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CO_2 Fleet Targets and Electric Vehicle Market Diffusion

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Executive Summary

Fuel economy regulation is a powerful instrument to reduce CO_2 emissions of newly sold vehicles by setting minimum performance standards. In the long run, CO_2 emissions from transport have to be dramatically reduced to reach ambitious CO_2 mitigation targets. Ambitious fuel economy standards below 75 gCO_2/km cannot be reached with combustion engine vehicles but require the introduction of Plug-in electric vehicles (PEVs). However, the specific relationship between stringent fuel economy standards on PEV market diffusion is not clear. Here, we analyse CO_2 fleet targets in Europe where the proposed update of regulation Regulation (EC) 443 No 443/2009 suggests a target of 68 – 75 gCO_2/km in 2030. We use a data set of 3.2 million records with passenger car sales in Europe from 2010 – 2016 to project future sales and CO_2 emissions of all major vehicle manufacturers in Europe. Our results demonstrate that an ambitious target leads to an uptake of PEV without additional policies or support. The required PEV sales shares to fulfil the proposed CO_2 targets are well below the stated sales targets of various manufacturers. In conclusion, ambitious CO_2 fleet regulation leads to fast market diffusion of PEVs, but the present proposal is less ambitious than car maker targets.

1 Introduction

Greenhouse gas (GHG) emissions from transport have to be strongly reduced to fulfil ambitious GHG mitigation targets. For passenger cars, reduced fuel consumption of conventional combustion engine vehicles and the widespread diffusion of plug-in electric vehicles (PEV) are two routes to achieve these goals. Two main policies exist to follow both routes: (1) minimum fuel economy standards for new sales of conventional vehicles and (2) policies to support market diffusion of EV for a long-term carbon neutral transport such as zero emissions vehicle mandates or purchase subsidies [1, 2]. The former has clearly reduced CO_2 emissions from passenger cars [3] and the latter have increased PEV sales in many countries [4, 5]. In the long term, both policy directions can stimulate the mass market diffusion of PEV.

In Europe, the European Commission introduced minimum fuel economy standards via Regulation (EC) No 443/2009 in 2009 [6]. The regulation sets passenger car emission standards for newly sold vehicles in the EU. More specifically, maximal CO_2 emission values of newly sold cars are determined for each vehicle manufacturer. The present target value is 130 gCO_2/km and will change to 95 gCO_2/km (measured in the New European Driving Cycle, NEDC) in 2020 for an average mass vehicle (cf. [7], for details). The manufacturer specific target is adjusted according to the average mass of a manufacturer's new car fleet. The higher the mass, the more emissions (in gCO_2/km) are permitted. On 8 November 2017, the European

Commission presented a legislative proposal to continue Regulation (EC) No 443/2009 for the period after 2020 [8]. CO_2 fleet emissions from new passenger cars shall be reduced by 15% until 2025 and by 30% until 2030 compared to 2020 levels. The new percentage reduction has been introduced due to the switch from NEDC to a new emissions test procedure, the Worldwide Harmonized Light Vehicles Test Procedure (WLTP).

In line with EU objectives, the regulation creates additional incentives to produce and sell low-emission and zero-emission vehicles (ZEVs). ZEVs are mostly battery electric vehicles (BEV). Vehicles with CO_2 emissions below 50 gCO_2/km are considered low-emission vehicles. Low-emission vehicles are mostly plug-in hybrid electric vehicles (PHEV). In the proposal for an updated regulation, the target value for ZEVs and low-emission vehicles in the new car fleet is 15% in 2025 and 30% in 2030. To strengthen the development and production of zero-emission and low-emission vehicles, manufacturers who exceed these percentages will receive additional rewards. These manufacturers must comply with lower emission values. However, manufacturers who do not meet this requirement will not be penalized [6, 8]. However, the new regulation is currently under discussion in the legislative process. The European Parliament voted on 3 October 2018 for more ambitious CO_2 fleet emission targets. They agreed to CO_2 emission reductions of 20 % in 2025 and 40 % in 2030 (cf. [9]).

Existing literature on policies affecting PEV sales has mainly analysed PEV specific policies. For example, [4, 10] reviewed the effect of monetary incentives and charging infrastructure on PEV sales. [5] reviewed econometric studies on the effect of various incentives on PEV sales. [1] studied ZEV mandates for Canada whereas [11] looked at the effect of ZEV mandates in California. Yet, the fact that ambitious long-term fleet regulation targets will require the introduction of PEV has not been analysed in this part of the existing literature.

The aim of the present paper is to analyse the effect of ambitious fuel economy standards on PEV market uptake. It differs from previous work in several aspects. First, we study the isolated fleet regulation effect for Europe. Second, our methodology is highly transparent by extrapolating existing fuel economy trends based on a large data set of actual car sales. Third, we analyse future CO_2 emissions and PEV sales of all major manufacturers explicitly which has – to the best of the authors' knowledge – not been done in the literature before.

2 Data and Methods

2.1 Data

Since 2010, EU Member States are obliged by Regulation (EC) No 443/2009 to record detailed information on vehicles registered in their territory and to make this data available to manufacturers and the European Environment Agency (EEA). These data are edited and evaluated by the EEA and used to determine compliance with Regulation (EC) No 443/2009. The final yearly data are published on the EEA website (the data are freely available on https://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-14) and form the empirical basis of our analysis.

For our analysis, a total of 3.2 million data records from 2010 – 2016 are available, corresponding to 400,000 to 500,000 data records per year. Since 2010, over 90 million vehicles have been sold by more than 150 different manufacturers comprising over 50,000 different models. The data contain 26 different variables for every year, of which Member state, Manufacturing pooling, Manufacturer name, Mass, Specific CO_2 Emissions, Year, Total new registrations, Fuel Type, Engine Capacity, Electric energy consumption are relevant for this paper.

As shown in Table 1, only few data are missing with exception of BEV electric consumption. However, the (sales weighted) availability of the relevant variables for our analysis - manufacturer, sales per model, CO2 emissions, mass and fuel type - is over 99 %. Altogether, the data are of very good quality. Some of the variables, such as country and engine capacity, have no missing valus at all.

Despite the good data quality, a few but relevant data corrections concerning implausible vehicle mass, wheelbase and fuel type were necessary. We corrected implausible data entries automatically and reviewed each potentially implausible data entry manually. For example, we manually checked vehicles with masses of more than 3,500 kg and less than 500 kg since these contain errors with only a few exceptions. Furthermore

we removed vehicles with a wheelbase of less than 1 mm from the data. In addition, we relabeled all 1,830 data records with CO_2 emissions of less than 50 gCO_2/km as PHEV to correct fuel type errors. Furthermore, hybrid electric vehicles (HEV) and PHEV are not differentiated in the EEA data, but both labeled as petrol or diesel hybrids. For this reason, we manually reviewed each of these data entries with more than 25 sales. This corresponds to a total of 98.5 % of all HEV entries. We labelled the identified HEV as gasoline vehicles.

Table 1: Missing values in the EEA data

	Manufacturer	OEM	Sales	CO_2 emissions	Fuel type	Electricity consumption	Mass	capacity
Missing values	0.03 %	0.76 %	<0.01 %	0.38 %	0.8 %	36.2 %	0.31 %	0 %
Sales weighted	<0.01 %	0.04 %	<0.01 %	0.05 %	0.8 %	19.4 %	0.05 %	0 %

According to Regulation (EC) No 443/2009, vehicle manufacturers have the option to form manufacturer pools to jointly meet the CO_2 fleet targets. Although new emission communities might emerge as a strategic instrument to comply with the CO_2 fleet targets, their analysis is beyond the scope of this paper. Accordingly, we use the status quo of manufacturer pools for our analysis.

2.2. Methods

Manufacturers need PEV to comply with the regulation if emission reduction of internal combustion engine vehicles (ICEV) is not sufficient. The research aim of this paper is to determine the PEV share needed for different ambition levels of ICEV CO_2 emission reduction. For this purpose, we determine the sales share of PEV that is needed to offset the gap between expected average CO_2 emissions of each manufacturer and their corresponding emission targets in each year until 2030.

To determine the CO_2 emissions targets for each manufacturer, we first project their average vehicle masses until 2030. Based on these vehicle masses, we calculate CO_2 emission targets based on the current commission proposal [8].

The determination of manufacturer specific future CO_2 emissions consists of three steps. First, we use the linear interpolation of the manufacturer's vehicle masses to determine a sales weighted average vehicle mass of all vehicles sold in one year. For this purpose, we assume the sales share of all manufacturers to remain constant. Second, we define three scenarios representing different ambition levels of ICEV emissions reduction. Based on cost-based assessments of ICEV reduction potentials in literature, we assume that in 2025, an average ICEV can reach an emission level of 85 gCO_2/km. Here, an average ICEV is defined as a ICEV with the average mass as determined in the previous step. To calculate manufacturer specific emissions, we third and finally assume vehicle emissions to be positively correlated with vehicle mass, analogously to Regulation (EC) No 443/2009. That is, we calculate the yearly emissions of a manufacturer based on its expected future vehicle mass, average vehicle mass of all manufacturers and a factor describing the correlation between CO_2 emissions and vehicle mass. For the years 2012-2016 we calculate this factor based on the EEA dataset. In 2012 this factor was 0.061 gCO_2/km per kg and it decreased over the years almost linearly to 0.047 gCO_2/km in 2016. For 2025, we use a factor of 0.038. To determine the factor for 2030 we use a linear extrapolation based on the values of the years 2012-2016 an 2025. This results in a factor of 0.033.

Based on the results from the previous steps, we calculate the market uptake of the electric vehicles. According to Regulation (EC) No 443/2009 we assume 0 gCO_2/km for BEV. For PHEV, we assume average emissions of 31 gCO_2/km in 2025 and 28 gCO_2/km in 2030. Based on this assumption, we generated different market uptake scenarios for different CO_2 emissions of the combustion fleet. In addition, the distribution of BEV and PHEV within the electric vehicle fleet is of great importance for the market uptake of electric vehicles.

3 Results

3.1 CO_2 reduction trends

In the past, vehicle masses have steadily increased over the years, mainly due to the growing share of SUVs. Also the sales of most manufacturers have increased over the past years. We calculated the specific CO_2 fleet emission value for each manufacturer based on the vehicle masses from the EEA data. We find all manufacturers but the pool of Hyundai/Kia to comply with the regulation when disregarding exceptional rules such as supercredits or other bonus.

We find that in 2025, no manufacturer can meet the CO_2 fleet target without selling electric vehicles (cf. Table 1). Manufacturers would miss their 2025 emission target if they would only rely on conventional cars. For compliance with the regulation, manufacturers thus need PEV sales share ranging from 1 to 11% in 2025.

Table 1: CO_2 targets and required PEV shares in 2025 by manufacturer.

	CO_2 emission target 2025	CO_2 emission target 2030	Required BEV share 2025	Required PHEV share 2025	Announced PEV sales share 2025
BMW	87 gCO_2/km	71 gCO_2/km	7%	11%	15 – 25 %
Daimler	87 gCO_2/km	72 gCO_2/km	8%	11%	15 – 25 %
PSA	77 gCO_2/km	63 gCO_2/km	1%	2%	-
Toyota	78 gCO_2/km	65 gCO_2/km	4%	6%	-
Volkswagen	81 gCO_2/km	67 gCO_2/km	5%	8%	20 – 25 %

Some manufacturers have made announcements regarding the market share of electric vehicles they want to achieve. For example, BMW announced a PEV share of 15 – 25% for 2025. The announcements of other manufacturers for 2025 also range from 15 % to 25 %. Obviously, the manufacturers' own ambitions are significantly higher than the PEV market shares required by the proposal. This may be due to the fact that manufacturers have set higher target values as a result of marketing strategies or as a result from manufacturers also having to comply with other regulations, most importantly the Chinese regulations on new energy vehicles.

3.2 EV market diffusion

To determine the total market uptake of electric vehicles, we calculated the number of electric vehicles the manufacturer must sell to meet the CO_2 fleet targets in different scenarios. Our model assumes that electric vehicles will replace combustion vehicles until the average CO_2 fleet emission is equal to the CO_2 fleet target value.

The basic rationale of the model is that manufacturers will continue to reduce CO_2 emissions of their ICE fleet until the introduction of PEV is more cost-efficient. The extrapolated average CO_2 emissions of the manyufacturers are shown in figure 1. The figure shows the historical manufacturer average CO_2 emissions from 2010 – 2016 and the linear extrapolated of the annual reduction until 2030 of the ICE fleet. Note that we do not assume that the full reduction in CO_2 emissions of the ICE fleet only until 2030. For each manufacturer, there will be a threshold in the reduction after which the average ICE fleet emissions will no further be redcued but insetad a growing sales share of PEV will be introduced to meet the manufacturer's CO_2 target.

The figure shows that the 5 selected manufacturers have achieved similar CO_2 reductions of about 4 gCO_2/km per year. Only Toyota had a smaller slope due to the fact that they already have had relatively CO_2 emissions, in particular given their fleets average vehicle mass. Furthermore, Renault-Nissan was able to reduce their fleet average CO_2 emission slightly faster than other manufacturers.

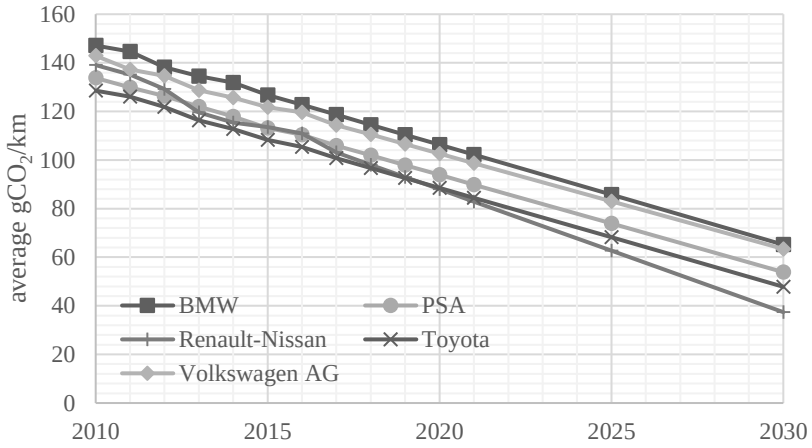

Figure 1: Average gCO_2/km by manufacturer over time. Historical values for 2010 – 20 16 and extrapolation thereafter.

The results for the PEV market shares in Europe, as required to meet the proposed CO_2 target for 2030 are shown in Figure 2. A stringent CO_2 reduction target for 2030 implies higher PEV sales shares than in 2025. Regulation (EC) No 443/2009 leads to a maximum share of 19 % BEV or 28 % PHEV in new car sales in 2030, if only BEV or PHEV were sold. The graph shows the total sales share evolution of PEV based on the weighted average of all manufacturers over time for the two cases of only BEV or only PHEV being sold.

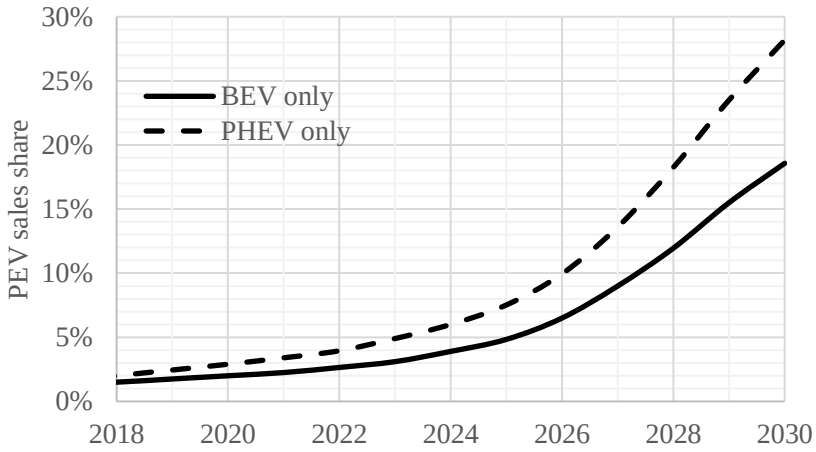

Figure 2: Calculated PEV sales shares in Europe to meet the proposed CO_2 reduction target.

A key assumption in the analysis is the (mass-dependent) limit in gCO_2/km that is economical for the car manufacturer produce. The chosen threshold of 85 gCO_2/km is most likely to be in the range of 80 – 90 gCO_2/km such that somewhat higher or lower market diffusion of PEV would than be chosen to meet the CO_2 fleet target.

In summary, these results show that there will be an impact of fuel economy standards on the market uptake of PEV. Even assuming that sales of electric vehicles continue to rise, as in recent years, the regulation has a noticeable effect.

4 Summary and Conclusion

We calculate the market uptake of plug-in electric vehicles as instrument needed to comply with proposed new Regulation (EC) No 443/2009 since the CO_2 emission targets cannot be reached with conventional vehicles in the future. We find that most manufacturers require PEV sales shares in 2025 well below their announced sales targets. Furthermore, the PEV sales shares in Europe will grow to 18–27% of newly sold cars in 2030 to meet the proposed CO_2 targets. Thus, our study explicitly modelled the connection between stringent CO_2 reduction targets and PEV sales shares.

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