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Feebates as a Fiscal Measure for Green Transportation: Insights from Europe and Policy Implications

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Abstract

Vehicle taxation based on CO_2 emissions is increasingly being adopted worldwide to shift consumer purchases to low-carbon cars, yet evidence on its effectiveness and economic impact is limited. We focus on feebate schemes, which impose a fee on high-carbon vehicles and give a rebate to low-carbon cars. We estimate demand for passenger cars in Germany and simulate the impact of alternative feebate schemes on emissions, consumer welfare, public revenues and firm profits. In this way we quantify trade-offs between environmental effectiveness and fiscal and economic impact of a market-based decarbonization policy. We find that revenue-neutral feebate schemes are welfare decreasing; welfare can only increase with schemes that increase tax revenues at the expense of consumer and producer surplus. After presenting briefly the methodology and results of our work, this paper proceeds with policy conclusions and presents directions for future research, both for improving the scientific analysis of feebates and for linking the modeling work more closely to the needs of policymakers – e.g. by simulating the short-and long-term response of consumers to a continuously more stringent feebate scheme, assessing induced technological progress by manufacturers and distributional aspects of these policies.

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1. Introduction

There is a wide consensus that carbon emissions from transportation need to be curbed substantially, in line with global climate stabilization objectives. Although the most widely discussed policy instruments for limiting automobile fuel consumption and CO_2 emissions are fuel economy standards and fuel taxes, an option that has been receiving increased attention is the design of motor vehicle taxation that induces consumers to purchase vehicles with low CO_2 emissions. The idea is to use the tax system to change the relative prices of vehicles of different carbon emission levels, thus leading to substitution from high-emission to low-emission vehicles. This is the rationale behind recently introduced feebate schemes (e.g. the French 'bonus-malus' system), which pay a rebate to consumers purchasing a fuel-efficient vehicle and impose a penalty on those purchasing gas-guzzlers.

The feebate system may be a promising fiscal policy option because it involves a market-based instrument that can affect consumer behavior, in contrast to command-and-control regulations that may be economically inefficient. Consumers may adjust their behavior more easily than auto producers, as the latter have to find a difficult (and costly) compromise between regulatory mandates for high fuel economy and consumer willingness to purchase bigger and more powerful (and hence less fuel efficient) cars. If the tax levied per unit of carbon emitted is fixed (i.e. if the tax is a linear function of a car's carbon emissions) this equates marginal compliance costs across car models and automakers, thus leading to an efficient outcome (Anderson et al. 2011). In countries that already have significant automobile taxes in place, the shift to CO_2-based taxation can be designed to be revenue-neutral by adjusting existing taxes and is therefore politically more palatable than unpopular gasoline taxes. It should be noted, however, that gasoline taxes may be more effective because they apply to all cars and because they penalize usage rather than ownership. Feebates apply to newly sold cars only and -- like fuel economy standards and unlike gasoline taxes -- may give rise to rebound effects[1].

Most European Union countries currently have in place a CO_2-based component in their calculation of vehicle taxes -- either as a part of registration taxes (paid once upon purchase) or of circulation taxes (paid annually). Despite the increased use of such schemes, there is little research regarding their appropriate design and impact, especially at the European level. The few existing studies focus on the United States, yet the impact of feebate schemes may be different in Europe (and other world regions) with its high gasoline taxes and relatively more efficient vehicle fleet.

[1] The term 'rebound effect' refers to the tendency for vehicle use to increase when fuel efficiency increases (since the cost per unit distance decreases)

Recently we completed a study of the economic and environmental effect from the hypothetical implementation of feebates for new cars in Germany, quantifying the tradeoffs involved in the design of emissions-based car taxation (Adamou et al. 2014). Germany is an important case study because it is the largest European economy and its regulatory initiatives can have a wider impact across the continent. We estimated demand for automobiles during 2002-2008 using three different variants of the widely used nested logit model. We then used the estimated demand systems to simulate feebate policies of varying stringency and compute the impact of the various policies on a) consumer welfare, b) profits, c) public revenues, and d) CO_2 emissions. In this way we explored trade-offs between environmental effectiveness and economic impact of feebates.

Our work adds to only a handful of studies of the impact of carbon-based vehicle taxation. Unlike other work that involves *ex-post* assessments of taxation schemes in specific countries (e.g. Rogan et al. (2011) for Ireland, D'Haultfoeuille et al. (2014) for France, and Huse and Lucinda (2014) for Sweden), ours is -- to our knowledge -- the first *ex-ante* econometric analysis of the possible impact of carbon-based vehicle taxation that conducts a detailed welfare analysis and focuses on the design of schemes that can deliver the desired outcomes.

This paper presents very briefly the methodology used; for more details on the models, the empirical strategy we employed and the numerous simulations performed the reader may consult our technical paper (Adamou et al. 2014). Section 3 presents the major policy conclusions, and section 4 outlines important elements of future research that can lead to improvements which may make the model even more useful for policy analysis.

2. Data, econometric methodology and simulations

Data for the empirical analysis were obtained from *JATO Dynamics*, a company specializing in the collection of automotive data worldwide. For every type of car on the market in each year we observe 17 attributes such as vehicle weight, engine displacement, sales volume and sales price. The data are highly disaggregated; as a result there is a very large number of observations (157,047 in total), some of which correspond to a very small number of units sold. Estimation of the model at this level of disaggregation is not advisable as observations with very low sales are susceptible to measurement or recording errors. Given that the choice of data aggregation is somewhat arbitrary but potentially important, we constructed two datasets, each at a different level of aggregation.

Table 1: Means of important variables of the dataset by vehicle segment.

Class	Obs.	Eng. disp.	CO_2 emis.	Sales	Price
Gasoline engine					
Small	705	1.33	0.149	6466	13.358
Medium	649	1.76	0.182	4660	19.884
Large	749	2.25	0.212	2497	29.496
Luxury	412	3.23	0.258	1179	53.155
SUV	421	2.90	0.268	987	37.229
Sport	408	2.63	0.229	1444	42.667
MPV	669	1.87	0.198	2662	22.654
Diesel engine					
Small	273	1.47	0.122	2227	15.037
Medium	280	1.84	0.143	7139	21.376
Large	378	2.13	0.167	7201	29.315
Luxury	230	2.81	0.213	4757	50.002
SUV	325	2.68	0.244	2849	40.343
Sport	49	2.16	0.164	1211	35.245
MPV	513	1.96	0.172	3508	25.378

Source: *JATO Dynamics.*

Table 1 provides some descriptive statistics of the data, by fuel type and segment. It should be noted, however, that the averages reported in this table mask substantial variability in CO_2 emissions of relatively similar cars: even within the same market segment, CO_2 emissions vary by up to a factor of two. This suggests that appropriate incentives such as vehicle taxation can induce consumers to switch to a low-carbon vehicle in their preferred segment without much utility loss. In the United Kingdom, for example, it has been assessed that choosing the lowest CO_2 emitters in any car market segment can make a difference of about 25% to fuel efficiency and CO_2 emissions (King 2007).

In our econometric analysis we specified and estimated a discrete choice model of demand for differentiated products. We chose to use the nested multinomial logit model (NML) as in Berry (1994) and Verboven (1996) over the random coefficients model developed by Berry et al. (1995). The random coefficients model is more flexible but also more computationally demanding. Both models have been used widely to estimate demand and market equilibrium in markets for differentiated products, and particularly automobile markets. We opted for the nested logit model because it is easier to estimate and has been successfully used in many applications. We used a flexible specification that allows for more consumer heterogeneity by specifying two levels of nests, as in Verboven (1996). We experimented extensively in order to identify the appropriate nesting structure for each dataset. As a further test, we experimented with the way price enters the demand equation. On the supply side, multi-product firms are assumed to choose prices in order to maximize total profits from all of their products.

In summary, we estimated three variants of the nested logit model by choosing different levels of data aggregation and different econometric specifications. The models deliver substantially different implications for demand elasticities; this serves as a reminder that every econometric model imposes restrictions that need to be well understood. For our purposes, the variation in outcomes is useful because it allowed us to perform our analysis with three different demand systems. As the conclusions from the three cases were similar, we can state them with greater confidence than if we had a single model. This is important because -- unlike most previous work -- our analysis does not seek to evaluate a specific program but rather to explore a wider range of options. Experimenting with several model variants allows us to be confident that our conclusions do not depend on a particular specification but have more general applicability.

In the rest of this Section we present in summary the counterfactual analysis using the estimates from one of these models (the disaggregated linear model), but conclusions hold for simulations with the other two models as well.

Using the econometrically estimated model outlined above, we proceeded with simulations of feebate systems. We assumed that a feebate A_j is introduced. The simplest case is that of a symmetrical linear tax that is positive for cars with CO_2 emissions over a given emission level (the so called pivot point) and negative for cars with emissions lower than this threshold:

$$A_j = t\ (E_j - PP),$$

where E_j is the CO_2 emissions level of model j and PP is the pivot point. Both E_j and PP are expressed in grams of CO_2 per kilometer (g/km), t is the tax rate in euros per g/km and A_j is the total tax in euros per car of model j. The rate t is independent of the total amount emitted by the vehicle (linearity) and is the same regardless of whether it is a tax or a subsidy (symmetry). The symmetric linear feebate is theoretically appealing because it imposes equal marginal abatement costs for all manufacturers, thus leading to an economically efficient solution. In practice, asymmetric schemes have been implemented in several countries (Bunch et al. 2011). For this reason, we also considered several asymmetric schemes that have different values for the 'fee' and the 'rebate' part. It is also possible to simulate schemes with a non-linear feebate function, but we did not pursue this possibility.

Table 2 summarizes the most important results. We initially focused on revenue-neutral schemes that are more likely to be implemented for political reasons. We found that revenue-neutrality can be achieved with a low tax rate and a pivot point that is somewhat lower than the current average CO_2 emission level of newly sold cars. However, the environmental benefit -- when evaluated using conventional measures of the damage caused by emissions -- is not enough to make up for the loss in consumer and producer surplus induced by the scheme. Hence, a key finding that emerges from our analysis is that revenue-neutral schemes cannot be welfare-improving. We then extended our investigation to identify welfare-improving schemes. We found that welfare can increase if the pivot point is set at a level that is considerably lower than the current average emission level and the marginal tax rate is not too high, i.e. corresponds to a price of less than 100 euros per tonne of CO_2. Such a combination increases overall welfare through the combined effect of improved public finances and lower environmental damage through reduced carbon emissions, despite a decline in consumer and producer surplus. Essentially, for welfare to increase the feebate must look a lot more like a fee than a rebate; only a small fraction of vehicles should receive rebates. Alternatively, we found that welfare improvements can be achieved with asymmetric schemes where the tax levied on high-emitting vehicles is higher than the rebate offered to low-carbon cars.

Table 2: Simulated impact of selected feebate schemes.

Scheme		Change in:				
t	PP	Total sales	Consumer surplus	Producer surplus	Emissions cost	Total welfare
Revenue-neutral symmetric schemes						
10	135.2	-23.8 (-0.8)	-96 (-1.7)	-30 (-0.8)	-60 (-4.2)	-66 (-0.3)
20	132.7	-47.6 (-1.6)	-191 (-3.3)	-58 (-1.5)	-110 (-7.7)	-139 (-0.7)
30	130.2	-71.9 (-2.5)	-288 (-4.9)	-84 (-2.1)	-155 (-10.7)	-217 (-1.0)
40	127.7	-97.3 (-3.3)	-388 (-6.7)	-109 (-2.8)	-196 (-13.4)	-300 (-1.4)
30.7	130	-73.7 (-2.5)	-295 (-5.1)	-86 (-2.2)	-158 (-10.9)	-223 (-1.1)
71.6	120	-186.7 (-6.4)	-732 (-12.6)	-175 (-4.4)	-315 (-20.8)	-593 (-2.8)
Revenue-neutral asymmetric schemes						
-10/+20	130.6	-26.3 (-0.9)	-106 (-1.8)	-34 (-0.8)	-66 (-4.6)	-74 (-0.3)
-20/+10	136.7	-43.5 (-1.5)	-175 (-3.0)	-52 (-1.3)	-101 (-7.0)	-127 (-0.6)
-5/+20	127.2	-14.4 (-0.5)	-58 (-1.0)	-19 (-0.5)	-38 (-2.7)	-39 (-0.2)
-20/+5	139.4	-41.0 (-1.4)	-165 (-2.8)	-49 (-1.2)	-95 (-6.6)	-119 (-0.6)
-10/+30	127.3	-28.2 (-1.0)	-114 (-2.0)	-36 (-0.9)	-70 (-4.9)	-80 (-0.4)
-30/+10	136.6	-61.8 (-2.1)	-248 (-4.3)	-72 (-1.8)	-134 (-9.3)	-185 (-0.9)
-5/+30	123.8	-15.4 (-0.5)	-62 (-1.1)	-21 (-0.5)	-41 (-2.9)	-43 (-0.2)
-30/+5	138.8	-58.8 (-2.0)	-236 (-4.1)	-67 (-1.7)	-127 (-8.8)	-176 (-0.8)
Welfare-improving schemes						
10	130	-29.1 (-1.0)	-118 (-2.0)	-37 (-0.9)	-62 (-4.4)	61 (0.3)
20	120	-73.2 (-2.5)	-293 (-5.0)	-92 (-2.3)	-122 (-8.4)	473 (2.2)
-2/+3	130.6	-6.0 (-0.2)	-24 (-0.4)	-8 (-0.2)	-14 (-1.0)	13 (0.06)
-10/+20	123.8	-34.2 (-1.2)	-138 (-2.4)	-44 (-1.1)	-68 (-4.7)	141 (0.7)
Sales-increasing schemes						
0/+10	120	0.6 (0.02)	3 (0.04)	0.3 (0.01)	-1.5 (-0.1)	-31 (-0.15)
0/+10	140	3.8 (0.1)	15 (0.3)	4 (0.1)	-6 (-0.4)	-167 (-0.8)
0/+10	160	12.7 (0.4)	52 (0.9)	15 (0.4)	-13 (-0.9)	-508 (-2.4)

Notes: reported changes are in levels; percentage changes are in parentheses. Total sales are expressed in thousands. Consumer and producer surplus and emissions costs are expressed in million euros. Government revenues for the welfare-improving schemes are 154 (+1.4%), 736 (+6.5%), 31(+0.3%) and 255(+2.3%) million euros respectively. Government revenues for the total sales-improving schemes are -36 (-0.3%), -193 (-1.7%) and -587 (-5.2%) million euros respectively. For the asymmetric schemes, the first number is the fee part and the second number the rebate part.

3. Conclusions

The effectiveness of different policy instruments in reducing the transport sector's carbon emissions is a subject of much interest in academic and policy circles. Our work contributes to this debate by providing a rigorous analysis of the impact of feebates, a combination of a tax for high-carbon vehicles and a rebate for low-carbon vehicles. Using data from Germany for the period 2002-2008, we estimated demand for automobiles using three variants of the widely used nested logit model. We used our estimates to simulate the impact of various feebate schemes. We first focused on revenue-neutral schemes that are less likely to face resistance from voters. The analysis showed that the environmental benefit from such schemes is not substantial enough to counterbalance the distortionary effects of taxation, meaning that the schemes are welfare-decreasing overall. We then found that it is possible to design welfare-improving schemes by setting a low pivot point and a low tax rate -- essentially the 'fee' part dominating the 'rebate' part. These schemes generate enough government revenue to outweigh the loss in consumer and producer surplus, while the environmental benefit remains modest.

This analysis is useful because it highlights and quantifies the tradeoffs involved in the design of an appropriate emissions-based taxation scheme for new automobiles. It shows that -- if revenue neutrality is a requirement -- an automobile feebate system will probably reduce total economic welfare in the short term. This should not be interpreted, however, as a recommendation against such schemes. A feebate program, which is a flexible market-based alternative to fuel economy or CO_2 standards, may have a small immediate impact because it addresses only new cars sold in the market. Nonetheless it can provide a long-term price signal to both auto manufacturers and consumers and hence can induce low-carbon investments in the auto industry. This signal will be even stronger if the system's pivot point decreases over the years, which is equivalent to an increasingly stringent CO_2 standard and provides incentives for continuous technological improvements.

At a time when national governments increasingly adopt a CO_2-based element in the calculation of their vehicle taxes, it is important to ensure that policies are properly designed in order to achieve their stated objectives without being detrimental to the sustainability of public finances. Current vehicle taxation policies seem to have been designed with rough approaches and have typically underestimated consumer response. As a result, these policies have proven more successful than initially thought, which in turn has led to a significant loss of public revenues in the Dutch, Irish and French experiences. Our study has highlighted the trade-offs between environmental quality, government revenues, and consumer and producer surplus that factor into the design of effective policies.

4. Outlook for future policy-relevant research

We have demonstrated the possibility of combining theoretically robust economic models with empirically meaningful simulations in order to come up with science-based and realistic recommendations for environmental fiscal reforms in transportation. However, there are several caveats to the analysis, which point to potential improvements that have to be explored in the future. It is important to bear in mind how to link such modeling work more closely to the needs of policymakers by providing the possibility to simulate policies that are usually adopted in the real world.

For this purpose, an important limitation is that this model can only address the short term. It analyzes the impact of a policy change in the first year that it is implemented, focusing on consumer response and keeping the supply side fixed. In the longer term manufacturers might respond to this policy by producing more fuel efficient vehicles. If this is the case, then our estimates will understate the policy's true impact.

Dynamics might also be important on the demand side. If the feebate is temporary -- or is perceived to be so by consumers -- then the consumer response might be substantially greater that what the model predicts. Consumers who were perhaps considering buying a new fuel-efficient car in the next couple of years might bring their purchase forward in order to take advantage of the feebate. Similarly, consumers who were planning on buying a gas-guzzler in the year of the rebate might put off their purchase to avoid paying the fee. This will result in a large but temporary shift from high-emission to low-emission vehicles. This may be at least part of the explanation behind the strikingly large consumer response in some countries, such as France.

Another caveat is that used vehicles were not included in the demand system because of lack of data. Hence, our model does not capture substitution from new to used vehicles due to the introduction of a new tax scheme. Finally, it is always possible to estimate more general models that generate richer substitution patterns.

Distributional aspects are key for the political acceptance of environmental fiscal reforms. The distributional impact of policies like feebates on different types of households cannot be examined with market level data – which points to another limitation of our modeling approach. Therefore, our automobile demand model has to be combined with datasets that include vehicle ownership and purchases of new vehicles for individual households. In the case of Germany that we analyzed, such datasets exist: the German Mobility Panel (MOP), the national survey of Mobility in Germany (MiD) and the survey of potential purchaser of non-conventional cars (ECOCAR). With the aid of such data, a model of individual household decision on demand for vehicles miles travelled can be developed. By simulating the changes in sales of new and used cars by segment and the changes in mileage driven per car and household after price shocks, it will be possible to analyse the environmental *and* distributional effects of alternative carbon-based vehicle tax policies.

Finally, the analysis should be enriched to take into account macroeconomic aspects. Economic crises often provide consumers with a stimulus to re-examine and adjust their spending habits. Durable goods are particularly vulnerable because consumers' first reaction to an income loss is often to postpone replacement of their existing equipment. There are clearly very interesting dynamics in the demand for cars that have yet to yet to carefully studied.

References

Adamou, A., Clerides, S. and Zachariadis, T. (2014). Welfare Implications of Automobile Feebates: A Simulation Analysis. *The Economic Journal* 124 (2014) F420–F443.

Anderson, S.T., Parry, I.W.H., Sallee, J. and Fischer, C. (2011). Automobile fuel economy standards: Impacts, efficiency, and alternatives. *Review of Environmental Economics and Policy*, vol. 5(1), pp. 89–108.

Berry, S.T. (1994). Estimating discrete choice models of product differentiation. *RAND Journal of Economics*, vol. 25(2), pp. 242–62.

Berry, S.T., Levinsohn, J. and Pakes, A. (1995). Automobile prices in market equilibrium. *Econometrica*, vol. 63(4), pp. 841–90.

Bunch, D.S., Greene, D.L., Lipman, T., Martin, E. and Shaheen, S. (2011). Potential design, implementation, and benefits of a feebate program for new passenger vehicles in California. Final report to California Air Resources Board and California Environmental Protection Agency.

D'Haultfoeuille, X., Givord, P. and Boutin, X. (2014). The environmental effect of green taxation: The case of the French "bonus-malus". *The Economic Journal* 124 (2014) F444–F480.

Huse, C. and Lucinda, C. (2014). The market impact and the cost of environmental policy: Evidence from the Swedish "green car" rebate. *The Economic Journal* 124 (2014) F393–F419.

King, J. (2007). The King review of low-carbon cars – part I: The potential for CO_2 reduction. HM Treasury, London.

Rogan, F., Dennehy, E., Daly, H., Howley, M. and ÓGallachóir, B.P. (2011). Impacts of an emission based private car taxation policy-first year ex-post analysis. *Transportation Research Part A*, vol. 45(7), pp. 583–97.

Verboven, F. (1996). International price discrimination in the European car market. *RAND Journal of Economics*, vol. 27(2), pp. 240–68.