Drivers of development of battery electric vehicles in Europe : A panel data analysis

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Drivers of development of battery electric vehicles in Europe: A panel data analysis

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Abstract

Transition towards a low-carbon energy mix and adoption of electromobility are important challenges in the decarbonisation of the transport sector. In this final thesis, we analyse the impact of monetary incentives introduced by national governments in order to foster the development of battery electric vehicles (BEVs). With panel data techniques, we find a positive and significant relationship between monetary incentives and BEVs' sales. When taken separately, the most effective monetary incentive seems to be the purchase premium. It also appears that the charging infrastructure has a positive impact on the development of an electric fleet. However, this impact becomes insignificant when the sample is reduced to the last four years or to western countries, which are in a more advanced stage regarding the charging network and BEV adoption.

Keywords : Electric vehicles, policy measures, monetary incentives, charging infrastructure, panel data.

Nomenclature

Abbreviation	*Description*
ICEV	ice combusting engine vehicle: driving with conventional combustion engine exclusively
HEV	hybrid electric vehicle: combination of a conventional internal combustion engine system and an electric propulsion system
EV	electric vehicle: any vehicle for which an electric motor is the primary source of propulsion
BEV	battery electric vehicle: driving with electric motor exclusively and storing energy in a battery
PHEV	plug-in hybrid electric vehicle: combination of a conventional internal combustion engine system and an electric motor that can be recharged with a plug-in

Contents

1 Introduction

Over the past few years, conservation of the environment has become one of the most important concerns of humankind. Nowadays, the reduction of the carbon dioxide (CO_2) emissions is a global priority. Indeed, there is a link between CO_2 emissions and long-term climate change (Crowley & Berner, 2001). In order to avoid dramatic impact of climate change, considerable effort must be made. Davis, Caldeira and Matthews (2010) insist on the need and the necessity to provide energy and transport services that emit no CO_2. Indeed, 25.8% of the greenhouse gas emissions in the European Union countries come from the transport sector (European Environment Agency, July 2017). This sector is thus a key lever to reduce human impact on earth.

Moreover, transportation is an important cause of air pollution. Motor vehicles with an internal combustion engine (ICEV) are responsible for several air pollutants, such as particulate matter (PM), hydrocarbons (HC), nitrogen oxides (NO_x), carbon monoxide (CO), sulphur oxides (SO_x) and hazardous air pollutants. This pollution represents a cause of many deaths in Europe. According to the European Environment Agency (2017), 487,600 premature deaths in EU-28 can be attributed to air pollution. It is therefore necessary to take action before it is too late.

In a recent study, Efstathiou and Merrill (2018) have computed the CO_2 emissions per mile for electric and gasoline vehicles in several countries. It appears that, even in China, whose electricity production facilities rely mainly on coal-fired plants, electric vehicles are cleaner than gasoline engines and the benefits improve over time. Bauer, Hofer, Althaus, Del Duce and Simons (2015) performed Life Cycle Assessment (LCA) of passenger cars in order to evaluate some vehicle technologies from a holistic perspective. As shown in Figure 1, battery electric vehicles (BEVs) will be the least polluting vehicle technologies in terms of life-cycle greenhouse gas (GHG) emissions by 2030. Indeed, their life-cycle GHG emissions are expected to drop by 60%[1] from 2012 to 2030. This computation is based on a reference scenario in which the European electricity mix is characterised

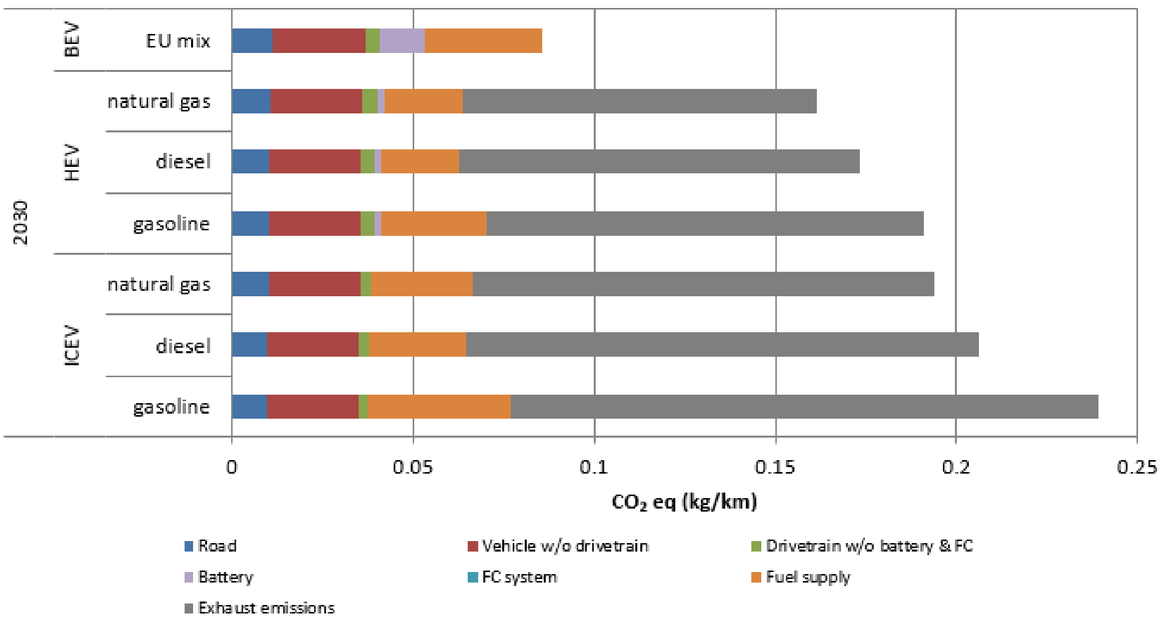

Figure 1: Life-cycle greenhouse gas emissions for different vehicle technologies in 2030 – adapted from Bauer et al. (2015)

[1] 0.214 kg CO_2eq/km in 2012 compared to the expected level of 0.086 kg CO_2eq/km in 2030.

by a lower greenhouse gas intensity compared to the current one[2].

The development of electromobility and the transition towards a low-carbon energy mix are thus important steps in the decarbonisation of the transport sector and in the improvement of air pollution. However, important obstacles to EV adoption exist, such as the higher price of the cars and the range limitations (McKinsey & Company, 2014). This will be discussed in more details in the next section. For some years now, national governments have intervened on the market to partly overcome those barriers. The exact effect of incentive programs set up by governments is quite unclear. On the one hand, as shown in Figure 2, the sales of BEVs in the EU (plus Norway) have been strongly growing in the past few years. On the other hand, the sales are represented in absolute numbers. Relatively speaking, the electric-vehicle market remains very small. Indeed, only six countries[3] in the world had an electric vehicle market share higher than 1% in 2016 (IEA, 2017).

Despite the great number of articles on electric cars, the impact of government support on the development of an electric fleet needs to be examined thoroughly. Whereas previous empirical studies mainly target a few countries and a specific year, our research takes into account several countries and years. More specifically, this present research investigates the impact of monetary incentives and other factors, such as the charging network, on BEV adoption in the European Union with a panel data approach.

Our findings suggest that the monetary incentives implemented by national governments have a positive and significant effect on the sales of BEVs. Viewed individually, the most effective monetary incentive to boost sales is the purchase premium. It seems that consumers are not fully rational when making their cost-benefit analysis. Similarly, the charging infrastructure has a positive impact on sales. However, the impact is insignificant when we only focus on the last years of the sample or on western European countries. Finally, results highlight a negative and statistically significant relationship between gasoline prices and the sales of BEVs.

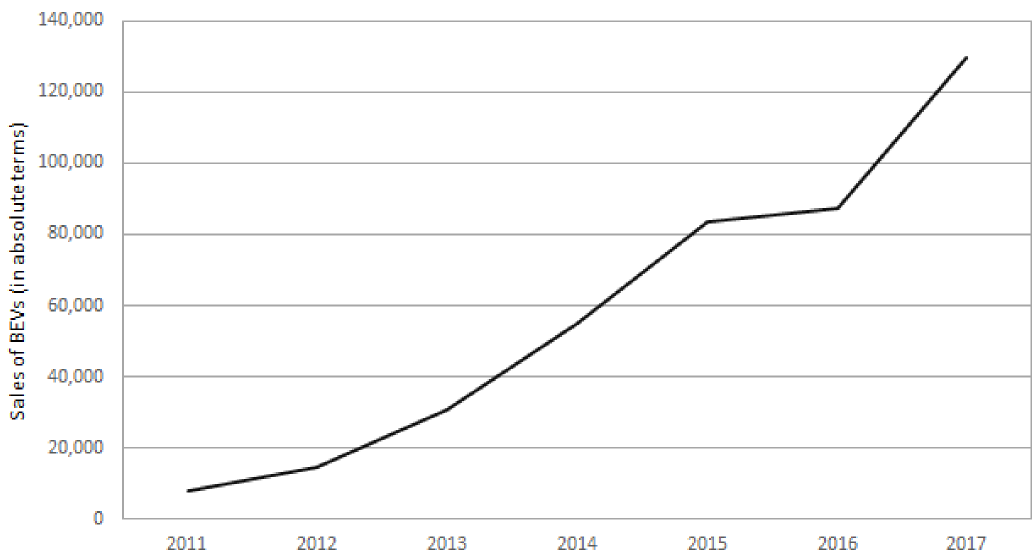

Figure 2: Sales of BEVs in EU-28 plus Norway – data from EAFO

[2]0.1496 kg CO_2eq/km in 2012 compared to the expected level of 0.0323 kg CO_2eq/km in 2030.
[3]Norway, the Netherlands, Sweden, China, France and the United Kingdom.

This paper is organised as follows: Section 2 offers a literature review of previous research on electric vehicles and policy measures. Section 3 explains carefully the data used and shows some descriptive statistics. The model and methodology applied in this analysis are described in Section 4, while the final results are presented in Section 5. The paper is brought to a close with general conclusions and policy implications.

2 Literature review

The European Union is facing a transition towards a full-scale commercialisation of EVs (Thiel, Krause, & Dilara, 2015). In addition, Thiel, Krause and Dilara (2015) insist that the development of an electric fleet has met some barriers and is thus strongly dependent on support policies. These particularities have gained research attention. Indeed, the literature on EVs has emerged over the past few years. The different barriers to the deployment of an electric fleet have been addressed in many papers. Some of them have also focused on policy measures promoting the adoption of EVs. This section aims at writing a review of the existing literature.

2.1 Barriers and purchasing process

Hidrue, Parsons, Kempton and Gardner (2011) have published the results of a stated preference study of electric vehicle choice. They found that the three main concerns about EVs are range anxiety, long charging time and high purchase price. These latters have already been identified in older studies, such as Tompkins et al. (1998) or Ewing and Sarigöllü (1998).

Recently, Gómez Vilchez, Harrison, Kelleher, Smyth and Thiel (2017) have conducted a stated preference survey to quantify the factors influencing people's car type choices in Europe. In comparison with a similar previous survey conducted by Thiel, Alemanno, Scarcella, Zubaryeva, and Pasaoglu (2012), it appears that the purchase price is still the most important factor when choosing a car. However, the authors highlight that a smaller proportion of the sample is in complete agreement with the statement that EVs are too costly. In addition to the high purchase price, the reasons why respondants do not buy EVs are the lack of charging infrastructure, range concerns and too little model choices (Gómez Vilchez et al., 2017). Moreover, it seems that the respondents now have greater uncertainty with regard to environmental benefits of an electric mobility (Gómez Vilchez et al., 2017). Regarding the improvement of the charging infrastructure, it has already been identified as a key factor to boost EV sales (Lin & Greene, 2011; Lieven, 2015).

In 2013, Franke and Krems focused on one of the three main concerns, namely the factors that can influence the range preferences. Their findings suggest a discrepancy between range preferences and range needs. This difference is getting smaller as the electric vehicle experience increases. Practical experience could thus play a key role in purchasing intentions.

With regard to the high purchase price, Newbery and Strbac (2016) argue that the high cost of batteries makes the investment cost of EVs comparatively higher. In order to make EV market more competitive, a carefully designed policy is still necessary (Thiel et al., 2015).

In conclusion, the development of electric vehicles is hindered by various barriers, such as the high purchase price and the lack of a consistent charging network, which are deciding factors.

2.2 Impact of policy measures

Over the past few years, various incentives have been introduced by national governments in order to promote electric mobility. Lieven (2015) identifies different categories of policy measures: monetary, traffic regulations and charging infrastructure. The first category has a direct impact on the total cost of ownership (TCO), whereas the others have an indirect impact on the purchasing process by improving the existing infrastructure or the benefits of having an electric vehicle. When taking a purchase decision, consumers make a cost-benefit analysis. Monetary incentives decrease the costs, while traffic regulations and charging infrastructure improve the benefit side. However, it is likely that consumers are not fully rational in their decision. For instance, some subsidies, such as the VAT exemption in Norway, are upfront and clear. Others, such as tax exemption, are only available at the end of the year. In that latter case, it is harder for consumers to perceive the exact benefit.

Despite the fiscal incentives, most of the ice combusting engine vehicles are still cheaper than their EV pairs on a TCO basis, except in Norway (Lévay, Drossinos, & Thiel, 2017). Overall, literature is quite unclear with regard to the effectiveness of policy measures on EV adoption (Sierzchula, Bakker, Maat, & van Wee, 2014). An overview of the main results of previous studies is presented below.

Several surveys have been conducted among (potential) consumers. Those surveys are based on a stated preference approach, in contrast to analysis of empirical data, which are based on a revealed preference approach. Franklin, Langbroek and Susilo (2016) have analysed the effect of policy incentives on EV adoption in Stockholm. By using constructs of the Transtheoretical Model of Change (Rogers, 1975) and the Protection Motivation Theory (Prochaska, 1991), they have shown that the incentives are less effective for people that are in more advanced stages-of-change. According to the authors, free parking or access to bus lanes (traffic regulations) seem to be good alternatives to costly subsidies. However, Lieven (2015) reminds that this alternative has a drawback: its decreasing efficiency. In his paper, based on a survey conducted in 20 countries, Lieven (2015) uses a combination of two methods: conjoint analysis (Green & Srinivasan, 1978) and the Kano method (Kano, Seraku, Takahashi, & Tsuji, 1984). His main conclusion is that lower grants combined with charging facilities are as attractive as high cash grants. In some countries, such as Norway, charging infrastructure plays a less important role (Bjerkan, Nørbech, & Nordtømme, 2016). In that country, purchase tax and VAT exemption are the most powerful policy measures to promote EV adoption (Bjerkan et al., 2016). Nonetheless, a strong charging network remains fundamental and necessary for subsidies to be efficient.

Due to a limited availability, quantitative analyses based on empirical data have not yet been sufficiently conducted for EVs. Using multiple linear regression analysis, Sierzchula et al. (2014) have analysed the influence of financial incentives and other socio-economic factors on EV adoption. The data used in that paper comes from 30 countries for the year 2012. According to the model, the EV market share does not only share a positive and significant relationship with financial incentives but also with charging infrastructure. Fluchs and Kasperk (2017) point out that government incentives can have an impact on the development of EV. However, the exact effect strongly depends on the type of countries and the type of EV. Regarding hybrid electric vehicles (HEV) adoption, empirical analysis suggests a strong and positive relationship between hybrid adoption and gasoline prices (Diamond, 2009; Gallagher & Muehlegger, 2011). Furthermore, Diamond (2009) highlights a weak relationship between HEV market share and monetary incentives.

To my knowledge, there is no empirical analysis for BEVs which captures their sales' reaction to monetary incentives over such a long period and across so many countries. Thus, this paper helps close this research gap and examines how monetary incentives and other factors affect BEVs' sales in the EU by panel data analysis.

3 Data

This section is divided into two parts. First, the raw data used in the analysis is presented and discussed in more details. Then, some descriptive statistics are shown.

3.1 Description

Data has been collected for 29 countries, from 2011 to 2017. The countries are the following: Austria; Belgium; Bulgaria; Croatia; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Ireland; Italy; Latvia; Lithuania; Luxembourg; Malta; the Netherlands; Norway; Poland; Portugal; Romania; Slovakia; Slovenia; Spain; Sweden and the United Kingdom. The independent variable is the sales of BEVs. The explanatory variables are the monetary incentives for promoting BEV and the number of publicly accessible power charging stations. Based on the factors highlighted in section 2 and previous research (Sierzchula et al., 2014; Gallagher & Muehlegger, 2011), control variables have been collected. These control variables can be divided into three categories:

1. *Environmental variables*: share of energy from renewable sources for electricity and environmental index ;
2. *Economic variables*: transport taxes, total receipts from taxes, prices of electricity, prices of gasoline/diesel and gross domestic product per capita ;
3. *Socio-demographic variables*: population, total land area and employment rate.

3.1.1 General remarks

Although Table 1 offers a good overview of the variables and data sources, some additional remarks need to be added.

The data on the number of publicly accessible power charging mainly comes from EAFO. However, due to missing values, especially for the years 2011 and 2012, national statistics have been consulted to complete the gaps. Since reliable sources have not been found for Croatia and Cyprus, the missing values are numerous for those countries. Based on previous literature such as Sierzchula et al. (2014), it would be interesting to (re)examine the relationship between the sales of BEVs and the charging infrastructure. This variable also serves as a good proxy for the range anxiety, which relates to the risk of not beeing able to drive the electric vehicle due to a lack of charging stations. Thus, we can easily assume that the more the network is advanced, the fewer consumers will feel range anxiety.

Table 1
Description of variables and sources

Variable	Data	Sources
Sales	National sales of battery electric vehicles	EAFO[a]
NewReg	National new registrations of battery electric vehicles	EAFO
Incentives	Monetary incentives provided by countries for the purchase and/or use of an electric vehicle	ACEA[b]
NPC	Number of publicly accessible normal power charging stations in a country	EAFO
HPC	Number of publicly accessible high power charging stations in a country	EAFO
RE	Share of energy from renewable sources for electricity in a country	Eurostat
EPI	Environmental index that ranks environmental regulation and performance by country	Yale University
Tax	National transport taxes as % of GDP (excluding fuel taxes)	Eurostat
Revenue	Total receipts from taxes and social contributions in % of GDP	Eurostat
Pelec	Average national price of electrical energy for houshold consumers (all taxes and levies included)	Eurostat
Pgas	Average consumer prices of Euro-super 95 (1000L) – duties and taxes included – in a country	DG Energy[c]
Pdie	Average consumer prices of gas oil automobile (1000L) – duties and taxes included – in a country	DG Energy
GDP	Gross domestic product per capita based on purchasing power parity	World Bank
Pop	Total population in a country based on the de facto definition of population which counts all residents	World Bank
Area	Total land area in square kilometer in a country	EAFO
Emp	Proportion of a country population that is employed	World Bank

[a] European Alternative Fuels Observatory
[b] European Automobile Manufacturers Association
[c] Directorate-General for Energy (European Commission)

The environmental performance index is a measure of state environmentalism which aggregates data on 24 individual metrics of environmental performance. It is used as a proxy to measure the relative value placed by inhabitants from each country on sustainability. Reverse causality between BEVs' sales and EPI does not represent a concern because the BEV market share is still very low in most of the countries. It is thus reasonable to assume that the current electric fleet has only a negligible impact on the indicators that formed the index (Sierzchula et al., 2014). Since EPI is published every two years, estimations have been used for the missing years. Considering the data composing the index, best ranked countries will face in all likelihood better BEVs' sales. A positive relationship between EPI and the sales is thus expected.

The share of energy from renewable sources for electricity in 2017 is, again, not yet available. We have not found reliable estimations and we have thus decided to let this year missing. There is a probable synergic effect between EV deployment and the decarbonisation of the power system (Thiel, Nijs, Simoes, Schmidt, van Zyl, & Schmid, 2016). The share of energy from renewable sources could thus be used as a measure of the decarbonisation of the power system and a positive relationship with the sales of BEVs is expected.

The data on national transport taxes and total receipts from taxes and social contributions comes from Eurostat. Data for 2017 is not yet available. Since no consistent estimations have been found, this year is missing for these two variables. The relationship between BEVs' sales and transport taxes deserves to be considered. At first sight, countries with both high levels of transport taxes and tax exemptions may experience a higher proportion of sales.

We may expect a negative relationship between the national electricity prices and the BEVs' sales. Indeed, if the electricity prices are taken into account in the computation of the total cost of ownership, a decrease in the prices could affect positively the sales.

The average consumer price of Euro-super 95 and gas oil automobile is expressed in euro per 1000 liters. The data comes from weekly oil bulletin published by the DG Energy. The data is unavailable for Norway and is thus missing for this country. According to literature and common sense, a positive relationship between gasoline (or diesel) prices and BEVs' sales is expected. An increase in the prices of gasoline could indeed make the electric vehicles more competitive compared to the ice combusting engine vehicles.

Gross domestic product per capita and the total population data comes from World Bank Open Data. Again, the year 2017 was not yet available. With regard to the gross domestic product, the estimated growth rate published by the European Commission has been used to compute the 2017 GDP estimations. Data from EAFO (2017) has been collected to complete the total population variable.

The driving range and charging time are not included in the model. Since the same electric vehicles are generally available in the 29 countries of the sample, there is no significant difference across the countries. Moreover, the number of charging stations, which is strongly linked to those variables, is taken into account in the regression. Another notable absence includes the price of vehicles. Sierzchula et al. (2014) use a reference model (Mitsubishi MiEV) to quantify this variable. In the context of this paper, it was decided not to include this variable in the model for many reasons. First, this information could not be easily gathered from any known public source. Second, one can assume that the prices of the vehicle (in terms of purchasing power) only differ slightly across countries. Furthermore, there is potential bias, namely the fact that the negotiated price between the dealer and the consumer is not known and may be lower than the official price.

3.1.2 Monetary incentives

This subsection aims to carefully explain the methodology used to construct the main variable of the analysis: the monetary incentives. Before that, additional comments regarding all the existing policy measures are made in order to be comprehensive and clarify the limits of this paper.

As stated above, Lieven (2015) identifies three categories of policy measures : monetary, traffic regulations and charging infrastructure. To that, we can add policy measures which aim at discouraging consumers from buying vehicles that emit a huge quantity of CO_2 or fines particules. The bonus-malus system in France is a good example of this. Such a system is based on the "polluter pays" principle. More radically, some local governments have already announced the interdiction of polluting cars in the coming years. For instance in Brussels, the government wants to ban diesel-powered vehicle by 2030. It is worth noting that this kind of measures is a bit different from the others. Indeed, their original aim is not to directly promote EVs but rather deter the use of "polluting vehicles". The Table 2 offers an overview of the different policy measures in Europe.

Policies which aim at developing the charging infrastructure are largely taken into account through the EV-specific variable. Regarding the traffic regulation policies, they are generally adopted at local levels. Moreover, their effectiveness is decreasing and strongly depends on the characteristics of the city (Lieven, 2015). Due to this heterogeneous environment, this variable has not been examined as part of this paper. Finally, the disincentives are different from incentives in terms of implications. In addition, there is a lack of qualitative studies regarding the disincentives. That is why this category of policy measures is not included in the regression. However, it is important to keep in mind that such measures may have an impact on the purchasing process.

Table 2
Existing policy measures in Europe

(Dis)incentives	Description
Monetary	
(1)	Purchase premium
(2)	Acquisition tax exemption
(3)	Ownership tax exemption
(4)	Company benefits
Charging infrastructure	Subsidies, cash-grants or investments which aim at developing the charging network
Traffic regulations	Policies generally adopted at local level, such as free use of bus lanes or free city center parking
Disincentives	Taxes or interdiction whose primary objective is to deter the use of "polluting vehicles"

Thus, this paper focuses on the monetary incentives, which represent the main explanatory variable of the empirical analysis. As shown in Table 2, these incentives can be divided into four categories:

(1) Purchase premium: premium granted for the purchase of a BEV ;

(2) Acquisition tax exemption: exemption of the registration tax ;

(3) Ownership tax exemption: exemption of the annual/monthly circulation tax or road tax ;

(4) Company tax benefits: measures that reduce the tax burden for company cars.

We have carried out an in-depth analysis of the monetary measures implemented by the countries from 2011 to 2017. The Tax Guide issued each year by the European Automobile Manufacturers Association (ACEA) represents the main source of information. The overview on tax incentives for electric vehicles in the European Union, also published by ACEA, is the second source of information. Finally, information from national studies have been gathered to complete the ACEA reports. In Appendix 1, a synthesis of the research for each country can be found. The quantification of the exact and respective savings of the monetary incentives is a complex task because each country has its own specific environment. A comparison between the kinds of monetary incentives and through the different countries represents a perilous mission that is not pursued in this cross-country analysis. Indeed, using a continuous measure of monetary incentives is complicated in such an analysis. In the context of this paper, the dummy variable is the most adequate tool to use. Thus, based on research conducted, the four categories of monetary incentives are represented by dummies, which is already a big challenge in terms of quantification.

There are several sources of potential bias. First, we may observe substantial change in the sales of electric vehicles essentially due to government announcements. For example, in 2013, the Dutch government announced incentives reduction for the following years. A peak of PHEV sales was thus observed in 2013, in large part explained by the customer's reaction to the announcement. However, the government has finally not reduced the incentive program.

Another potential source of bias is that some countries may implement monetary incentives without the citizens being aware of it. In other words, the effectiveness of policy measures could be underestimated. It was, for instance, the case for Slovenia in 2011 and 2012.

Finally, as highlighted by Gallagher and Muehlegger (2011), the selection of policy measures may be endogenous. One can imagine that a country may choose the most appropriate monetary incentives according to the local environment. The analysis could thus overestimate the effectiveness of government incentives. Moreover, a country may experience a better outcome (in terms of monetary savings for the consumers) by only putting in place one category of monetary measures than a country which implements the four categories. As a reminder, the exact savings are not taken into account in this paper because monetary measures are represented by dummies.

3.2 Descriptive statistics

3.2.1 Summary statistics[4]

Table 3 presents the summary statistics for the different variables of the analysis. Each country-year is treated as a single observation. The number of observations that corresponds to the whole sample (29 countries from 2011 to 2017) is 203. As shown in the table below, there are 9 missing observations for the normal power charging stations and 4 missing observations for the high power

Table 3
Summary statistics

Variable	***N***	**Mean**	**Std. dev.**	**Min**	**Max**
Sales					
BEV	203	2,014	5,092	0	33,025
Explanatory variables					
Purchase premium	203	0.33	0.47	0	1
Acquisition tax exemption	203	0.40	0.49	0	1
Ownership tax exemption	203	0.43	0.50	0	1
Company benefits	203	0.29	0.45	0	1
Incentives[a]	203	1.45	1.25	0	4
NPC	194	1,802	4,322	0	32,120
HPC	199	197	478	0	3,027
ChgInf[b]	194	2,005	4,654	0	32,875
Environmental variables					
RE	174	0.29	0.29	0.005	1.10
EPI	203	73.55	9.39	48.34	90.68
Economic variables					
Tax	203	0.55	0.36	0	1.6
Revenue	203	0.37	0.06	0.24	0.50
Pelec	232	0.18	0.05	0.08	0.31
Pgas	196	1,384	181	984	1,788
Pdie	196	1,287	165	922	1,755
GDP	203	37,902	16,345	15,676	105,871
Socio-demographic variables					
Pop	203	1.77E+07	2.28E+07	416,268	8.25E+07
Density ($\frac{Pop}{Area}$)	203	166	243	15.30	1,384
Emp	203	52.66	5.32	38.69	63.26

[a] Defined as the sum of the four categories of incentives
[b] Defined as the sum of the normal power charging stations (NPC) and the high power charging stations (HPC)

[4]Additional descriptive statistics can be found in Appendix 2.

charging stations. As mentioned above, it is due to a lack of information for Croatia and Cyprus. Regarding the share of energy from renewable sources for electricity, observations for 2017 are missing for each country. There is thus 29 missing observations for this variable.

The prices of gasoline and diesel were unavailable for Norway. This explains the lowest number of observations (196) for both of these variables.

The maximum BEVs sold in a year is 33,025. This number corresponds to the sales in Norway for the year 2017. With regard to the incentives, we can notice that the ownership tax exemption is the most used tool, while the company benefits is the less used one. The maximum publicly accessible power charging stations is 32,875. This number corresponds to the existing stations in the Netherlands in 2017. The density, measured in inhabitants per square kilometer, varies from 38.69 (Norway) to 1,384 (Malta).

3.2.2 Bivariate relationship

In this part, the relationship between the BEV market share – defined as the BEVs' sales in a year divided by the total new passenger car registrations of the corresponding year – and explanatory variables are examined.

Figure 3 shows a positive relationship between the BEV market share and the main explanatory variable, namely the monetary incentives. However, some disparity in the data can be noted. For instance, Greece and France experienced the same intensity of monetary incentives, but France had a much larger market share. In addition, there are some countries with a low intensity of monetary incentives and a significant market share. Denmark is a good example of this. Thus, it seems that other factors may influence BEV adoption. Norway is not represented in the figure due to its significantly higher BEV market share compared to other countries.

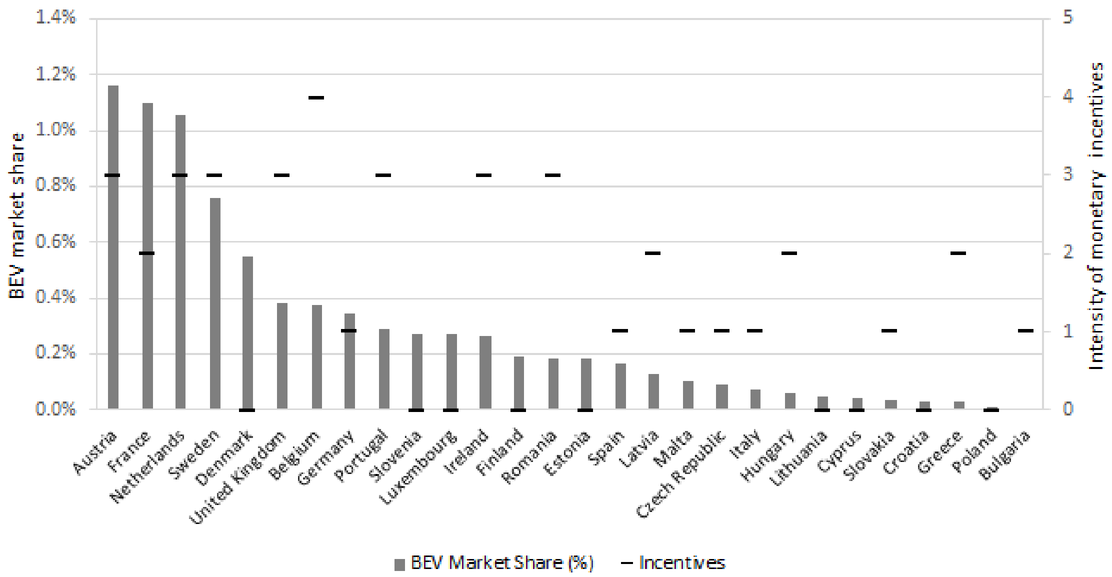

Figure 3: National intensity of monetary incentives and corresponding BEV market share for 2016 – data from EAFO and ACEA

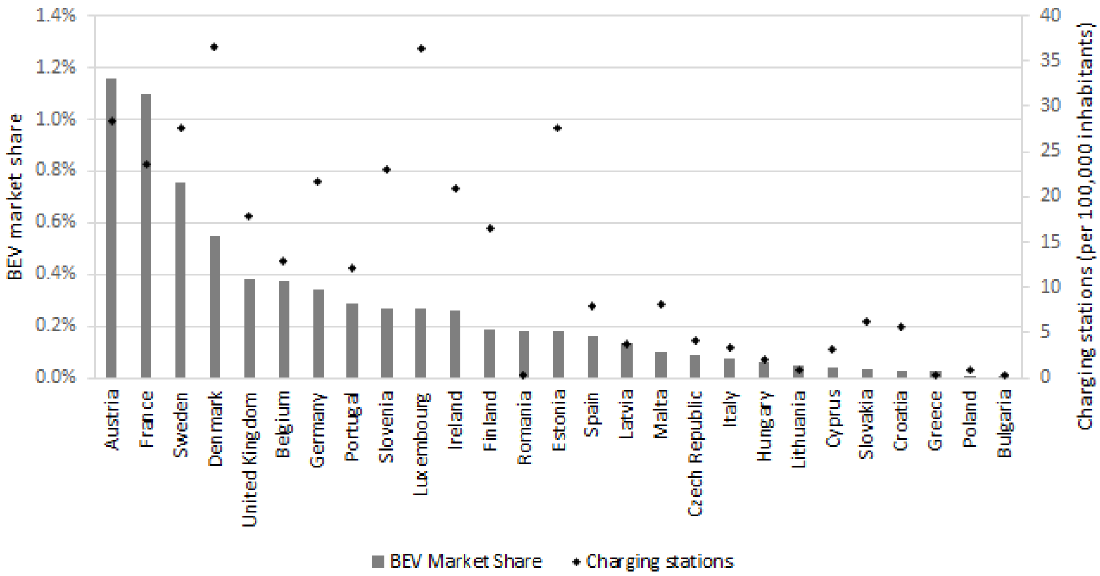

Figure 4: National publicly power charging stations and corresponding BEV market share for 2016 – data from EAFO

A positive relationship between the number of charging stations (per 100,000 inhabitants) and BEV market share is shown in Figure 4. Moreover, the chart seems to highlight two groups of countries. The first group is distinguished by countries with more than 10 charging stations (per 100,000 inhabitants). It corresponds to the first 12 countries represented in the figure. They all experienced higher BEV market share. The other group is constituted by countries with less than 10 charging stations and a lower BEV market share. It corresponds to the last 13 countries represented in the figure. Estonia and Romania are two exceptions. While Romania exhibited an abnormally high proportion of charging stations, it is the exact opposite for Estonia. However, both countries experienced the same level of market share. Norway and the Netherlands are not represented in the figure due to their significantly higher proportion of charging stations compared to other countries. For information, scatterplot of the average sales of BEVs and average charging stations can be found in Appendix 4.1.

4 Empirical approach

This section aims at showing the main equation of the analysis and discussing the empirical technique used.

The dataset constitutes a cross-sectional time series of observations. Thus, the panel data regressions methods have been used in order to estimate the effect of monetary incentives and the charging network on the sales of BEVs. The model controls for country fixed effects. These effects are unobserved characteristics that are time-invariant and that differ between countries. Hence, the idea is to control for omitted variables such as the climate, the religion or the road infrastructure. In addition, we control for time fixed effects. This captures the effects of specific omitted variables that are constant across countries. For instance, those omitted variables could be new technologies reducing the price of the batteries or homogeneous macroeconomic shocks, such as an economic crisis in Europe. Time fixed effects help reduce the omitted variable bias. We also take the log of all the variables (except incentives) for two main reasons. First, this allows us an easier interpretation and comparison of the coefficients, since they represent an elasticity or a semi-elasticity. Second, taking the log reduces the problem of heteroskedasticity and the harm of outliers (Woolridge, 2015). Finally, we use the robust estimators to deal with the persistent presence of heteroskedasticity.

Indexing country and time as i and t respectively, the main regression model of the analysis is represented by the following equation:

$$\begin{aligned} log(Sales_{it}) = \beta_1\, incentives_{it} + \beta_2\, log(ChgInf) + \beta_3\, log(EPI_{it}) + \beta_4\, log(elec_{it}) + \beta_5\, log(gas_{it}) \\ + \beta_6\, log(GDP_{it}) + \beta_7 log(pop_{it}) + \beta_8\, log(emp_{it}) + \alpha_i + \gamma_t + \varepsilon_{it} \end{aligned}$$

where α_i is the country heterogeneity term (constant over time), γ_t is a year dummy (constant across countries) and ε_{it} is the idiosyncratic error.

The country fixed effects can be controlled through two competing methods (Torre & Myrskylä, 2011). One consists in differencing the data, the other includes fixed or random effects in the model. The first-difference method has the drawback to reduce the size of the sample and thus the statistical power. Since the number of observations is not as high, we preferred to avoid using the first-differencing method. Moreover, this method is less appropriate given the characteristics of the dependent variable, namely the sales of battery electric vehicles.

After that, we did the Hausman test in order to compare the fixed effects (FE) model to the random effect (RE) model. The test failed to reject the null hypothesis that states the RE model is appropriate. In the context of this analysis, we decided though to use the FE model, which allows a limited form of endogeneity. Indeed, a correlation is likely to exist between the unknown intercepts (α_i) and the explanatory variables. This could lead to inconsistency in the RE model (Cameron & Trivedi, 2009). For information, one can also note that both models give similar results with regard to the main explanatory variables.

Finally, we tested the relevance to include time fixed effects in the model. We strongly rejected the null hypothesis that coefficients for all years were jointly equal to zero. Time fixed effects are therefore needed. In any case, it is often important to include year dummies in the regression in order to isolate causal relationship. It should also be mentioned that Norway has been removed from the regressions due to its abnormal characteristics compared to other countries[5].

The empirical strategy is thus a panel model that includes fixed and year effects, whose estimators are robust to heteroskedasticity.

5 Results

This section is divided into four parts. The first part deals with the main regression results. The second one discusses main results when the initial sample is modified. After that, alternative specifications are used to check the consistency of the final model. Finally, estimates are computed with interaction terms in order to test the complementarity between monetary policies and charging stations.

[5]See Appendix 4.2.

5.1 Main regression results

Table 4 shows the main regressions of the analysis. The first column (1) is a pooled OLS. This can be seen as a benchmark. The model's R^2 is 0.871 and 0.877 for the adjusted R^2. This means that almost 9/10 of the variation in national sales of BEVs is explained by the independent variables. The coefficients for the two main explanatory variables – the monetary incentives and the charging infrastructure – are both positive and statistically significant at the one per cent level. Holding all factors constant, the implementation of an additional monetary incentive would cause of BEVs' sales to increase by 29%. Similarly, when the national charging infrastructure grows by 1%, the sales of BEVs are expected to increase by 0.44%. The pooled OLS also reveals a positive and statistically significant relationship between the sales and the environmental index EPI. The more a country is well environmentally ranked, the more sales this country would have. As expected, the coefficients for GDP per capita and population are positive and statistically significant. The most surprising result is the absence of positive relationship between the prices of gasoline and BEVs' sales. Indeed, the coefficient is negative and statistically significant. In other words, an increase of 1% in average prices of gasoline would lead to a 2% decrease in the sales of BEVs. This outcome is in contradiction with previous studies on HEV (Diamond, 2009; Gallagher & Muehlegger, 2011) that found a positive relationship between HEV market share and gasoline prices. More recently, Sierzchula et al. (2014) did not find a statistically significant relationship between EV market share and gasoline prices. Possible explanations for this conflicting result are discussed in more detail later.

Table 4
Main regressions

Variables	(1) Pooled OLS	(2) Random effects	(3) Fixed effects	(4) Fixed and year effects
	log_Sales	log_Sales	log_Sales	log_Sales
Incentives	0.287***	0.376***	0.443***	0.484***
	(0.066)	(0.076)	(0.124)	(0.125)
log_ChgInf	0.443***	0.407***	0.390***	0.213**
	(0.062)	(0.078)	(0.083)	(0.097)
log_EPI	1.765**	1.629	1.051	0.473
	(0.840)	(1.366)	(1.808)	(1.239)
log_Pelec	2.801	2.568	-0.678	-6.491
	(2.734)	(4.042)	(8.320)	(7.596)
log_Pgas	-1.897***	-2.006**	-2.339	-7.943**
	(0.650)	(0.930)	(1.896)	(3.165)
log_GDP	2.055***	2.162***	3.825	-1.458
	(0.339)	(0.425)	(2.252)	(1.771)
log_pop	0.619***	0.637***	-7.956	-8.699
	(0.089)	(0.132)	(7.183)	(5.771)
log_emp	0.535	0.831	-1.882	-0.126
	(0.804)	(1.185)	(5.665)	(3.719)
(Constant)	-25.64***	-26.76*	109.0	212.7*
	(8.894)	(14.14)	(131.1)	(110.3)
N	187	187	187	187
R^2 (overall)	0.88	0.88	0.13	0.25
Year FE	No	No	No	Yes
Country FE	No	Yes	Yes	Yes

Robust standard errors in parentheses. * *$p < 0.1$*, ** *$p < 0.05$*, *** *$p < 0.01$*

The second regression (2) estimates the equation with the random effects model, which controls for country heterogeneity. The most notable difference concerns the Environmental Performance Index. The coefficient is still positive but no longer statistically significant. A possible explanation is the fact that the index does not evolve much across years and the random effect captures this. With regard to the other variables, only minor changes in magnitude occur. The conclusions are thus quite similar to the pooled OLS (1).

The third regression (3) uses the fixed effects model instead of the random effects. The coefficients for the two main explanatory variables are still positive and significant at the one per cent level. However, one can notice that the effect of the monetary incentives is now stronger. Holding all factors constant, the adoption of an additional monetary incentive would, on average, result in a 42% increase of the sales. In contrast, the effect of an improvement of the charging infrastructure on the sales of vehicles is now less important. The other variables are all statistically insignificant.

The final model (4) adds period dummies[6] in order to capture the influence of aggregate trends. Except for 2016, each coefficient for year dummies is positive and statistically significant. The strongest effect occurred for the year 2014. The coefficients for monetary incentives and charging infrastructure are, here again, positive and significant. Nevertheless, the significativity switches to the five per cent level for the charging infrastructure variable. Compared to the other models, the economic impact of the monetary incentives is even greater, whereas the charging infrastructure plays a minor role. It is worth pointing out that this is the general conclusion of the final model. However, it is likely that this result does not hold for each country in the sample, as shown in Figure 3 and 4. For instance, the case of Estonia and Romania has already been discussed. The next section helps go deeper into this remark.

The prices of electricity appear to have an insignificant effect on the number of BEVs sold. There are, at least, three plausible reasons to explain this result. First, the prices of electricity per kWh are rather low and, therefore, constitutes only a small part of the total cost of ownership (TCO). Second, in the recent years, cars could be charged for free quite easily on charging points. Finally, the current electricity markets are liberalised and in constant evolution with the development of the renewable energies. The prices of electricity in Europe are thus very volatile (Perez-Linkenheil & Göss, 2017). This volatility is shown graphically in Appendix 4.3 using the spot prices of Belpex exchange. For these reasons, it is quite unlikely that consumers react to changes in electricity prices.

Just as in the first two models, the coefficient for prices of gasoline is negative and statistically significant. We found similar results when using the lag of the prices of gasoline. As stated above, this result is in contradiction with earlier studies. It is nevertheless important to mention that those studies are quite different from the present one. For instance, they focus on a single country over several years or on several countries for a single year. The dependent variable examined in those papers also differs from ours[7]. Be that as it may, the negative relationship between gasoline prices and BEVs' sales is surprising if we refer to common sense. Indeed, from an economic perspective, combustion engine vehicles and electric vehicles can be seen as substitute. Thus, one would think that an increase in the prices of gasoline would lead to an increase in the sales of BEVs. To clarify the result, let us talk first about possible endogeneity problems. If we focus on the oil consumption in EU-28, the road transport represented less than 50% of the total consumption in 2015 (Eurostat,

[6]The year dummies are not shown in Table 4 for the sake of clarity but all results can be found in Appendix 3 (Table A.34).

[7]Diamond (2009) uses the HEV market share; Gallagher and Muehlegger (2011) use the sales per capita of HEV and Sierzchula et al. (2014) use the EV market share.

2017). Moreover, as mentioned in the introduction, only six countries in the world had an electric vehicle market share higher than 1% in 2016 (IEA, 2017). Therefore, it is reasonable to assume that the demand for electric vehicles does not impact the demand for gasoline. In other words, endogeneity does not seem to occur in the model and is thus not a consistent reason to explain the surprising result obtained from the regression. Two plausible explanations are put forward. First, it is worth reminding that the data has been collected yearly. The prices of gasoline included in the final model are averages of all the weekly prices in a year. Any variation within a year has thus been partly lost. It would have been interesting to look on a monthly basis at the correlation between BEVs' sales and the prices of gasoline[8]. Another explanation is given when the estimates are computed on two subsamples of countries, as shown in Table 5 in the next section. The coefficient for prices of gasoline in eastern countries is significant and largely negative, whereas the coefficient is positive and insignificant when the sample is reduced to western countries. Important lessons can be learned from this result. Indeed, it seems that the negative and significant relationship between BEVs' sales and gasoline prices is mainly attributable to the eastern countries of the sample. Additional research is necessary in order to identify the reasons of such a relationship in the eastern countries. This could help throw light on this result.

5.2 Sample adjustment

Table 5 shows five regression results when the initial sample is modified. Each regression is estimated with the year and fixed effects. Since the initial sample is unbalanced due to a lack of data regarding the charging infrastructure, the first column (5) shows the estimates when Croatia and Cyprus are removed from the sample. Compared to the final model in Table 4, the results are qualitatively similar.

The second regression (6) replicates the main analysis for the first four years of the sample (2011-2014). Again, the results do not differ so much. It may be noted, however, that the effect of the monetary incentives has almost doubled.

When only the last four years of the sample are considered (2014-2017), the coefficient for monetary incentives is still positive and a little bit greater to what we obtain in the final model. However, it appears that the effect is much weaker for the second period of time than the first one. In other words, the monetary incentives are all the more important when the market is at its first development phase. Regarding the charging infrastructure, the story is now different. Indeed, the coefficient is positive but no longer significant, even at the ten per cent level. From a statistical point of view, this result may be partly explained by the lower variation in the charging infrastructure dataset over the second period of time (2014-2017). As shown in Appendix 2.2, the standard deviations (overall, between and within) are indeed lower in the second period compared to the first one (2011-2014). Another explanation is to say that holding all factors constant, the development of the charging infrastructure does not affect BEV adoption when the network has reached a certain level. As shown in Figure 5, the number of charging stations has risen dramatically since 2014. According to the result, the development of the network has an insignificant impact on the sales of vehicles from this date. We also add the square of the charging infrastructure variable in the final model in order to find evidence of the existence of a turning point. Although the

[8] As Diamond (2009) did with the market share.

Table 5
Sample adjustment

Variables	(5) *CRO-CYP*	(6) 2011-2014	(7) 2014-2017	(8) Eastern area	(9) Western area
	log_Sales	log_Sales	log_Sales	log_Sales	log_Sales
Incentives	0.452***	0.975***	0.583***	0.505***	0.442**
	(0.127)	(0.264)	(0.183)	(0.171)	(0.198)
log_ChgInf	0.218**	0.303**	0.141	0.480**	0.0167
	(0.098)	(0.125)	(0.258)	(0.179)	(0.149)
log_EPI	0.449	1.743	-0.499	1.770	1.080
	(1.273)	(1.652)	(2.259)	(1.362)	(2.653)
log_Pelec	-6.979	-2.266	-4.693	-7.580	-20.96
	(7.768)	(10.45)	(11.74)	(14.09)	(15.14)
log_Pgas	-7.809**	-8.884**	-7.601*	-13.31**	5.154
	(3.210)	(3.437)	(4.193)	(2.505)	(4.432)
log_GDP	-1.365	-2.320	0.518	-3.531	-1.447
	(1.743)	(8.670)	(1.896)	(3.495)	(1.129)
log_pop	-7.894	-2.552	-19.26	-23.23**	-0.883
	(6.130)	(9.805)	(15.25)	(8.991)	(10.22)
log_emp	0.097	2.611	-3.918	1.086	4.938
	(3.684)	(8.072)	(7.583)	(5.540)	(6.966)
(Constant)	197.6*	113.0	378.6	478.5**	-24.40
	(115.4)	(199.6)	(268.9)	(146.2)	(176.9)
N	182	104	109	89	98
R^2 (overall)	0.24	0.08	0.41	0.01	0.01
Year FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

coefficient of this term is, as expected, negative, it is not significant at the ten per cent level[9].

Since the initial sample is characterised by a wide variety of countries, we compute the estimates on two subsamples of countries. Results are shown in column (8) and (9). The first group is composed of 14 eastern countries: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia. Among observations, the average number of BEVs sold is only 60 and the average number of charging stations is 109. The second is composed of 14 western countries: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. The average number of BEVs sold is much higher than the other group: 3,840. The average number of charging stations is 3,612. In both subsamples, the coefficient for monetary incentives is positive and significant (at the five per cent level for the western countries and one per cent level for the eastern countries). We can thus say that this variable seems to play a role in the development of battery electric vehicles regardless of the region. The picture is quite different for the charging infrastructure. While the coefficient is still positive and significant for the subsample of eastern countries, it is no more significant for the subsample of western countries. Since the standard deviation does not differ so much from one group of countries to the other, it does not represent a consistent reason to explain the difference of significativity in the coefficients. Remembering the characteristics of the two subsamples presented above, an important conclusion can be drawn. Sales of battery electric cars in countries that are in a more advanced stage of

[9]Results are available upon request.

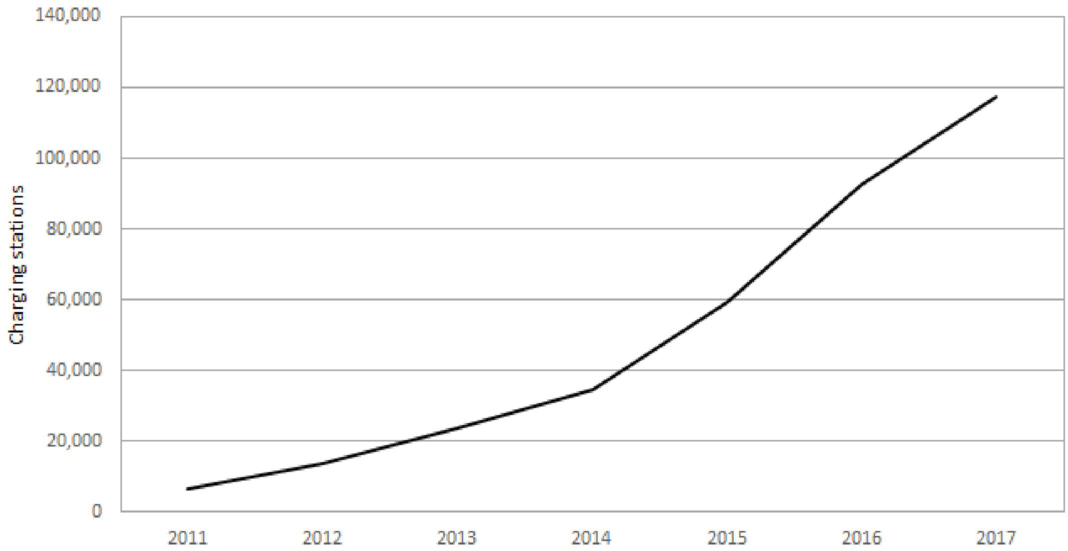

Figure 5: Evolution of the number of publicly power charging stations in Europe – data from EAFO

development regarding their charging infrastructure and BEV adoption do not seem to be impacted by an improvement of the network. Nevertheless, it is worth noting that an increase in the number of charging stations is a necessity as the number of electric cars' users increases.

5.3 Alternative specifications

Table 6 shows three regression results using alternative specifications. In this way, it is possible to examine whether previous results are robust or not.

The first specification of the table (10) uses the lag of incentives instead of incentives. The idea is to check if there is a delay between the implementation of an incentive and the purchasing decision. It appears that the coefficient is positive and insignificant, even at the ten per cent level. There is no evidence that BEV purchasers react to the incentives with a certain time lag. We can thus come up to the conclusion that there is no delay effect with regard to the monetary incentives. Since the data has been collected yearly, the result is not surprising. Again, further studies with quarterly observations could help draw more accurate conclusions. Two changes among the control variables worth being noted. The coefficient for GDP per capita is positive and significant at the ten per cent level. Holding all factors constant, a 1% increase of the GDP would result in a 2% increase in the sales of BEVs. If we refer to common sense, this conclusion makes sense. The wealthier a country is, the more BEVs it sells. As regards the population variable, its coefficient is negative and significant. At first sight, this result is surprising. However, when this variable is replaced by the density[10], all the results are qualitatively similar. This may represent a more complete picture of what happens. An increase in the population leads to an increase in the country density, which would affect negatively the sales of vehicles.

The second specification (11) uses another dependent variable, namely the new registrations of battery electric vehicles. Most often, there is a period of time between the purchase of a new car and its registration. This explains the difference between the two dependent variables. The

[10]Defined as the population of a country divided by the area (in m^2) of this country.

Table 6
Alternative specifications

Variables	(10) Fixed and year effects	(11) Fixed and year effects	(12) Tobit model
	log_Sales	log_NewReg	log_Sales
Incentives		0.582***	0.400***
		(0.193)	(0.092)
lag_Incentives	0.222		
	(0.206)		
log_ChgInf	0.175*	0.0645	0.312***
	(0.094)	(0.0585)	(0.055)
log_EPI	-0.365	-1.572	1.218
	(1.111)	(1.059)	(1.113)
log_Pelec	-6.485	-4.264	3.863
	(7.406)	(5.362)	(3.308)
log_Pgas	-9.423***	-1.617	-3.212**
	(3.098)	(1.926)	(1.330)
log_GDP	2.308*	2.029	2.345***
	(1.181)	(1.441)	(0.455)
log_pop	-22.21***	-6.432	0.746***
	(7.001)	(5.558)	(0.105)
log_emp	-6.104	-2.844	1.467
	(4.806)	(4.535)	(1.308)
(Constant)	428.10***	114.70	-22.76*
	(119.50)	(89.69)	(11.83)
N	161	187	187
R^2 (overall)	0.30	0.21	
Log likelihood			-236.44
Year FE	Yes	Yes	Yes
Country FE	Yes	Yes	No

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

mean of the new registrations variable (2,061) is slightly greater than those of the sales (2,014). The coefficient for monetary incentives is positive and significant. Holding all factors constant, the implementation of an additional monetary incentives would lead to a 58% increase in the sales of BEVs. Surprisingly, the coefficient for the charging infrastructure variable is no more significant, even at the ten per cent level. Moreover, the effect is almost indistinguishable from zero (0.06). As shown in Appendix 2.2, new registrations data demonstrates less variation compared to the sales data. This could be a possible explanation to clarify this result.

The last specification (12) estimates the final regression using the Tobit method. When the dependent variable is censored, regression model could result in econometric problems (Humphreys, 2013). Since around 12% of the observations that compose the dependent variable take the value zero, it is worth running a Tobit regression. The basic insight behind this regression is to model explicitly the presence of corner solutions, namely the several zeros. It appears that the coefficients for the two main explanatory variables are both positive and significant. The effects do not differ so much compared to the main results shown in Table 4. The most noticeable changes appear for the GDP per capita and the population data. Their coefficients are positive and statistically significant.

While previous regressions use the sum of the four categories of monetary incentives[11] as the main explanatory variable, Table 7 presents regressions results using the categories separately. As a reminder, each category is represented by a dummy variable that takes the value one when the specific policy is implemented; otherwise, it is set to 0.

In the first specification of the table (13), it appears that the coefficient for purchase premium is statistically significant at the one per cent level. Moreover, the effect on the dependent variable is very strong. Indeed, the model estimates that the adoption of such a policy is associated with a 110% increase in BEVs' sales. Inversely, the other specifications (14), (15) and (16) reveal that the coefficients for acquisition tax exemption, ownership tax exemption and company benefits are not statistically different from zero. In other words, when each monetary incentive is taken separately, the purchase premium is the unique effective tool to foster the development of battery electric vehicles. Consumer behavior could help throw light on this result. As discussed in a previous section, one can assume that consumers are not fully rational in their purchase decision

Table 7
Alternative specification: disaggregation of the monetary incentives

Variables	(13) FE and YE	(14) FE and YE	(15) FE and YE	(16) FE and YE
	log_Sales	log_Sales	log_Sales	log_Sales
Premium	1.105***			
	(0.224)			
Acqu_exemp		-0.095		
		(0.170)		
Own_exemp			0.208	
			(0.277)	
Comp_benefits				0.479
				(0.411)
log_ChgInf	0.233**	0.241**	0.227**	0.253**
	(0.086)	(0.104)	(0.110)	(0.107)
log_EPI	0.472	0.326	0.315	0.401
	(1.335)	(1.489)	(1.392)	(1.496)
log_Pelec	-8.051	-8.375	-8.601	-6.713
	(6.758)	(6.870)	(7.229)	(7.613)
log_Pgas	-8.382***	-8.277**	-7.978**	-8.594***
	(2.649)	(3.031)	(3.214)	(3.077)
log_GDP	-3.171*	0.283	0.179	0.394
	(1.578)	(1.666)	(1.703)	(1.694)
log_pop	-10.47**	-13.55**	-12.23**	-13.19**
	(4.381)	(6.171)	(6.726)	(6.104)
log_emp	1.329	-1.265	-1.181	-1.151
	(3.375)	(3.863)	(3.862)	(3.814)
(Constant)	256.50***	280.30**	257.90**	274.70**
	(82.33)	(107.40)	(119.40)	(108)
N	187	187	187	187
R^2 (overall)	0.27	0.26	0.26	0.25
Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

[11] Purchase premium, acquisition tax exemption, ownership tax exemption and company benefits.

when making the cost-benefit analysis. Even if the final amount is exactly the same, it is unlikely that consumers react to a premium and a tax exemption in the same way. They will be more sensitive to an upfront premium[12] in comparison with a tax exemption. In contrast to loss aversion principle, one can say that receiving a premium seems to have a higher impact on the utility (in absolute value) than paying the whole tax. Another potential explanation could be the additional administrative paperwork required to be exempted from the taxation.

With regard to the charging infrastructure, the results are similar to what we obtain in the main regression in Table 4. Development of the network has indeed a positive impact on BEV adoption, whatever the category of monetary incentives. All the specifications reveal a negative and significant relationship between gasoline prices and BEVs' sales, as found and discussed in the first subsection. Similarly, all the specifications highlight a negative and significant relationship between population and BEVs' sales. However, as shown in Appendix 3 (Table A.35), the results are similar – except for the constant – when the density of population is used in place of the population variable. As discussed above, this alternative specification could help us get a clearer picture of this surprising result.

5.4 Complementarity between monetary incentives and charging stations

In this final subsection, interaction terms are added to five models in order to examine a possible complementarity between monetary policies and charging infrastructures. The five models are similar to the final model presented in subsection 5.1. Only the definition of the explanatory variable "monetary incentives" – and thus the interaction term – differs from one model to the other. The table below offers an overall picture of each specification.

Table 8
Interaction terms depending on the specification

Specification	Monetary incentives	Interaction term	Interpretation of the coefficient (β_2) if it is positive and significant
(1)	Incentives (aggregated)	Incentives*ChgInf	Complementarity between the two policies
(2)	Premium	Premium*ChgInf	Complementarity between the two policies
(3)	Acquisition tax exemption	Acqu_ex*ChgInf	Complementarity between the two policies
(4)	Ownership tax exemption	Own_ex*ChgInf	Complementarity between the two policies
(5)	Company benefits	Comp_ben*ChgInf	Complementarity between the two policies

Table 9 presents the regression results using interaction terms. For all the specifications, most of the results are qualitatively similar to the ones of their pair without the interaction term. The sign of the coefficient for the interaction term is negative in each specification. With regard to the significativity, the coefficient is statistically significant at the five per cent level in the first (incentives), second (premium) and fifth (company benefits) model. For instance, one can thus say that the impact of the aggregated monetary incentives on the sales of BEVs is expected to be weaker the more the charging network is developed. Similarly, the impact of the charging infrastructure on the sales of BEVs is expected to be weaker when monetary incentives are implemented by governments. However, the effect is, for each regression, indistinguishable from zero. For instance, the coefficient is equal to -0.0000135 in the first specification. Therefore, whatever the definition

[12]Here, we assume that the premium is upfront but it is worth pointing out that it is not always the case.

of monetary incentives used, results suggest that the two policies do not reinforce each other. In other words, it is not necessarily better for policy makers to put their eggs in different baskets.

Table 9
Complementarity between policies

Variables	(17) FE & YE	(18) FE & YE	(19) FE & YE	(20) FE & YE	(21) FE & YE
	log_Sales	log_Sales	log_Sales	log_Sales	log_Sales
Incentives	0.559***				
	(0.121)				
Incentives*ChgInf	-0.000**				
	(0.000)				
Premium		1.194***			
		(0.227)			
Premium*ChgInf		-0.000**			
		(0.000)			
Acqu_exemp			-0.019		
			(0.176)		
Acqu_ex*ChgInf			-0.000		
			(0.000)		
Own_exemp				0.200	
				(0.279)	
Own_ex*ChgInf				-0.000	
				(0.000)	
Comp_benefits					0.734**
					(0.302)
Comp_ben*ChgInf					-0.000**
					(0.000)
log_ChgInf	0.195*	0.231**	0.231**	0.224*	0.250**
	(0.100)	(0.085)	(0.108)	(0.112)	(0.108)
log_EPI	0.117	0.353	0.227	0.205	0.117
	(1.268)	(1.322)	(1.498)	(1.437)	(1.549)
log_Pelec	-7.299	-6.242	-9.900	-8.845	-7.049
	(7.898)	(6.816)	(7.499)	(7.438)	(7.707)
log_Pgas	-7.309**	-8.371***	-7.977**	-7.840**	-8.214**
	(3.248)	(2.589)	(3.145)	(3.277)	(3.063)
log_GDP	-2.056	-3.634**	0.104	0.096	0.255
	(1.939)	(1.654)	(1.783)	(1.767)	(1.763)
log_pop	-7.691	-6.246*	-13.83**	-12.20*	-13.02*
	(6.320)	(4.547)	(6.267)	(6.867)	(6.416)
log_emp	-0.711	1.639	-2.053	-1.294	-1.802
	(3.735)	(3.466)	(3.784)	(3.864)	(3.772)
(Constant)	202.10	240.70***	288.30**	258.20**	274.30**
	(119.40)	(84.33)	(109.40)	(121.60)	(113.30)
N	187	187	187	187	187
R^2 (overall)	0.26	0.28	0.27	0.26	0.25
Year FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses. * *p* < 0.1, ** *p* < 0.05, *** *p* < 0.01

6 Conclusion and policy implications

The main objective of this research was to examine the impact of monetary incentives and other factors on the development of battery electric vehicles in Europe. In order to do so, we have constructed a panel dataset composed of European countries over seven years. We have then analysed the database with panel data techniques. The empirical results lead to several important conclusions that may inspire current or future policy makers. However, it is important to bear in mind that specific recommendations to policy makers are beyond the scope of this final thesis.

First, we find evidence that monetary incentives implemented by national governments have a positive impact on the development of electromobility. When each monetary incentive is taken separately, the results suggest the purchase premium as the most powerful tool to promote battery electric cars. The effects of the other monetary policies are insignificant.

With regard to the charging infrastructure, which is an important factor in BEV adoption, the results need to be qualified. The analysis on the whole sample suggests a positive and statistically significant relationship between charging infrastructure and BEVs' sales. However, when the sample is reduced to the last four years, we find inconsistent evidence that consumers react to an increase in the number of charging stations. Similarly, we do not find evidence that the charging infrastructure has an impact on the sales when the sample is reduced to western countries. According to the data, those countries are in a more advanced stage regarding the charging network and BEV adoption. In other words, the analysis suggests the existence of a stage of development from which an improvement of the charging network does not impact the purchasing decision. It is clear, however, that the number of charging stations has to increase as the number of electric cars on the road becomes higher. It is also worth noting that the two main policies in the hands of policy makers – the monetary incentives and the charging infrastructure – do not seem to reinforce each other.

Surprisingly, we find a negative and statistically significant relationship between gasoline prices and the sales of BEVs. This is in contradiction with previous studies on HEV (Diamond, 2009; Gallagher & Muehlegger, 2011) that found a positive relationship between HEV market share and gasoline prices. The positive relationship can be partly attributable to the eastern countries composing the sample.

Finally, this analysis represents one of the first empirical study that examines the impact of monetary incentives and other factors on BEVs' sales across so many countries and over such a long period. While several insights have emerged from this work, it also reveals the importance of further research on the subject. For instance, additional research need to examine in depth the relationship between gasoline prices and BEVs' sales in eastern Europe. It would also be nice to have access to data at the municipality level in order to reach more robust results.

Although it was not the central focus of this paper, we would like to conclude by taking up the point that producing low-carbon electricity is crucial. Electric vehicles can only become a consistent alternative if we have a cleaner European energy mix in the long-run.

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A Appendices

A.1 Monetary incentives per country

Table A.1
Austria

Year	Monetary incentives
2011	- EV are exempt from the fuel consumption tax (Nova) and from the monthly vehicle tax. - HEV and other alternative fuel vehicles benefit from an additional bonus under the fuel consumption tax: bonus-malus system, cars emitting < 120g/km: maximum bonus of €300. Alternative fuel vehicles including hybrid vehicles attract an additional bonus of maximum € 500.
2012	- EV are exempt from the fuel consumption tax (Nova) and from the monthly vehicle tax. - HEV and other alternative fuel vehicles benefit from an additional bonus under the fuel consumption tax: bonus-malus system, cars emitting < 120g/km: maximum bonus of €300. Alternative fuel vehicles including hybrid vehicles attract an additional bonus of maximum € 500.
2013	- EV are exempt from the fuel consumption tax (Nova) and from the monthly vehicle tax. - HEV and other alternative fuel vehicles benefit from an additional bonus under the fuel consumption tax: bonus-malus system, cars emitting < 120g/km: maximum bonus of €300. Alternative fuel vehicles including hybrid vehicles attract an additional bonus of maximum € 500.
2014	- EV are exempt from the fuel consumption tax (Nova) and from the monthly vehicle tax.
2016	- EV are exempt from the fuel consumption tax (Nova) and from the monthly vehicle tax. - deduction of VAT for zero CO2-emissions vehicles
2017	- EV are exempt from the fuel consumption tax (Nova) and from the monthly vehicle tax. **Private customers** - 4.000 Euro per BEV (2.500 from the federal government; 1.500 additional rebate by the industry) - 1.500 Euro per PHEV (750 by the federal government; 750 additional rebate by industry) - 2 additional conditions: purchase price not over 50.000 Euro incl. VAT & minimum electrical range of 40 kilometers (for PHEVs) **Businesses, municipalities** - 3.000 Euro per BEV (1.500 from the federal government; 1.500 additional rebate by the industry) - 1.500 Euro per PHEV (750 by the federal government; 750 additional rebate by industry) **Company Tax benefits** - The in-kind benefits for the private usage of company cars is taxed with 0% (formerly 18%). PHEV's remain at 18%. Company are exempt from VAT (eligible for pre-tax deduction).

Table A.2
Belgium

Year	Monetary incentives
2011	- federal fiscal rebate of 30% of the purchase price (limited to 9,000 €) – vehicles exclusively powered by an electric motor - purchase incentives (15%/-3% for cars emitting a little CO2 emissions) - eco-bonus in Wallonia - EV : lowest rate of tax under the registration tax and the annual circulation tax - deductibility from corporate income expenses for company cars (120% for zero-emissions vehicles, 100% if 1-60 g/km and the rate decrease gradually from 90% to 50% after 60 g/km)
2012	- federal fiscal rebate of 30% of the purchase price (limited to 9,000 €) - eco-bonus in Wallonia - EV : lowest rate of tax under the registration tax and the annual circulation tax - deductibility from corporate income expenses for company cars (120% for zero-emissions vehicles, 100% if 1-60 g/km and the rate decrease gradually from 90% to 50% after 60 g/km
2013	- no more federal fiscal rebate - eco-bonus (up to 2,500 €) in Wallonia - EV are exempt from registration tax in Flanders - EV : lowest rate of tax under the annual circulation tax - deductibility from corporate income expenses for company cars (120% for zero-emissions vehicles, 100% if 1-60 g/km and the rate decrease gradually from 90% to 50% after 60 g/km.
2014	- no more eco-bonus in Wallonia - EV are exempt from registration tax in Flanders - EV : lowest rate of tax under the annual circulation tax - deductibility from corporate income expenses for company cars (120% for zero-emissions vehicles, 100% if 1-60 g/km and the rate decrease gradually from 90% to 50% after 60 g/km
2015	- EV & PHEV (50 g/km) are exempt from registration tax in Flanders - EV : lowest rate of tax under the annual circulation tax - deductibility from corporate income expenses for company cars (120% for zero-emissions vehicles, 100% if 1-60 g/km and the rate decrease gradually from 90% to 50% after 60 g/km.
2016	- EV and PHEV (< 50 g/km) are exempt from registration tax in Flanders - incentives for electric and hydrogen-powered cars (Zero Emission Bonus) in Flanders (= purchase subsidies) - EV : lowest rate of tax under the annual circulation tax - deductibility from corporate income expenses for company cars (120% for zero-emissions vehicles, 100% if 1-60 g/km and the rate decrease gradually from 90% to 50% after 60 g/km.
2017	- incentives for electric and hydrogen-powered cars (Zero Emission Bonus) in Flanders (= purchase subsidies) - EV : lowest rate of tax under the annual circulation tax - EV and PHEV (< 50 g/km) are exempt from registration tax in Flanders - Ecology-premium for companies that invest in environmentally friendly or energy-efficient technologies (in Flanders). - deductibility from corporate income expenses for company cars (120% for zero-emissions vehicles, 100% if 1-60 g/km and the rate decrease gradually from 90% to 50% after 60 g/km.

Table A.3
Bulgaria

Year	Monetary incentives
2011	- none
2012	- none
2013	- none
2014	- none
2015	- EV are exempt from the annual circulation tax.
2016	- EV are exempt from the annual circulation tax.
2017	- EV are exempt from the annual circulation tax.

Table A.4
Croatia

Year	Monetary incentives
2011	- none
2012	- none
2013	- none
2014	- big subsidies (purchase premium) for EV & HEV
2015	- big subsidies (purchase premium) for EV & HEV
2016	- none (ineffectiveness)
2017	- none

Table A.5
Cyprus

Year	Monetary incentives
2011	- none
2012	- none
2013	- none
2014	- none
2015	- none
2016	- none (think to offer incentives in the following years)
2017	- Vehicles emitting less than 120g/km are exempt from the registration tax

Table A.6
Czech Republic

Year	Monetary incentives
2011	- EV, HEV and other alternative fuel are exempt from the road tax (only for business cars).
2012	- EV, HEV and other alternative fuel are exempt from the road tax (only for business cars).
2013	- EV, HEV and other alternative fuel are exempt from the road tax (only for business cars).
2014	- EV, HEV and other alternative fuel are exempt from the road tax (only for business cars).
2015	- EV, HEV and other alternative fuel are exempt from the road tax (only for business cars).
2016	- EV, HEV and other alternative fuel are exempt from the road tax (only for business cars).
2017	- EV, HEV and other alternative fuel are exempt from the road tax (only for business cars). - no purchase tax

Table A.7
Denmark

Year	Monetary incentives
2011	- EV lower than 2,000 kg are exempt from the registration tax.
2012	- EV lower than 2,000 kg are exempt from the registration tax.
2013	- EV lower than 2,000 kg are exempt from the registration tax.
2014	- EV lower than 2,000 kg are exempt from the registration tax.
2015	- EV lower than 2,000 kg are exempt from the registration tax. Announcement that tax break will be deleted in the future.
2016	- From 2016, BEV are included in the same tax scheme of petrol and diesel cars. The resulting increase in the registration tax will be gradually phased in, at 20% of the full tax in 2016, 40% in 2017, 65% in 2018, 90% in 2019 and 100% in 2020.
2017	- Government keeps the rate of 2016 (20%).

Table A.8

Estonia

Year	Monetary incentives
2011	- financial aid program (purchase grant)
2012	- financial aid program (purchase grant)
2013	- financial aid program (purchase grant)
2014	- The government abolishes the purchase grant in August.
2015	- none
2016	- none
2017	- none

Table A.9

Finland

Year	Monetary incentives
2011	- none
2012	- EV pay the minimum rate (5%) of the CO2 based registration tax. - Annual circulation tax is also based on CO2 emissions.
2013	- EV pay the minimum rate (5%) of the CO2 based registration tax. - Annual circulation tax is also based on CO2 emissions.
2014	- EV pay the minimum rate (5%) of the CO2 based registration tax. - Annual circulation tax is also based on CO2 emissions.
2015	- EV pay the minimum rate (5%) of the CO2 based registration tax. - Annual circulation tax is also based on CO2 emissions.
2016	- EV pay the minimum rate (5%) of the CO2 based registration tax. - Annual circulation tax is also based on CO2 emissions.
2017	- EV pay the minimum rate (5%) of the CO2 based registration tax. - Annual circulation tax is also based on CO2 emissions.

Table A.10
France

Year	Monetary incentives
2011	- Vehicles emitting 60 g/km or less benefit from a premium of maximum 5,000 € under a bonus-malus scheme. - HEV emitting less than 110 g/km are exempt from the company car tax.
2012	- Vehicles emitting 60 g/km or less benefit from a premium of maximum 5,000 € under a bonus-malus scheme (until July 2012). - From August, vehicles emitting less than 20g/km benefit from a premium of 7,000 € (bonus-malus scheme). For vehicles between 20 & 50 g/km, the premium is 5,000 € and between 50 & 60 g/km : 4,500 € (some restrictions exist). - HEV emitting less than 110 g/km benefit from a premium of 4,000 €. - EV are exempt from the company car tax. HEV emitting less 110 g/km are exempt during 2 years.
2013	- Vehicles emitting less than 20g/km benefit from a premium of 7,000 € (bonus-malus scheme). For vehicles between 20 & 50 g/km, the premium is 5,000 € and between 50 & 60 g/km : 4,500 € (some restrictions exist). - HEV emitting less than 110 g/km benefit from a premium of 4,000 €. - EV are exempt from the company car tax. HEV emitting less 110 g/km are exempt during 2 years.
2014	- Vehicles emitting less than 20g/km benefit from a premium of 6,300 € (bonus-malus scheme). For vehicles between 20 & 50 g/km, the premium is 4,000 € (some restrictions exist). - HEV emitting less than 110 g/km benefit from a premium of 4,000 €. - EV are exempt from the company car tax. HEV emitting less 110 g/km are exempt during 2 years.
2015	- Vehicles emitting less than 20g/km benefit from a premium of 6,300 € (bonus-malus scheme). For vehicles between 20 & 50 g/km, the premium is 4,000 € (some restrictions exist). - HEV emitting less than 110 g/km benefit from a premium of 4,000 €. - super bonus (3,700 €) for customers scrapping an old diesel-powered car - EV are exempt from the company car tax. HEV emitting less 110 g/km are exempt during 2 years.
2016	- Regions have the option to exempt from the registration tax (total or 50%) for EV, HEV, etc. - Bonus-malus system (purchase premium) : • 750,00 € for car emitting between 61 & 110 g/km • 1,000 € for car emitting between 21 & 60 g/km • 6,300 € for car emitting <= 20 g/km - super bonus (3,700 €) for customers scrapping an old diesel-powered car - EV are exempt from the company car tax. HEV emitting less 110 g/km are exempt during 2 years.
2017	- Regions have the option to exempt from the registration tax (total or 50%) for EV, HEV, etc. - Bonus-malus system (purchase premium) : • 750,00 € for car emitting between 61 & 110 g/km • 1,000 € for car emitting between 21 & 60 g/km • 6,300 € for car emitting <= 20 g/km - super bonus (3,700 €) for customers scrapping an old diesel-powered car - EV are exempt from the company car tax. HEV emitting less 110 g/km are exempt during 2 years.

Table A.11
Germany

Year	Monetary incentives
2011	- EV are exempt from the annual circulation tax (during 5 years).
2012	- EV are exempt from the annual circulation tax (during 5 years).
2013	- EV are exempt from the annual circulation tax (during 10 years). - New law that ends the tax disadvantage for corporate plug-in electric cars.
2014	- EV are exempt from the annual circulation tax (during 10 years).
2015	- EV are exempt from the annual circulation tax (during 10 years).
2016	- EV are exempt from the annual circulation tax (during 10 years). - from july : environmental bonus of 4,000 € for EV and fuel-cell vehicles and environmental bonus of 3,000 € for PHEV
2017	- EV are exempt from the annual circulation tax (during 10 years) - Environmental bonus of 4,000 € for EV and fuel-cell vehicles and environmental bonus of 3,000 € for PHEV - new perks for private usage of company cars

Table A.12
Greece

Year	Monetary incentives
2011	- EV and HEV are exempt from the registration tax.
2012	- EV and HEV are exempt from the registration tax.
2013	- EV and HEV are exempt from the registration tax.
2014	- EV and HEV are exempt from the registration tax, the luxury tax and the luxury living tax. - EV & HEV with an engine lower than 1,929 cc are exempt from the circulation tax. 50% of the tax for engine higher than 1,929 cc.
2015	- EV and HEV are exempt from the registration tax, the luxury tax and the luxury living tax. - EV & HEV with an engine lower than 1,929 cc are exempt from the circulation tax. 50% of the tax for engine higher than 1,929 cc.
2016	- EV & HEV are exempt from the registration tax, the luxury tax and the luxury living tax. - EV & HEV with an engine < 1,549 cc are exempt from the circulation tax.
2017	- EV & HEV are exempt from the registration tax, the luxury tax and the luxury living tax. - EV & HEV with an engine < 1,549 cc are exempt from the circulation tax.

Table A.13
Hungary

Year	Monetary incentives
2011	- EV are exempt from the annual circulation tax.
2012	- EV are exempt from the registration tax and the annual circulation tax.
2013	- EV are exempt from the registration tax and the annual circulation tax.
2014	- EV are exempt from the registration tax and the annual circulation tax.
2015	- EV are exempt from the registration tax and the annual circulation tax.
2016	- EV are exempt from the registration tax and the annual circulation tax.
2017	- EV are exempt from the registration tax, the annual circulation tax and company car tax. - national subsidy : 21% of the purchase price of the vehicle

Table A.14
Ireland

Year	Monetary incentives
2011	- From May, EV are exempt from registration tax VRT (max 5,000 € for EV and 2,500 € for PHEV and 1,500 € for BEV or other flexible fuel).
2012	- EV are exempt from registration tax VRT (max 5,000 € for EV and 2,500 € for PHEV and 1,500 € for BEV or other flexible fuel).
2013	- EV are exempt from registration tax VRT (max 5,000 € for EV and 2,500 € for PHEV and 1,500 € for BEV or other flexible fuel).
2014	- EV are exempt from registration tax VRT (max 5,000 € for EV and 2,500 € for PHEV and 1,500 € for BEV or other flexible fuel).
2015	- EV are exempt from registration tax VRT (max 5,000 € for EV and 2,500 € for PHEV and 1,500 € for HEV or other flexible fuel). - EV & PHEV benefit from a grant of up to 5,000 €.
2016	- EV are exempt from registration tax VRT (max 5,000 € for EV and 2,500 € for PHEV and 1,500 € for HEV or other flexible fuel). - EV & PHEV benefit from a grant of up to 5,000 €. - EV pay the minimum rate (120,00 €) of the road tax.
2017	- EV are exempt from registration tax VRT (max 5,000 € for EV and 2,500 € for PHEV and 1,500 € for HEV or other flexible fuel). - EV & PHEV benefit from a grant of up to 5,000 € - EV pay the minimum rate (120,00 €) of the road tax. - Company tax benefits since 2008 : this scheme has been allowing companies to write off 100% of the purchase value of qualifying energy efficient equipment against their profit in the year of purchase. The scheme supports the purchase of BEVs, PHEVs, hybrid vehicles and the associated charging equipment.

Table A.15
Italy

Year	Monetary incentives
2011	- EV are exempt from the annual circulation tax (during 5 years). After, 75% reduction of the tax rate.
2012	- EV are exempt from the annual circulation tax (during 5 years). After, 75% reduction of the tax rate.
2013	- EV are exempt from the annual circulation tax (during 5 years). After, 75% reduction of the tax rate.
2014	- EV are exempt from the annual circulation tax (during 5 years). After, 75% reduction of the tax rate.
2015	- EV are exempt from the annual circulation tax (during 5 years). After, 75% reduction of the tax rate.
2016	- EV are exempt from the annual circulation tax (during 5 years). After, 75% reduction of the tax rate.
2017	- EV are exempt from the annual circulation tax (during 5 years). After, 75% reduction of the tax rate.

Table A.16
Latvia

Year	Monetary incentives
2011	- none
2012	- none
2013	- EV are exempt from the registration tax.
2014	- EV are exempt from the registration tax. - EV are exempt from vehicle operation tax. - EV has a reduced payment for technical inspection.
2015	- EV are exempt from the registration tax. - EV are exempt from vehicle operation tax. - EV has a reduced payment for technical inspection.
2016	- EV are exempt from the registration tax. - EV are exempt from vehicle operation tax. - EV has a reduced payment for technical inspection.
2017	- EV are exempt from the registration tax. - EV are exempt from vehicle operation tax (registration tax has been included in it). - EV has a reduced payment for technical inspection. - EV pay the lowest amount (10,00 €) for the company car tax.

Table A.17
Lithuania

Year	Monetary incentives
2011	- none (registration tax based on CO_2)
2012	- none
2013	- none
2014	- none
2015	- none
2016	- none
2017	- none

Table A.18
Luxembourg

Year	Monetary incentives
2011	- Purchase premium of 3,000 € with condition of buying electricity from RE sources (PRIMe CAR-e).
2012	- Purchase premium of 3,000 € with condition of buying electricity from RE sources (PRIMe CAR-e).
2013	- Purchase premium of 5,000 € with condition of buying electricity from RE sources.
2014	- Purchase premium of 5,000 € with condition of buying electricity from RE sources.
2015	- none
2016	- EV pay the minimum rate (30,00 €) of the annual circulation tax.
2017	- EV and fuel cell vehicles benefit from a tax allowance on the registration fees of 5,000 €. - EV pay the minimum rate (30,00 €) of the annual circulation tax.

Table A.19
Malta

Year	Monetary incentives
2011	- none
2012	- none
2013	- scrapping program (buying an EV is not a condition)
2014	- scrapping program (buying an EV is not a condition)
2015	- scrapping program (buying an EV is not a condition)
2016	- scrapping program (buying an EV is not a condition)
2017	- different purchase subsidies (7,000 € – 4,000 €) for new EV and 3,000 € for HEV - EV are exempt of the registration tax. - EV pay only 10,00 € for the ownership tax benefits. - Company tax benefits : different purchase subsidies and deduction EV rules

Table A.20
Netherlands

Year	Monetary incentives
2011	- tax exemption (registration tax BPM and the annual circulation tax) for EV - tax exemption (registration tax BPM and the annual circulation tax) for other vehicles if maximum 95 g/km or 110 g/km (CO_2)
2012	- tax exemption (registration tax BPM and the annual circulation tax) for EV - tax exemption (registration tax BPM and the annual circulation tax) for other vehicles if maximum 95 g/km or 110 g/km (CO_2)
2013	- tax exemption (registration tax BPM and the annual circulation tax) for EV - registration tax exemption for other vehicles if maximum 88 g/km or 95 g/km and annual circulation tax if maximum 95 g/km or 110 g/km (CO_2)
2014	- tax exemption (registration tax BPM) for EV - registration tax exemption for other vehicles if maximum 85 g/km or 88 g/km and annual circulation tax if maximum 95 g/km or 110 g/km (CO_2) - annual circulation tax exemption for vehicles emitting less than 50 g/km (CO_2) - 4% addition to taxable income for lease-car drivers of full electric vehicles (BEVs) and 7% addition for lease-car drivers of plug-in hybrid electric vehicles (PHEVs with CO_2 emissions of 1 to 50 grams per kilometre) - subsidies in some municipalities
2015	- tax exemption (registration tax BPM) for EV - annual circulation tax exemption for vehicles emitting less than 50 g/km (CO_2) - 4% addition to taxable income for lease-car drivers of full electric vehicles (BEVs) and 7% addition for lease-car drivers of plug-in hybrid electric vehicles (PHEVs with CO_2 emissions of 1 to 50 grams per kilometre) - subsidies in some municipalities
2016	- tax exemption (registration tax BPM) for EV - annual circulation tax exemption for vehicles emitting less than 1 g/km (CO_2) and 50% for vehicles between 1 and 50 g/km - 4% addition to taxable income for lease-car drivers of full electric vehicles (BEVs) and 7% addition for lease-car drivers of plug-in hybrid electric vehicles (PHEVs with CO_2 emissions of 1 to 50 grams per kilometre) - subsidies in some municipalities
2017	- tax exemption (registration tax BPM) for EV - annual circulation tax exemption for vehicles emitting less than 1 g/km (CO_2) and 50% for vehicles between 1 and 50 g/km - special registration tax BPM for PHEV - passenger car with zero CO2 emissions are exempt from motor vehicle tax - discounted income tax (4%) is levied on fuel-efficient cars and deductible investment

Table A.21
Norway

Year	Monetary incentives
2011	- no purchase tax - no VAT on purchase - reduction of the annual road tax for both the EV & PHEV - 50% discount for both EV and PHEV (company car)
2012	- no purchase tax - no VAT on purchase - reduction of the annual road tax for both the EV & PHEV - 50% discount for both EV and PHEV (company car)
2013	- no purchase tax - no VAT on purchase - reduction of the annual road tax for both the EV & PHEV - 50% discount for both EV and PHEV (company car)
2014	- no purchase tax - no VAT on purchase - reduction of the annual road tax for both the EV & PHEV - 50% discount for both EV and PHEV (company car)
2015	- no purchase tax - no VAT on purchase - reduction of the annual road tax for both the EV & PHEV - 50% discount for both EV and PHEV (company car)
2016	- no purchase tax - no VAT on purchase - reduction of the annual road tax for both the EV & PHEV - 50% discount for both EV and PHEV (company car)
2017	- no purchase tax - no VAT on purchase - reduction of the annual road tax for both the EV & PHEV - 50% discount for both EV and PHEV (company car)

Table A.22
Poland

Year	Monetary incentives
2011	- none
2012	- none
2013	- none
2014	- none
2015	- none
2016	- none
2017	- none

Table A.23
Portugal

Year	Monetary incentives
2011	- EV benefit from a premium of 5,000 € (limited to 5,000 vehicles) and a possible additional 1,500 € (scrapping program). - EV are exempt from the registration tax ISV and from the annual circulation tax. - HEV benefit from a 50% reduction for the registration tax.
2012	- EV benefit from a premium of 5,000 € (limited to 5,000 vehicles) and a possible additional 1,500 € (scrapping program). - EV are exempt from the registration tax ISV and from the annual circulation tax. - HEV benefit from a 50% reduction for the registration tax.
2013	- EV are exempt from the registration tax ISV and from the annual circulation tax. - HEV benefit from a 50% reduction for the registration tax.
2014	- EV are exempt from the registration tax ISV and from the annual circulation tax. - HEV benefit from a 50% reduction for the registration tax.
2015	- EV are exempt from the registration tax ISV and from the annual circulation tax. - HEV benefit from a 40% reduction for the registration tax. - scrapping program (end-of life incentive) of 4,500 € or 2,250 €
2016	- EV are exempt from the registration tax ISV and from the annual circulation tax. - HEV benefit from a 75% reduction for the registration tax. - scrapping program (end-of life incentive) of 2,250 € or 1,125 €
2017	- EV are exempt from the registration tax ISV and from the annual circulation tax. - HEV benefit from a 75% reduction for the registration tax. - scrapping program (end-of life incentive) of 2,250 € or 1,125 € - VAT is deductible for company

Table A.24
Romania

Year	Monetary incentives
2011	- EV & HEV are exempt from the special pollution tax (registration tax).
2012	- EV and HEV are exempt from the registration tax.
2013	- EV and HEV are exempt from the registration tax.
2014	- EV and HEV are exempt from the registration tax.
2015	- EV and HEV are exempt from the registration tax - EV are exempt from the annual circulation tax (HEV 95% exemption).
2016	- EV and HEV are exempt from the registration tax. - EV are exempt from the annual circulation tax (HEV 95% exemption). - “ Rabla plus “ program : government grant of 5,000 €
2017	- EV and HEV are exempt from the registration tax. - EV are exempt from the annual circulation tax (HEV 95% exemption). - “ Rabla plus “ program : government grant of 10,000 €

Table A.25
Slovakia

Year	Monetary incentives
2011	- none
2012	- none
2013	- none
2014	- none
2015	- EV are exempt from the annual circulation tax. - HEV : 50% reduction of the annual circulation tax (for business cars only)
2016	- EV are exempt from the annual circulation tax. - HEV : 50% reduction of the annual circulation tax (for business cars only)
2017	- EV pay the lowest amount for the registration tax (33,00 €). - EV are exempt from the annual circulation tax - 50% reduction on the annual circulation tax for HEV, CNG, etc. - purchase subsidies (5,000 € or 3,000 €)

Table A.26
Slovenia

Year	Monetary incentives
2011	- eco grant available
2012	- eco grant available
2013	- none
2014	- none
2015	- none
2016	- none
2017	- financial incentives : from 3,000 € to 7,500 € depending on the vehicle category - EV : exemption for the annual circulation tax - EV : lowest rate of tax for registration tax

Table A.27
Spain

Year	Monetary incentives
2011	- regional governments : grant incentives from 2,000 € to 7,000 € for the purchase of EV, HEV, etc.
2012	- regional governments : grant incentives from 2,000 € to 7,000 € for the purchase of EV, HEV, etc. - Programa de Incentivos al Vehículo Eficiente (PIVE)
2013	- regional governments : grant incentives from 2,000 € to 7,000 € for the purchase of EV, HEV, etc. - Programa de Incentivos al Vehículo Eficiente (PIVE)
2014	- regional governments : grant incentives from 2,000 € to 7,000 € for the purchase of EV, HEV, etc. - Programa de Incentivos al Vehículo Eficiente (PIVE)
2015	- Programa de Incentivos al Vehículo Eficiente (PIVE)
2016	- Programa de Incentivos al Vehículo Eficiente (PIVE) - end in July - Main cities reduce the annual circulation tax for EV & fuel efficient vehicles by 75 %.
2017	- Main cities reduce the annual circulation tax for EV & fuel efficient vehicles by 75 %. - Reductions are applied on company car (30% for EV & PHEV). - luxury tax exemption - movea plan : national subsidy up to 5,000 € - no purchase tax

Table A.28
Sweden

Year	Monetary incentives
2011	- EV & HEV are exempt from the annual circulation tax (under some conditions and for 5 years). - EV & HEV : taxable value of the car for the purpose of calculating the benefit in kind of a company car under personal income tax is reduced by 40%. (max 16,000 SEK)
2012	- EV & HEV are exempt from the annual circulation tax (under some conditions and for 5 years). - EV & HEV : taxable value of the car for the purpose of calculating the benefit in kind of a company car under personal income tax is reduced by 40%. (max 16,000 SEK) - super green car premium (for EV & PHEV) : purchase premium of max 40,000 SEK
2013	- EV & HEV are exempt from the annual circulation tax (under some conditions and for 5 years). - EV & HEV : taxable value of the car for the purpose of calculating the benefit in kind of a company car under personal income tax is reduced by 40%. (max 16,000 SEK) - super green car premium (for EV & PHEV) : purchase premium of max 40,000 SEK
2014	- EV & HEV are exempt from the annual circulation tax (under some conditions and for 5 years). - EV & HEV : taxable value of the car for the purpose of calculating the benefit in kind of a company car under personal income tax is reduced by 40%. (max 16,000 SEK) - super green car premium (for EV & PHEV) : purchase premium of max 40,000 SEK
2015	- EV & HEV are exempt from the annual circulation tax (under some conditions and for 5 years). - EV & HEV : taxable value of the car for the purpose of calculating the benefit in kind of a company car under personal income tax is reduced by 40%. (max 16,000 SEK) - super green car premium (for EV & PHEV) : purchase premium of max 40,000 SEK
2016	- EV & HEV are exempt from the annual circulation tax (under some conditions and for 5 years). - EV & HEV : taxable value of the car for the purpose of calculating the benefit in kind of a company car under personal income tax is reduced by 40%. (max 16,000 SEK) - super green car premium (for EV & PHEV) : purchase premium of max 40,000 SEK
2017	- EV & HEV are exempt from the annual circulation tax (under some conditions and for 5 years). - EV & HEV : taxable value of the car for the purpose of calculating the benefit in kind of a company car under personal income tax is reduced by 40%. (max 16,000 SEK) - super green car premium (for EV & PHEV) : purchase premium of max 40,000 SEK

Table A.29
UK

Year	Monetary incentives
2011	- EV & PHEV with CO_2 emissions less than 75 g/km : premium of 5,000 £ or 25% of the value of the new car - EV and all vehicles emitting less than 100 g/km (CO_2) are exempt from the annual circulation tax. - EV are exempt from company car tax (5 years).
2012	- EV & PHEV with CO_2 emissions less than 75 g/km : premium of 5,000 £ or 25% of the value of the new car - EV and all vehicles emitting less than 100 g/km (CO_2) are exempt from the annual circulation tax. - EV are exempt from company car tax (5 years).
2013	- EV & PHEV with CO_2 emissions less than 75 g/km : premium of 5,000 £ or 25% of the value of the new car or 8,000 £ or 20% of the value of a new LCV - EV and all vehicles emitting less than 100 g/km (CO_2) are exempt from the annual circulation tax. - EV are exempt from company car tax (5 years).
2014	- EV & PHEV with CO_2 emissions less than 75 g/km : premium of 5,000 £ or 25% of the value of the new car or 8,000 £ or 20% of the value of a new LCV - EV and all vehicles emitting less than 100 g/km (CO_2) are exempt from the annual circulation tax. - EV are exempt from company car tax (5 years). - EV and others vehicles emitting less than 95 g/km (CO_2) can claim a 100% first-year allowance for depreciation.
2015	- EV & PHEV with CO_2 emissions less than 75 g/km : premium up to 5,000 £ (three categories) - EV and all vehicles emitting less than 100 g/km (CO_2) are exempt from the annual circulation tax. - EV and vehicles emitting less than 50 g/km (CO_2) are exempt from company car tax (5 years).
2016	- EV & PHEV with CO_2 emissions less than 75 g/km : premium up to 5,000 £ (three categories) - EV and all vehicles emitting less than 100 g/km (CO_2) are exempt from the annual circulation tax. - EV and vehicles emitting less than 50 g/km (CO_2) are exempt from company car tax (5 years).
2017	- EV & PHEV with CO_2 emissions less than 75 g/km : premium up to 5,000 £ (three categories) - EV and all vehicles emitting less than 100 g/km (CO_2) are exempt from the annual circulation tax. - EV and vehicles emitting less than 50 g/km (CO_2) are exempt from company car tax (5 years). - EV benefit from a registration tax exemption.

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A.2 Additional descriptive statistics

A.2.1 Correlation matrix

Table A.30
Correlation matrix

Var	Sales	*NewR.*	*Inc*	*Chg*	*RE*	*EPI*	*Elec*	*Gas*	*Die*	*GDP*	*Dens*	*Emp*	*Pop*
Sales	1.00												
NewR.	0.99	1.00											
Inc	0.43	0.44	1.00										
Chg	0.65	0.65	0.39	1.00									
RE	0.37	0.37	0.42	0.10	1.00								
EPI	0.32	0.31	0.23	0.30	0.24	1.00							
Elec	0.16	0.17	0.25	0.21	0.19	0.18	1.00						
Gas	0.07	0.08	0.22	0.13	0.06	-0.29	0.45	1.00					
Die	-0.04	-0.03	0.14	-0.04	0.04	-0.48	0.27	0.86	1.00				
GDP	0.27	0.28	0.32	0.23	0.17	0.37	0.39	0.13	-0.04	1.00			
Dens	-0.04	-0.04	0.03	0.09	-0.35	-0.06	0.03	0.12	0.05	0.07	1.00		
Emp	0.30	0.30	0.29	0.33	0.30	0.27	0.19	-0.04	-0.01	0.47	-0.05	1.00	
Pop	0.40	0.40	0.14	0.38	-0.09	0.11	0.33	0.23	0.22	-0.01	0.01	-0.09	1.00

Not surprisingly, the matrix highlights a very strong correlation between the sales and the new registrations. There is no concern for that because the new registrations variable is used in the robustness check as the dependent variable. The correlation between Gas and Die is also very strong. This is quite logical because diesel and gasoline prices fluctuate in a similar way. Only one of this variable will be used in the regression to avoid collinearity problems. Finally, one can note that the correlation between Die and EPI (-0.48) could be problematic. We should thus use Gas rather than Die, as it is better from a statistical point of view.

A.2.2 Summary statistics for additional variables

Table A.31
Summary statistics: additional variables

Variable	*N*	Mean	Std. dev.	Min	Max
$log(Sales + 1)$	203	4.78	2.91	0	10.41
NewReg	203	2,061	5,092	0	33,025
$log(NewReg + 1)$	203	5.11	2.66	0	10.41
$log(ChgInf + 1)$	194	5.20	2.92	0	10.40
$log(elec + 1)$	232	0.16	0.04	0.08	0.27
$log(epi)$	203	4.29	0.13	3.88	4.50
$log(gas)$	196	7.22	0.13	6.89	7.49
$log(die)$	196	7.15	0.13	6.83	7.47
$log(GDP)$	203	10.47	0.37	9.66	11.57
$log(emp)$	203	3.96	0.10	3.66	4.15
$log(pop)$	203	15.87	1.37	12.94	18.23
$log(density)$	203	4.61	0.96	2.73	7.23

Table A.32
Additional statistics for the charging infrastructure

Variable		Mean	Std. Dev.	Min	Max	Observations
log_ChgInf	overall	4.18	3.13	0	9.40	N = 108
(2011-2014)	between		2.82	0	8.33	
	within		1.44	-1.22	7.37	T = 4
log_ChgInf	overall	6.26	2.13	0	10.40	N = 113
(2014-2017)	between		2.07	2.66	9.95	
	within		0.64	3.60	8.16	T = 3.90

Table A.33
Additional statistics for the sales and new registrations data

Variable		Mean	Std. Dev.	Min	Max	Observations
log_Sales	overall	4.78	2.91	0	10.41	N = 203
	between		2.55	1.03	9.33	
	within		1.47	-0.63	7.98	T = 7
log_NewReg	overall	5.11	2.66	0	10.41	N = 203
	between		2.42	1.20	9.35	
	within		1.17	2.38	7.83	T = 7

A.3 Additional regressions

Table A.34

Fixed and year effects: decomposition of the main regression

Variables	(1')	(2')	(3')	(4')	(5')
	log_Sales	log_Sales	log_Sales	log_Sales	log_Sales
Incentives	0.600***	0.560***	0.559***	0.532***	0.484***
	(0.125)	(0.129)	(0.129)	(0.133)	(0.125)
log_ChgInf		0.197**	0.196**	0.211**	0.213**
		(0.092)	(0.092)	(0.101)	(0.097)
log_EPI			0.071	0.721	0.473
			(1.520)	(1.224)	(1.239)
log_elec				-4.562	-6.491
				(7.759)	(7.596)
log_gas				-8.822**	-7.943**
				(3.465)	(3.165)
log_GDP				-1.286	-1.458
				(1.583)	(1.771)
log_pop					-8.699
					(5.771)
log_emp					-0.126
					(3.719)
2012.year	0.449*	0.233	0.238	0.972**	0.919**
	(0.252)	(0.250)	(0.268)	(0.370)	(0.353)
2013.year	1.212***	0.960***	0.959***	1.490***	1.506***
	(0.268)	(0.277)	(0.275)	(0.393)	(0.386)
2014.year	2.208***	1.768***	1.762***	2.026***	2.106***
	(0.281)	(0.358)	(0.387)	(0.505)	(0.503)
2015.year	2.608***	1.953***	1.941***	1.232	1.465*
	(0.276)	(0.411)	(0.431)	(0.759)	(0.753)
2016.year	2.699***	1.946***	1.929***	0.570	0.917
	(0.280)	(0.425)	(0.495)	(0.956)	(0.940)
2017.year	3.020***	2.221***	2.209***	1.451	1.740*
	0.279	(0.445)	(0.496)	(0.852)	(0.858)
(Constant)	2.164***	1.791***	1.495	76.73**	212.72*
	(0.299)	(0.404)	(6.366)	(32.07)	(110.30)
N	203	194	194	187	187
R^2 (overall)	0.63	0.63	0.64	0.10	0.25
Year FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A.35
Disaggregation of the monetary incentive with the density

Variables	(6') FE and YE	(7') FE and YE	(8') FE and YE	(9') FE and YE
	log_Sales	log_Sales	log_Sales	log_Sales
Premium	1.105***			
	(0.224)			
Acqu_Exemp		-0.095		
		(0.170)		
Owne_Exemp			0.208	
			(0.277)	
Comp_Benefits				0.479
				(0.411)
log_ChgInf	0.233**	0.241**	0.227**	0.253**
	(0.086)	(0.104)	(0.110)	(0.107)
log_EPI	0.472	0.326	0.315	0.401
	(1.335)	(1.489)	(1.392)	(1.496)
log_elec	-8.051	-8.375	-8.601	-6.713
	(6.758)	(6.870)	(7.229)	(7.613)
log_gas	-8.382***	-8.277**	-7.978**	-8.594***
	(2.649)	(3.031)	(3.214)	(3.077)
log_GDP	-3.171*	0.283	0.179	0.394
	(1.578)	(1.666)	(1.703)	(1.694)
log_density	-10.47**	-13.55**	-12.23**	-13.19**
	(4.381)	(6.171)	(6.726)	(6.104)
log_emp	1.329	-1.265	-1.181	-1.151
	(3.375)	(3.863)	(3.862)	(3.814)
(Constant)	138.50***	127.60***	120**	125.90**
	(39.22)	(44.58)	(49.87)	(45.65)
N	187	187	187	187
R^2 (overall)	0.03	0.02	0.02	0.02
Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses. * *$p < 0.1$*, ** *$p < 0.05$*, *** *$p < 0.01$*

A.4 Additional figures

A.4.1 Scatterplot of average BEVs' sales and average charging stations

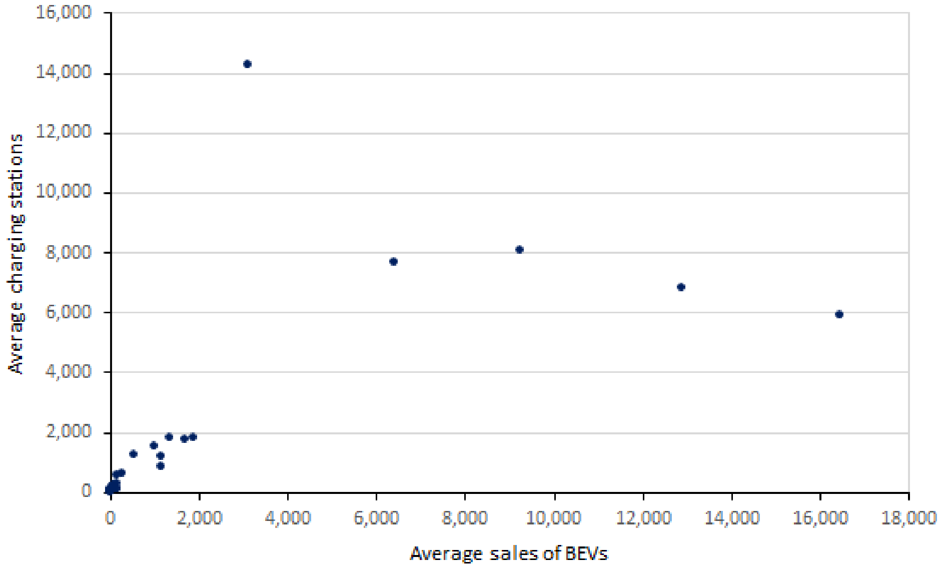

Figure A.1: Scatterplot of the average sales of BEVs and average number of charging stations from 2011 to 2017 – data from EAFO. Each data point represents a country.

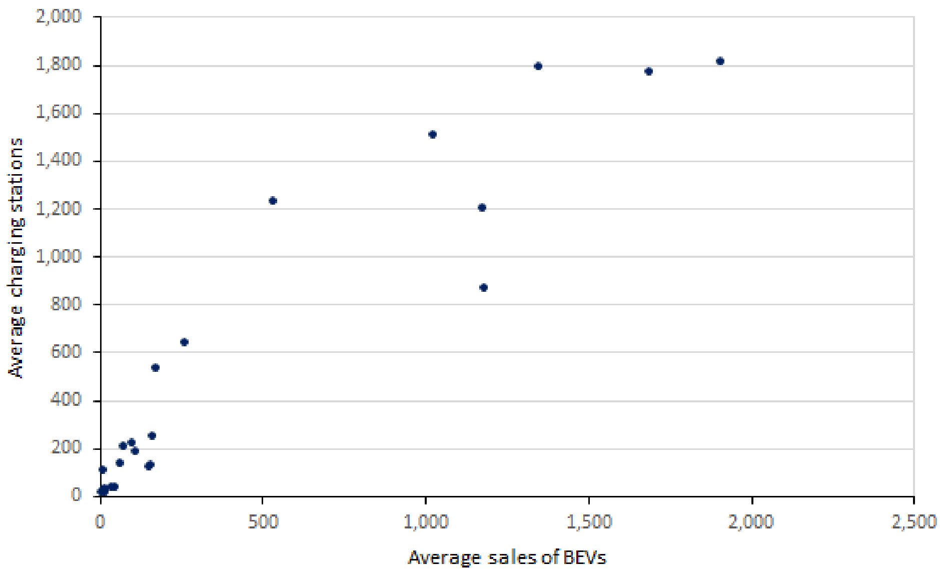

Figure A.2: Scatterplot of the average sales of BEVs and average number of charging stations from 2011 to 2017 without 5 countries – data from EAFO. The five countries that were removed are France, Germany, Norway, the Netherlands and the United Kingdom.

A.4.2 Sales in Norway and EU-28

Figure A.3 shows the evolution of the BEVs' sales for Norway and EU-28 in absolute terms. It clearly appears that Norway experiences a much higher proportion of sales regarding the battery electric cars. In other words, it seems that Norway is an outlier.

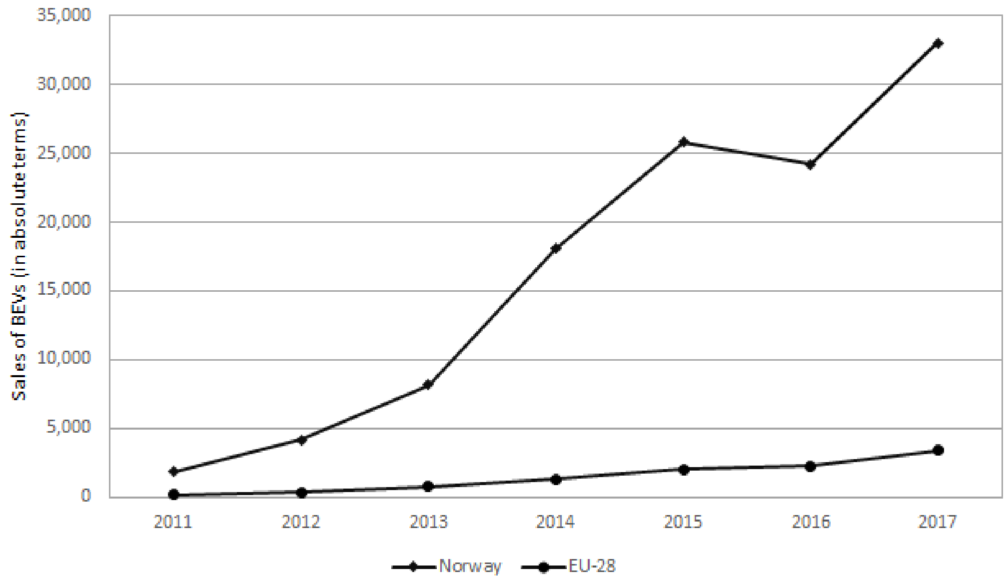

Figure A.3: Sales of BEVs from 2011 to 2017 for Norway and EU-28 (average) – data from EAFO

A.4.3 Volatility of electricity prices

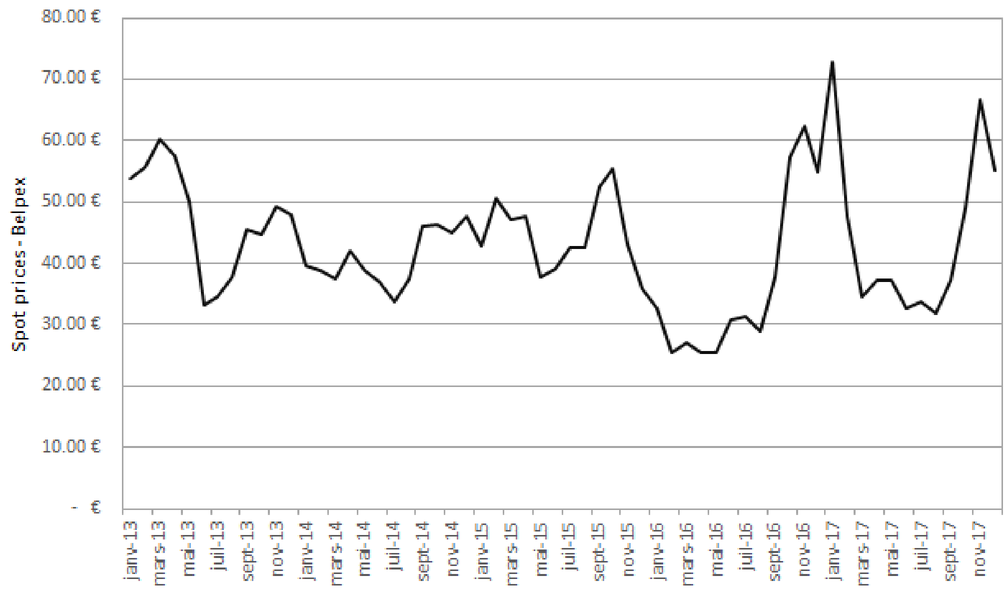

Figure A.4: Evolution of the spot prices of electricity from 2013 to 2017 – data from Belpex