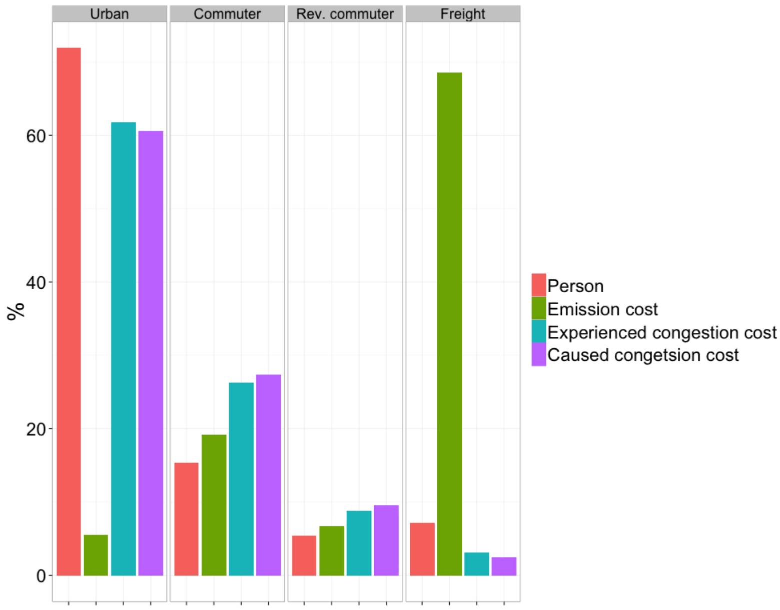

Figure 1: Share of persons, emission and congestion costs for business as usual scenario

For the isolated pricing strategies (i.e. emission or congestion only), the preliminary results indicate that – the latter are the major driving force for travelers to switch from car to non-car modes. Furthermore, it is found that pricing emissions pushes users on routes with shorter distances, whereas pricing congestion steers users on routes with shorter travel times. That is, for congested areas, the two regimes influence route choice behavior by tendency into opposite directions. Still, the positive correlation between emissions and congestion costs is found for the scenario under consideration.

The combined pricing scheme yields the highest level in system welfare, and lowest level of congestion and emissions. The algebraic sum of toll payments from the separate pricing strategies results in tolls higher than the toll payments from the joint internalization approach. In consequence, simply combining the toll levels from these separate pricing strategies would yield over-pricing and reduce system welfare.

Lastly, the preliminary results show that, in order to reach the EU 2020 CO_2 reduction goals, individual toll levels need to be set significantly higher than marginal costs.

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