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The optimal subsidy on electric vehicles in German metropolitan areas: A spatial general equilibrium analysis☆

Georg Hirte, Stefan Tscharaktschiew *

Technische Universität Dresden, Institute of Transport & Economics, 01062 Dresden, Germany

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ABSTRACT

E-mobility and diffusion of electric vehicles have become a major policy issue in many countries. For example, the German federal government pursues the strategy of achieving one million electric vehicles by 2020. In this paper we examine whether it is optimal to subsidize the use of electric vehicles by granting electric power subsidies and how large the corresponding optimal rate is. We, first, analytically derive the optimal power tax in a spatial model of a city with two zones where commuting, carbon emissions, endogenous labor supply, fuel and power taxes are considered. It is shown that in a spatial urban environment, the optimal tax rate depends in particular on transport related externalities, tax interaction effects and redistribution effects working via the urban land market. Second, we extend the model to a full spatial general equilibrium model and employ simulations to calculate sign and size of the optimal tax/subsidy rate. This model is calibrated to a typical German metropolitan area. The results show that electric vehicles should not be subsidized but taxed. The results are robust with respect to changes in the willingness to adopt electric vehicles, the costs of driving electric vehicles, and even if emissions of electric vehicles are zero.

1. Introduction

E-mobility and the impacts of the diffusion of electric vehicles (EVs) have become a topic of high interest for policymakers and scientists in many countries. Lots of governments aim at raising the share of EVs[1] – e.g. either as hybrid electric vehicles, plug-in hybrid electric vehicles or full electric vehicles – in the automobile fleet to lower greenhouse gas emissions of road transport and, thus, to mitigate traffic's contribution to climate change.[2] For example, Germany's federal government pursues the strategy of achieving one million electric vehicles by 2020 (see Bundesregierung, 2009). [3] However, switching to EVs on account of economic incentives which lower the high costs of these cars raises questions concerning the net social benefits of these decisions and the optimal level of politically set incentives such as subsidies granted for buying or driving EVs. We explore these issues in the following by applying a spatial urban model approach not yet considered in the research on EVs.

Of course, there is a large body of literature on this and other EV related issues. Generally, researchers are by far less optimistic than governments concerning the benefits or net benefits of EVs. It is even disputed whether EVs can lower CO_2 emissions in passenger transport (beneficial effects of EVs are found by e.g. Karplus et al., 2010; Kazimi, 1997a, 1997b; Nanaki and Koroneos, 2013; Thiel et al., 2010; but negative effects are found by Doucette and McCulloch, 2011; Massiani and Weinmann, 2012; Öko-Institut, 2011).[4] There are even some studies calculating social net benefits/costs of EVs (Baum et al., 2011; Carlsson and Johannson-Stenman, 2003; Christensen et al., 2012; Funk and Rabl, 1999; Lave and

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* Corresponding author.
E-mail addresses: georg.hirte@tu-dresden.de (G. Hirte), stefan.tscharaktschiew@tu-dresden.de (S. Tscharaktschiew).

[1] Smith (2010) provides an overview of the advantages and disadvantages of EVs. See also Ehsani et al. (2010).

[2] According to Thiel et al. (2010), transport related greenhouse gas emissions account for more than a quarter of today's global greenhouse gas emissions where road transport is the biggest contributor to these emissions.

[3] For the UK see Department for Transport (2009).

[4] Also regarding environmental impacts of EVs in general, the analysis of Hawkins et al. (2013) suggests that the environmental net benefit of EVs is ambiguous, critically depending on the combination of the vehicle and electricity production impacts as well as key factors such as energy use and battery and vehicle lifetimes. For further EV related studies on emissions or environmental quality, respectively, see Hahn (1995), Lave et al. (1995), Wang (1997), King et al. (2010), Smith (2010), Brady and O'Mahony (2011), Kyle and Kim (2011), Knittel (2012), Shin et al., 2012, Bosetti and Longden (2013), Harvey (2013), and Windecker and Ruder (2013).

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MacLean, 2002; Massiani and Radeke, 2013; Prud'homme and Koning, 2012). Most of them find negative social benefits of EVs. Further, demand for EVs is currently very low despite evidence in favor of a high willingness-to-pay for EVs (e.g. Axsen and Kurani, 2012; Graham-Rowe et al., 2012).[5] Studies on pure private costs and benefits of EVs including life cycle cost analyses mostly find negative private net benefits which might explain low demand (e.g. Axsen and Kurani, 2009; Carley et al., 2013; Delucchi, 2005; Delucchi and Lipman, 2001; Kurani et al., 1996; Werber et al., 2009). To foster demand it might, therefore, be appealing to grant subsidies to R&D, or the purchase and use of EVs.[6]

However, research concerning efficient policies supporting the diffusion of EVs and the analyses of related impacts is surprisingly rare. Moreover, existing studies evaluating potential policies lack general equilibrium considerations which allow accounting for several feedback effects. This is our point of departure. We explore whether the use of EVs shall be subsidized by granting electric power subsidies and how large the corresponding subsidy rate shall be.[7] In contrast to the literature, we take a more general view and consider a broad range of developments in technology, emission levels, EV prices and responsiveness of demand for EVs. We employ a fully specified spatial general equilibrium approach in a second best urban environment that allows us to consider social benefits and costs, to calculate changes in emission costs and to derive the optimal subsidy rate. Therefore, our findings are very robust with respect to many issues examined in the literature.[8] The focus is on cities because we expect that the use of EVs will be particularly high in cities. They offer sufficiently short cruising ranges and enough density required for battery loading systems. However, in cities congestion is usually higher and travel related taxes/subsidies affect transport decisions. This might also influence spatial location decisions and, thus, decisions on, e.g., distances traveled.[9]

The general equilibrium approach is appropriate because the welfare outcome of subsidies on the use of EVs depends intuitively on a number of countervailing effects. For example, even if a higher share of EVs in the car fleet actually lowers carbon emissions there might negative side effects of this policy as well as interactions with other policy instruments. These side effects depend on the level of subsidies required to achieve a certain level of diffusion of EVs. For example, if a subsidy is not high enough to fully compensate for the higher vehicle costs of EVs but people switch to EVs because they have a higher willingness-to-pay for EVs, then travel costs increase. This in turn may lower congestion, labor supply and shopping activities in the city. As a consequence, emissions are reduced further but employment declines too. In contrast, if subsidies overcompensate the higher costs of EVs, traffic increases and so do emissions. In addition, financing this subsidy is likely to cause distortions. In a second-best world tax interaction effects and interaction effects among externalities matter too (see Parry and Small, 2005). There might also be spatial relocation as well as changes in the modal split. Whether this strengthens or weakens net benefits is also a priori undetermined. The overall outcome depends on the relative strength of these and other interdependent effects. As a consequence, the overall effect of subsidies to EVs can only be assessed if feedback effects working through different markets are considered.

We proceed as follows: First, we analytically derive the optimal power tax in a spatial model of a city with two zones where commuting, carbon emissions, endogenous labor supply, fuel and power taxes are considered, and where we distinguish between conventional fuel-powered cars and electric vehicles. Second, we extend the model to a spatial computable general equilibrium model (CGE) in the tradition of Anas and Co-authors (see Anas and Rhee, 2006; Anas and Xu, 1999; see also Tscharaktschiew and Hirte, 2010a, 2010b, 2012) and employ simulations to calculate sign and size of the optimal subsidy or tax rate. This simulation model is calibrated to a typical German metropolitan area. The spatial CGE approach encompasses endogenous individual decisions of urban households (e.g. spatially differentiated consumption requiring shopping trips, housing, labor–leisure choice where labor supply decisions are associated with commuting trips, location decisions concerning the place of residence and employment, travel mode choice), and accounts for market distortions caused by taxes and subsidies levied by a local/federal government as well as distortions stemming from externalities caused by urban transport activities (e.g. congestion and carbon dioxide emissions). All these decisions and related effects caused by these decisions provoke feedback effects working via urban land, labor and good markets. Public policies which aim to increase the diffusion of EVs and so the share of e-mobility can then have a wide range of differentiated effects eventually affecting welfare of the economic actors.

In the analytical part it is shown that, in a spatial urban environment, the optimal power tax rate depends in particular on transport related externalities, tax interaction effects and redistribution effects working via the urban land market. Because of the presence of these differentiated, occasionally countervailing, effects, the sign of the optimal tax rate is ambiguous. In the baseline simulations of the numerical part we find that the social costs of subsidizing the use of EVs exceed the social benefits, thus EVs shall not be subsidized but taxed. This refers to all tax rate levels below the current power tax rate in Germany. In the next stage, we examine whether this result also holds if assumptions are changed as much as possible in favor of EVs. We raise the willingness to adopt EVs so that a subsidy more effectively pushes diffusion of EVs implying that a smaller subsidy is sufficient for achieving the government target regarding the diffusion level of EVs. Again, the findings stay the same. Next, we assume that technological progress and scale economies reduce the average costs of EVs by thirty percent. This also does not change the findings. Eventually, we assume that neither the use of EVs nor the upstream production of power implies any carbon emissions. This might mimic a scenario where power generation exclusively comes from renewable resources. Even this does not change our findings. Hence, our analyses suggest that as long as demand for EVs only boosts if they are subsidized they are not an efficient device to achieve climate change goals as well as to improve urban welfare.

2. Optimal power tax rate in a spatial urban model

In this section we analytically derive the optimal power tax in a closed city model with absentee landowners. This model is, though

[5] See, further, Ewing and Sarigöllü (2000), Gardner and Abraham (2007), Lieven et al. (2011), Musti and Kockelman (2011), or Delang and Cheng (2012).

[6] Actually, public funds put into related policies are often not negligible. For example, the UK grants a subsidy of up to 5000 British Pounds for buying such a car (Department for Transport, 2012). See also Peterson and Michalek (2013) for an overview on US subsidy policy.

[7] There is no single and unified definition of transport subsidies across countries. According to the OECD (2005), a subsidy in general is a result of a government action that confers an advantage on consumers or producers in order to supplement their income or lower their costs. Delucchi and Murphy (2008) use the term 'tax subsidy' if there is a difference between actual tax payments and payments under some alternative tax baseline. Such a 'tax subsidy' reduces government tax revenues due to a preferential tax treatment in the form of deductions, credits, exemptions, or reduced tax rates. In our study the term subsidy refers to a tax cut that results in a power tax level below the current regular tax level. Alternative subsidization strategies can be: no purchase or value added tax on electric cars; a reduced annual tax; free or cheap use of toll roads, parking places, ferries, and bus lanes on the roads (see Klöckner et al., 2013).

[8] The study most related to our paper is Carlsson and Johannson-Stenman (2003), who provide a cost–benefit analysis of policy towards electric vehicles in Sweden. Their theoretical derivation shows that net benefits are equal to net gains in external costs minus the net costs of losses in tax revenue. The latter results from substituting subsidized hybrid or electric cars for highly taxed cars. As a consequence of this negative effect on the public budget, EVs are socially not profitable. Because this effect is weaker for hybrid cars, they might be socially profitable. Similar results are found by Prud'homme and Koning (2012), though they focus on a comparison of EVs with conventional cars. Massiani and Radeke (2013) even focus on Germany by applying a simulation model designed to forecast and evaluate policies towards the diffusion of EVs in Germany.

[9] Grazi and van den Bergh (2008) offer a conceptual analysis of the relationship between spatial organization, transport and greenhouse gas emissions. They emphasize the necessity of studying climate related policies (e.g. levying fees and taxes in the transport sector) from a local, spatial planning and policy perspective in order to contribute to efficient and effective mitigation of greenhouse gas emissions.