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How to road price in a world with electric vehicles and government budget constraints

Paal Brevik Wangsness

Institute of Transport Economics – Norwegian Centre for Transport Research, Gaustadaleen 21, 0349 Oslo, Norway

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ABSTRACT

In this paper we examine what characterizes second-best road prices targeting external costs from driving electric (EV) and conventional (ICEV) vehicles when there are distortionary labor taxes and binding government budget constraints. Further, we examine how this second-best pricing fits with government set goals of reducing CO_2 emissions. The paper further develops an analytical framework for assessing first- and second-best road prices on vehicle kilometers, extending it to include EVs and externalities that vary geographically and by time of day. We find that optimal road prices largely vary with external cost, but are also significantly affected by the interactions with the rest of the fiscal system. Not surprisingly, the highest road prices should be for ICEVs in large cities during peak hours due to high external costs. More surprisingly, we find that the road price for ICEVs in rural areas should be lower than that for EVs due to large fiscal interaction effects. These road prices give large welfare gains, but they lead to no reduction in carbon emissions when applying the currently recommended social cost of carbon.

1. Introduction

The road transport market is associated with market imperfections such as local and global pollution, accidents, noise and road wear. Thune-Larsen et al. (2014) calculate external costs in Norway of up to NOK 30 billion (Norwegian kroner; 1 NOK = €0.11 = $0.13) per year from road transport – a figure that does not include CO_2 costs, even though road transport in 2015 accounted for 19% of Norway's greenhouse gas (GHG) emissions (Ministry of Finance, 2017). In addition to externalities from road transport, inefficiencies in the economy arise from distortionary taxes elsewhere. Externalities and inefficiencies in the tax system have recently come under renewed scrutiny with government-assigned expert committees publishing so-called Norwegian Official Reports (Norges Offentlige Utredinger – NOU), with NOU 2014:13 – *Capital Taxation in an International Economy* and NOU 2015:15 – *Green Tax Commission.* Looking for ways by which to mitigate these inefficiencies is in itself motivation for this paper.

As recommended by many transport economists before us, we propose a road pricing scheme for mitigating these inefficiencies. More specifically, we propose distance-based road pricing, differentiated across vehicle types and pre-defined areas and time periods according to their external costs, also factoring in revenue recycling through labor taxation.

We raise the following research questions: What characterizes the set of second-best road prices targeting external costs from driving EVs and ICEVs when there are distortionary labor taxes and binding government budget constraints? How are these prices affected by tax distortions in the labor, electricity and car ownership market? How does this second-best pricing fit with government set goals of reducing CO_2 emissions?

Our paper makes the following contributions: First, it extends an established modeling framework for optimal taxation in

E-mail address: pbw@toi.no.

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transport with revenue recycling of distortionary labor taxes to include (a) different areas and time periods where external costs vary, and (b) both ICEVs and EVs and their associated taxes. This allows us to take a broad view how a national road pricing scheme optimally would look like. As road prices per combination of vehicle type, area and time period, and the labor tax rate are determined simultaneously, this model also allows us to see the endogeneity of how changes in one road price affects the levels of the others. This can result in road prices that differ from traditional Pigovian solutions in several dimensions. We can also see how costs and benefits of the scheme are distributed geographically. Second, it provides numerical results for the case of Norway, a country where the Ministry of Transport has started investigating the possibilities for distance-based road pricing applying satellite technology. It is also the country with the highest EV share of the car fleet in the world, strengthening both fiscal and externality arguments for moving from fuel tax to a more sophisticated way of road pricing.

Our paper is constructed as follows. In Section 2 we provide some background and literature review. In Section 3 we introduce the analytical framework and derive expressions for optimal road prices. The numerical modeling with parameter values and scenarios is explained in Section 4, while the results from the modeling exercise are given in Section 5. Section 6 concludes.

2. Background and literature

In order to strike the appropriate balance between costs and benefits in the affected markets, the "textbook economics" solution would be to find a set of taxes that provide the incentives for economic agents to do so. The optimal gasoline (or diesel) tax is given as one solution in several papers; for instance, in the cases of the UK and USA (Parry and Small, 2005), and Germany (Tscharaktschiew, 2014, 2015).

However, there are shortcomings to correcting road transport market failures through fuel taxation. First, the external costs of driving vary depending on where and when it takes place, making a fuel tax an imprecise instrument. In addition, a fuel tax provides incentives for more energy efficiency, which could be beneficial with regard to carbon emissions and oil reliance, but lead to higher external costs because lower user costs per kilometer would induce more driving. This has been pointed out in several papers (see e.g., Parry et al., 2014a; Parry and Small, 2005; Proost et al., 2009).

Second, the possibility for fuel taxes to (imprecisely) correct for externalities and generate government revenue is reduced when EVs (electric vehicles)[1] are introduced. EVs have many of the same externalities as ICEVs (internal combustion engine vehicles), but they cannot be captured by a gas tax and it seems implausible they can be taxed explicitly from electricity use.

So, are there better ways of taxing, ways that internalize external cost more precisely and allow for the taxation of all cars? This brings us into the discussion of road pricing. A vast literature on road pricing has accumulated over the decades. Button and Verhoef (1998, p. 4) refer to Pigou (1920) and Knight (1924) as the spiritual fathers of road pricing. Since then, hundreds of theoretical and empirical papers on a wide variety of road pricing schemes have been published, making it useful to specify exactly what kind of road pricing this article will focus on. Levinson (2010) developed a typology with 90 types of road pricing, organizing it along the three dimensions; the spatial resolution, the temporal resolution and the pricing objective. Within the dimensions of this typology, this article focuses on area based,[2] time-varying, second-best road pricing.

We focus on this specific type of road pricing because we believe it has a potential to generate large efficiency improvements for a country like Norway. Support for the merits of the distance-based aspects can be found in the literature. Analysis from Parry and Small (2005) and from May and Milne (2004) shows that distance-based road pricing can generate greater social benefits than, for example, fuel taxation and cordon-tolling. Furthermore, modeling analysis from Meurs et al. (2013) suggests that distance-based road pricing using satellite technology can be beneficial for the Netherlands compared to the current tax system for car-use and car-ownership. Small and Verhoef (2007) along with André de Palma and Lindsey (2011) argue for the potential for high economic efficiency of distance-based road pricing, and note that GPS technology is suitable for a scheme like this. The latter argue that a satellite-based road-pricing system has advantages with regards to scale economies and in the potential for value-added services and revenue generation.

The technologies underlying satellite-based road pricing have matured over the last decades, meaning that the timing is good for research having this in mind. Such technology could in theory enable the theoretically best type of road pricing according to the typology from Levinson (2010); dynamic marginal cost pricing on differentiated links. However, both privacy concerns and the understandability of the system for the general public sets a limit on spatial and temporal granularity. It will probably not be permissible for the road pricing authority to monitor car users at the finest level of detail, and a large number of car users cannot be expected to understand a system with a wide variety of dynamically changing road prices. This makes distance-based prices differentiated across pre-defined areas and time periods a promising alternative. Finally, because of the new emphasis on reducing inefficiencies in the Norwegian tax system, we want to focus on second-best road prices as a part of a tax reform where revenues are recycled back into the economy through reduced distortionary labor taxes.

Many of the aspects included in this specific form of road pricing have been covered in previous literature. The term road pricing has primarily been associated with road traffic congestion (Button and Verhoef, 1998, p. 6), and this has been the study of numerous papers. Over time, several papers have included environmental and/or accident externalities along with congestion (De Borger and Mayeres, 2007; De Borger and Wouters, 1998; André De Palma et al., 2004; Munk, 2008). Several papers have considered how road

[1] In this paper, when we refer to electric vehicles (EVs) we consistently mean pure battery electric vehicles (BEVs), without any hybrid technology.

[2] More specifically, distance-based road pricing that vary by a small number of areas; large city, small city and rural.