WHAT ROLE FOR ELECTRIC VEHICLES IN THE DECARBONIZATION OF THE CAR TRANSPORT SECTOR IN EUROPE?

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Overview

In this paper, we compare how targeted consumer and supply chain policy instruments affect the share of electric vehicles (EVs). This paper offers several contributions. First, it endogenizes the progress in the costs and performance of EVs and of gasoline vehicles (GVs) by making technological progress a function of the policy instruments that are used. Second, it considers the role of the batteries in the EV to increase the share of renewable energy in the transport sector. Further, we consider the different car use externalities as well as the network externality that arises in the development of EV charging infrastructure. Finally, it assesses a wide range of policy options to stimulate the penetration of EV.

We use a two-period partial equilibrium model for a simplified dynamic cost comparison of three main types of policy instruments: fuel efficiency standards for gasoline cars, a portfolio mandate for electric vehicle sales, and high purchasing taxes or subsidies combined with charging network subsidies. We assess the cost-efficiency of these policy instruments evaluating production costs, fuel costs, and externalities. We calibrate the model to Germany. With our two-period model, we take as given the EU objective to reduce average CO_2 emissions of new cars to 95 g/veh-km (or 4.1 liter gasoline/veh-km) over a period of 5 years and a reduction to 59 g/veh-km (or 2,56 liter of gasoline/veh-km) after 15 years. This numerical comparison shows that the market share of EVs depends strongly on the type of policy instrument used but that the share of EVs is not necessarily a good indicator for a successful carbon policy. We find that the fuel efficiency standard for gasoline vehicles with a tradeable permit scheme achieves the emissions reduction goals at the lowest cost.

Methods

To include the learning by doing and the R&D effects, we adapt the renewable electricity model of Fisher and Newell (2008) to the passenger car market. EVs can become cheaper through two knowledge building effects: by learning by doing and by pure R&D. Also, the fuel efficiency of GVs can improve over time thanks to pure R&D. How much both technologies improve depends on the policies in place. Policies can incentivize car producers to produce more cars (learning by doing) but can also stimulate them to invest in R&D that reduces the costs of crucial car components. Consumers are differentiated in function of the number of days per year they make a short or long trip. In our model, the car ownership and the car use is given. The only equilibrium value of interest is therefore the market share of GVs and EVs. The major disadvantage of EVs compared to GVs is their limited range. So we can expect a user equilibrium where EVs are selected by consumers that make mainly short trips. The break-even point will be determined by the number of long trips where the consumer cost in the first period for GV and EV are equalized.The number of days with short trips will also determine the availability of batteries for Vehicle to Grid (V2G) storage. The electricity production sector is simple and the V2G option is modelled as in Greaker et al. (2019).

The EV and GV producers maximize profits under perfect competition. In our formulation, we limit the effect of endogenous technological progress for GVs to the costs that are specific to fuel efficiency. As the main challenge in terms of technological progress for EV producers is to make batteries cheaper (and lighter), we assume that learning by doing and R&D serve to decrease the cost of the battery component of EVs.

Results

The easiest instrument to understand is the portfolio mandate where the EU targets have to be met by increasing the market share of EVs that have 0 emissions. We assume here that the GVs keep their current fuel efficiency level of 0,056 liter/ veh-km[1]. This implies that the EVs have to reach a market share of 27% at end of period 1 and a market share of 54% at the end of period 2. The GV producers have no incentive to improve the fuel efficiency as the policy instrument requires them to contribute to the EV market share by buying portfolio credits from the EV producers. In

[1] We assume that GV producers do not decrease the fuel efficiency of their cars. In our model simulations we keep the gasoline tax unchanged so that they have no incentive to change the initial fuel efficiency level.

the absence of induced technological progress, we see that in the first period, the GV producers have to pay 886 €[2] for every EV, so per GV this is 328 € annually. In the second period, the share of EVs needs to be higher, as EVs have a higher user cost for longer trips, they need a lower purchase price and this requires a higher portfolio credit for the EVs (1764 €). Together with the lower market share of GVs, this results in an increase of the purchase cost of GVs on an annuity basis of 2070 € per gasoline car. The purchase cost of EVs is just one of the elements in the user cost equilibrium as also the fuel costs, the V2G benefits and the endogenous refueling network density play a role. The average cost of emission reduction is 226 €/ ton of CO_2. To put this cost in perspective, it can be compared with the current gasoline tax (0,68 €/liter) that comes down to 293 €/ ton of CO_2. Replacing a portion of the GV fleet with EVs would save emissions at a lower cost: 165 €/ ton of CO_2 because EVs have very low emissions.

We can now introduce the effects of technological progress. In the case of the portfolio mandate, the technological progress is limited to the EVs because the fuel efficiency of the GVs does not matter for meeting the portfolio mandate. The producers of EVs benefit from the two mechanisms to reduce the costs of EV batteries. First they realize that producing a larger quantity (and selling below the marginal cost in the first period decreases their production cost in the second period, part of this cost reduction spills over to the rest of the industry but there remains a clear incentive to produce more and achieve a stronger learning by doing effect. When the market share of EVs increases in the first period to 27%, there is a significant learning by doing effect. The second mechanism that is activated by the EV producers is the pure knowledge build up about battery production that requires firms to invest in R&D. EV producers invest some 10% of their income in the first period in pure R&D. This allows to reduce the cost of batteries by 97%. This does not increase the share of EVs because the EV-share is determined by the portfolio obligation that is still binding. But the technological progress reduces the costs of meeting the target and the cost of emissions reduction decreases to 199 €/ ton CO_2.

We can now analyze the fuel efficiency standard that forces car producers to achieve a lower average emission rate in the first period and an even lower emission rate in the second period. The GV producers can do this by making their cars more efficient and by buying fuel efficiency credits from EV producers. Excluding technological progress forces the GV producers to make more efficient GVs (0.0488 liter/vehkm) but this is expensive and increases the production cost of GVs (annual equivalent) to 4025 €. They need to complement this effort with fuel efficiency credits they buy from EV producers. In the second period, reaching the fuel efficiency target becomes very expensive for the GV producers and they have to rely on purchasing fuel efficiency permits from the EV producers. In the end this solution produces slightly less CO_2 emission reduction: there are less EVs but the GVs are more fuel efficient. CO_2 emissions are also reduced at slightly lower cost (186 €/ton CO_2) than in the case of the portfolio standard, all this in the absence of technological progress.

When we include technological progress, the GV producers have a strong incentive to reduce the cost of fuel efficiency improvement via R&D expenditures as the cost of reaching the target in the second period is very high. The investments in R&D allow them to improve the fuel efficiency from 0.056 liter/vkm (starting value) to 0.0288 liter/vkm after 15 years. For the last bit (to reach the target 0.0254), they rely on fuel efficiency credits of EVs. The share of EVs in the second period is lowest in this scenario. The most important advantage of this scenario is the lower cost of reducing CO_2 emissions. Total emission reductions are somewhat lower than in the other scenarios (51% in the second period rather than 64%) but the overall cost of the scenario is much lower and the emissions reduction cost is just 100 €/ton CO_2. The main reason is that the option to improve the fuel efficiency of GV has become interesting for GV producers so that they will invest in bringing down the cost of fuel efficiency improvements.

Conclusions

The current EU policy instrument is a tradable fuel efficiency standard where gasoline fueled cars have to improve their fuel efficiency but can purchase efforts from EV producers as EVs are considered zero-emission cars. We show that this instrument outperforms the portfolio mandate where the same reduction of the average emission rate is obtained via a tradable portfolio mandate. The fuel efficiency mandate is better because it contains an incentive to improve the fuel efficiency of GVs through R&D. The fuel efficiency mandate is dynamically more efficient than a portfolio mandate that targets a high share of EVs. With endogenous technological progress, the cost of saving CO_2 emissions is reduced to about 100 €/ton CO_2.

The investments in technological progress require that car producers consider the EU target as credible and a real commitment. The EU fuel efficiency target for 2021 will very likely not be met and this means that car producers may not take the current targets as a strong commitment from the side of the policy makers.

[2] This is an annual equivalent; this means that the EVs receive a credit of 6610 € per car produced.