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Abstract. Hybrid and battery-electric vehicles promise to reduce the use of fossil fuels in road transport, and hence carbon emissions and dependence on oil imports. The price of these vehicles may however create hurdles to their widespread adoption. Automakers claim that these technologies come with higher production costs. We ask three questions. First, do consumers value fuel economy, even among all-electric and hybrids? Second, do the prices of electric vehicles reflect "range anxiety"? Third, is there an all-electric or hybrid "premium" above and beyond the savings in fuel costs made possible by these cars over their conventional counterparts? We answer these questions using data on new cars sold in eight European Union countries from January 2011 to September 2017. Using hedonic pricing regressions and careful sample design, we find that more fuel-efficient variants of the same cars do cost more, but either the fuel economy is undercapitalized, or consumers and automakers are assuming a payback period of 2.5-4.6 years. We also find evidence of large all-electric and plug-in hybrid premiums above and beyond the savings in fuel costs, while regular hybrids cars carry a modest premium. We find no evidence that the prices of all-electric cars reflect their battery range.

Keywords: valuation of fuel economy; electric vehicles; hybrid vehicles; hedonic pricing; energy transition.

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1. Introduction

Efforts to reduce the emissions of carbon dioxide (CO_2), a major cause of climate change (IPCC, 2018[1]), have prompted the European Union to adopt emissions regulations for passenger vehicles (European Parliament, 2009) and to encourage increasingly larger shares of electric vehicles (European Commission, 2017).[2] In a conventional gasoline- or diesel-powered vehicle the CO_2 emissions rate is negatively related to the fuel economy of the engine. Hybrids and plug-in hybrids boast impressive fuel economy figures and correspondingly low CO_2 emissions rates, and battery electric vehicles (which rely on a completely differ source of power and have zero tailpipe emissions) are regarded as extremely energy efficient. In theory, this would make them appealing to persons who must drive many miles for work or personal reasons, persons who are fuel-economy conscious, and persons who wish to help meet emissions reductions targets.

The sales of these vehicles have indeed grown rapidly since the beginning of the decade (see figure 1), whether or not aided by favorable government policies. Yet, as of 2016, hybrids, plug-in hybrids and battery-electric cars accounted only for only a small share of the total sales of new passenger cars in the five largest EU markets (see table 1). Possible hurdles to faster adoption rates may lie in the comparatively high prices of these vehicles, and, for electric cars, the so-called "range anxiety," where the range is the distance that can be driven on the fully charged battery.

Economic theory suggests that consumers would buy low-emissions, fuel-efficient vehicles if the fuel costs savings were sufficient to justify the higher cost of these cars. This raises once

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[1] See https://www.ipcc.ch/site/assets/uploads/sites/2/2018/11/SR15_Chapter1_Low_Res.pdf.
[2] See https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union and https://ec.europa.eu/commission/publications/2nd-report-state-energy-union_en.

again the question whether consumers correctly perceive the benefits of fuel efficiency and are prepared to pay for additional improvements in fuel economy (Anderson et al., 2011).

Efforts to answer these questions have spanned for decades (e.g., Atkinson and Halvorsen, 1984), examined new cars and the used car market (e.g., Busse et al., 2013; Allcott and Wozny, 2014; Sallee et al., 2016), and focused on actual prices and sales as well as on intentions (Krause et al., 2013) and stated preference methods (Brownstone et al., 2000; Achtnicht and Madlener, 2014; Ščasný et al., 2018). The evidence is mixed as to whether consumer "value" the fuel economy, namely whether they are prepared to pay one more dollar today to save one dollar's worth of discounted fuel costs (Greene, 2018). This may be due to the fact the fuel economy of a car might be only a secondary attribute when consumer make their car purchase decisions (Turrentine and Kurani, 2007), failure to grasp the notion of fuel economy (Anderson et al., 2013; Alcott and Knittel, 2017), loss aversion (Helfand and Wolverton, 2011; Greene, 2018), expectations about future fuel prices (Anderson et al., 2013; Allcott and Wozny, 2014), heavy discounting of future costs (Busse et al., 2013), and/or quite simply the fact that the conventional economic model, whereby consumers look at the discounted fuel costs over the entire lifetime of a vehicle, does not reflect how consumers make decisions.[3]

Based on surveys conducted at a time when plug-in hybrids and electric cars were still new on the car market, Krause et al. (2013) find that consumers overestimate the purchase price of plug-in hybrids (PHEVs) as well as their maintenance costs, but underestimate the fuel economy of PHEVs and electric vehicles, a result also reported in Dumortier et al. (2015). It remains to be seen whether these considerations are still true, or have been corrected by the growing familiarity

[3] Recent papers about the valuation of energy costs in a completely different durable—homes—have found that the energy costs are capitalized at reasonable discount rates (8-10%) into the prices of homes (Myers, 2017; Harjunen and Lipski, 2014).

with the technologies and/or by the inducements (e.g., income tax credits, direct incentives, reduced car tax burden) offered by many countries since. In practice, however, these government policies have not been fully understood by consumers either in the US or in Europe (Gallagher and Muehlegger, 2009, Dumortier et al., 2015, and Haq and Weiss, 2016).

In this paper, we ask three research questions. First, is the fuel economy reflected in the vehicle's price, all else the same? Second, do the prices of pure-electric vehicles provide evidence of "range anxiety" on the part of the consumer? Third, information about actual prices suggests that hybrid, plug-in hybrids and battery-electric cars are more expensive than conventional fuel cars. Is the higher price solely due to the higher cost of producing them, and is that made up for by the savings in fuel costs, or are the manufacturers seeking to extract a premium from certain consumers? Earlier studies have found that producers seek to extract a premium from consumers for energy-efficient products that cannot be explained by energy cost differentials alone (Alberini et al., 2016; Houde, 2018). There is also evidence that certain consumers are prepared to pay for a public good—namely lower CO_2 emissions—in the form of higher product prices or higher energy input prices (Jacobsen et al., 2012; Kotchen et al., 2013; Alberini et al., 2018).

We answer these questions using a dataset documenting the characteristics, prices, and monthly sales of conventional diesel and gasoline, plus hybrids, plug-in hybrids and pure-electric passenger cars from January 2011 to September 2017 in eight European countries. Attention is restricted to the new car market. We merge this dataset (compiled by IHS-Markit) with monthly fuel and electricity prices during the same period, and information about vehicle taxes and government incentives (or disincentives). We express the fuel economy of the cars in cost per kilometer, which allows us to compare cars with different "fuels."

The simplest way to answer our research questions is to estimate a hedonic pricing model where the price of a car (or its log transformation) is regressed on car characteristics (Rosen, 1974), including the fuel economy and the range of the battery, if the car is electric. Appealing as this approach might be, it is complicated by three major difficulties.

The first is that market prices reflect both demand and supply: Prices therefore do not trace out perfectly the willingness to pay for improved fuel economy on the part of the consumer, holding the quantity demanded the same, because they also reflect production and marketing decisions on the part of the manufacturers. For example, manufacturers have been observed to offer cash rebates and other discounts when the price of fuel is high in an effort to make existing new cars more appealing to consumers (Langer and Miller, 2013), and Swiss auto importers have sought to extract a premium on cars that receive the "A" grade for fuel economy (Alberini et al., 2016). The premium is a 5-11% increase over the price of comparable vehicle that barely failed to qualify for the "A" grade.

The second is that, for sheer automotive engineering reasons, many car attributes are strongly correlated with one another, making regressions results unstable to even minor specification changes and difficult to interpret (Atkinson and Halvorsen, 1984; Arguea and Hsiao, 1993; Knittel, 2011). The third is that, if there are omitted vehicle attributes that are correlated with the fuel economy, the coefficient on the fuel economy is biased, in that it captures both the valuation of the fuel economy and that of the omitted attributes.

We deal squarely with the first problem in another paper (Alberini, Eguiguren and Linn, 2019). In this paper, we seek to circumvent the latter two problems through careful sample construction. We work with two alternate samples. In the first, we exploit the variation in fuel economy, and other characteristics, across trim-variants within the same make-model (e.g., Audi

Q5). These trims and variants may have different powertrains—some may run on gasoline, others on diesel, and others yet may have a hybrid or plug-in hybrid technology, or be completely electric—but generally share the looks, size, overall performance and reputation of any given make-model. Including make-model fixed effects in our regressions thus allows us to control for these unobservables. In the second, which we use primarily to perform robustness checks, we form classes of cars that are similar for size, body type, and general performance, and exploit the variation in fuel economy within such otherwise reasonably homogeneous classes.

Briefly, our data confirm that, at least on the basis of the testing system for manufacturers in force until September 2017 (the NEDC) and government calculations, hybrids and battery-electric cars do boast excellent fuel economy compared with conventional fuel vehicles. We find that, all else the same, the price of a car is indeed higher for variants with better fuel economy. But the coefficient on the fuel economy—which we measure as the cost per kilometer driven—hints at either heavy discounting of future fuel costs (with discount rates—15 to 20%--well in excess of the interest rate applied by automakers to facilitate the purchase of a new car or by banks on private car loans) or to the possibility that consumers might be referring to payback periods of 2.5 – 4.6 years. Data about the duration of ownership in the countries covered in this paper are scanty, but the most recent (ACEA, 2018[4]) would suggest that consumers generally keep their new car between 3.5 and 5.6 years, a span that is consistent with the abovementioned payback period and is certainly much shorter than the expected lifetime of a vehicle (13 years).

Our data provide no evidence that the price of all-electric cars reflect their better or worse battery range. However, we do find evidence of a "battery" premium. For regular hybrids, this premium is rather modest (some €2000 or less), comparable to that on the diesel version of any

[4] See https://www.acea.be/uploads/statistic_documents/ACEA_Report_Vehicles_in_use-Europe_2018.pdf.

given car, and less than, say, the extra that must be paid for the all-wheel drive version of any given car. The premium is large for plug-in hybrids (some €10,000) and BEVs (some €12,000), and is not explained away by the additional weight and size typical of these cars (due in part to the battery), or the fact that many plug-ins are sports utility vehicles. Incentives from the government cover in most cases only a portion of this premium, suggesting that the consumers who purchase these vehicles must be doing so for different reasons than the fuel economy.

The remainder of this paper is organized as follows. Section 2 presents background information. Section 3 describes methods and models, and Section 4 the data. Section 5 presents the results and section 6 concludes.

2. Background

2.1 Battery Vehicles

Hybrid cars were first introduced in 1997. The first specimen was the Toyota Prius, followed in 1999 by the Honda Insight. Although initially they had limited appeal because the price of motor fuels was low, towards the end of the 2000s hybrid cars became much more popular as other automakers started offering hybrid models. Briefly, hybrids have an internal combustion engine powered by gasoline or diesel, plus an electric motor and battery. Hybrids are designed to capture the energy that would otherwise be dissipated when swerving, breaking, slowing down, etc., and use it to charge the battery. The internal combustion engine and the battery alternate as the source of energy, depending on whether the car is driven at high, sustained speed or in city-driving type of conditions.

Plug-in hybrids were first introduced in 2010-11. They too have both an internal combustion engine and a battery, which is recharged using regenerative energy, much like a regular hybrid. This however accounts for only a small portion of the total battery charge, with the majority coming from actually plugging in the vehicle. Both hybrids and plug-in hybrids are regarded as more fuel-efficient and emit less than their conventional fuel counterparts (see https://www.ucsusa.org/clean-vehicles/electric-vehicles/how-do-hybrids-work#.XBGf3mhKj4c).

All-electric cars were first introduced in late 2010 in the US and in 2011 in Europe and Canada. They do not contain an internal combustion engine and their power comes solely from the battery and electric motor. Their generally regarded as efficient and inexpensive to drive, and have zero tailpipe emissions,[5] but the more or less limited range they can cover before the battery is depleted is regarded as a potential downside. Their widespread adoption is presumably influenced by the availability of a suitable charging station infrastructure.

2.2 Motor Fuel Prices and Regulations

It is often argued that motor fuel prices and regulations create pressure to improve the fuel economy of cars, and reduce emissions of conventional air pollutants or CO_2 (Anderson et al., 2011).

Gasoline and diesel prices generally follow the price of oil. In Europe, however, taxes account for much larger shares (often in excess of 50%) of the price at the pump than they do in the US.[6] Gasoline and diesel prices rose in 2012 and 2013, but have been generally declining since, as can be seen in figure 2, which displays gasoline prices at the pump, converted into harmonized 2015 euro, for three major car markets in Europe, namely France, Germany, and Italy.

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[5] Depending on the location, CO_2 and other emissions may be released when the electricity is generated. Holland et al. (2017) examine the emissions of conventional air pollutants and CO_2 associated with electric cars, showing how the "environmental footprint" of electric vehicles varies across the US. When electricity is generated in the Midwest, for example, which uses coal for baseload and gas for peak load, an electric vehicle will have a more adverse environmental impact than in an area that relies on renewables (e.g., the Pacific Northwest).

[6] See http://siteresources.worldbank.org/EXTFINANCIALSECTOR/Resources/282884-1303327122200/240Bacon-831.pdf and http://www.oecd.org/tax/tax-policy/tax-database.htm.

Regarding regulations, new cars were to abide by the Euro VI standards as of September 2014, which impose specific limits to the emissions of several pollutants (CO, NOx, HC and PM) both for diesel and gasoline cars.[7] Moreover, starting August 2012 automakers were to comply with a new regulatory program that obliges manufacturers to meet fleetwide CO_2 emissions targets (e.g., 130 g/km for 2012-2015; all cars below 95 g/km by 2021, see https://ec.europa.eu/clima/policies/transport/vehicles/cars_en). The emissions limits are set according to the weight of the vehicle using a limit value curve, requiring automakers to achieve the target for their fleet average emissions rate. The emissions rates were measured using the New European Driving Cycle (NEDC), which in September 2017 was replaced by the Worldwide Harmonised Light Vehicle Test Procedure (WLTP).

2.3 Policy Inducements

Several governments offer subsidies to help defray the cost of purchasing efficient, low-emissions cars. These include price subsidies (Lin and Wu 2018), rebates (DeShazo et al. 2017), tax credits (Gallagher and Muehlegger, 2011), sales tax exemptions (Mersky et al. 2016), subsidized financing (Beresteanu and Li, 2011; Sierzchula et al., 2014, and Langbroek et al., 2016) and sometimes in-kind benefits and rewards (free parking, preferential use of high-occupancy lanes, free or heavily discounted access to charging facilities, etc.).

Different measures were implemented in Europe during our study period, as summarized in table 2. Incentives to electric cars and plug-in hybrids were offered in the UK, Germany, Austria

[7]See http://www.europarl.europa.eu/RegData/etudes/STUD/2016/587331/IPOL_STU(2016)587331_EN.pdf, pg. 23, Table 6.

and Spain. Other measures (such as bonus/malus schemes, registration tax reductions and exemptions) were introduced in Italy, France or the UK (Cerruti et al., 2018).

These inducements were in some cases superimposed on existing label schemes that seek to remind car buyers about the emissions and the fuel economy of the vehicle (Haq and Weiss, 2016). However, the impact of labels to inform consumers about the potential savings associated with efficient cars has been questioned in the literature (Krause, 2013, and Dumortier, 2015).

3. Methodology

3.1 Sources of Data

We answer our research questions using data from IHS-Markit. Attention is restricted to passenger vehicles that weigh less than 3500 kilograms. Our dataset documents, for each vehicle approved for sale in each of eight important EU markets,[8] the make, model, submodel, trim and version and physical characteristics of the vehicle (including the fuel economy expressed in liters of fuel per 100 km), the price and the monthly sales from January 2011 to September 2017.

The original IHS-Markit dataset contains scanty information about the characteristics of electric and plug-in hybrids, so we supplement it with information from UK and French government sources,[9] such as the kilowatts needed to drive a kilometer (for the electric battery) and the maximum range afforded by the battery. We further merged the car dataset with the price of gasoline and diesel at the pump, and the price of electricity to residential customers who use up to about 5000 kWh/month, for each month of our study period.[10]

[8] The eight countries are Austria, Belgium, France, Germany, Italy, the Netherlands, Spain and the UK.

[9] See https://carfueldata.vehicle-certification-agency.gov.uk/downloads/default.aspx and https://www.ademe.fr/consommations-carburant-emissions-co2-vehicules-particuliers-neufs-vendus-france (last accessed 20 January 2019).

[10] Motor fuel prices were provided by Global Petroleum Prices. The original data were at the week level, so we aggregated them to form monthly averages. The electricity prices are monthly, for residential customers (under the assumption that people will plug in at home, presumably in the evening and at night), and come from Eurostat.

The fuel economy of gasoline and diesel cars is generally expressed in miles per gallon (MPG), or using its reciprocal and metric-system equivalent, namely liters of fuel per 100 km. With MPG, a greater number represents a better fuel economy. With liters per 100 km, a lower number is a lower consumption rate and thus a better fuel economy. The "fuel" efficiency of all-electric cars is measured in kWh/km, a completely different unit. For PHEVs we have the consumption rate of the internal combustion engine plus that of the battery. To compare such diverse cars we compute the cost per km driven by combining these physical units with the price of gasoline, diesel and electricity at that time.[11]

3.2 Main Sample

We extract from our dataset observations on the price for a total of 94 make-models that include electric cars, hybrids and/or different powertrains (for example, diesel and gasoline plus hybrid and/or all-electric versions).[12] We exploit the variation across trim-variants and powertrains within the same make-model and estimate the regression equation:

$$P_{ijct} = \alpha_i + \tau_t + \mathbf{X}_{ijc}\boldsymbol{\beta} + F_{ijt}\gamma + \varepsilon_{ijct} \quad (1)$$

where *i* denotes the make and model (e.g., Audi Q5), *j* denotes the submodel, version and trim (e.g., version="Audi Q5 3.0 D AWD," where 3.0 refers to the engine size (in liters), "D" stands for diesel, and "AWD" means "all-wheel drive"; trim="S Line Plus"), *c* is the country where this vehicle is sold, and *t* is the earliest date (month and year) when this vehicle is put on the market at

[11] This is accomplished by multiplying the fuel consumption rates of gasoline and diesel cars by the price of the relevant fuel and dividing by 100. With BEVs, we multiply the kilowatt-hours per kilometer by the price per kilowatt-hour of electricity. With PHEVs, we follow the procedure described by the UK government (https://carfueldata.vehicle-certification-agency.gov.uk/additional/aug2017/VCA-Booklet-text-Aug-2017.pdf), which is based on the specifics of NEDC testing procedure and where the cost per km from the internal combustion engine is averaged with the cost per km from the battery.

[12] Out of the 94 make-models, 11 are comprised exclusively of battery electric cars, 2 exclusively of plug-in hybrids, 7 exclusively of hybrids, and the remaining 74 feature one or more of these powertrain plus conventional fuel versions. Using the most detailed definition (make-model-submodel-version-trim), there are a total of 6734 unique cars.

this price. The price includes the VAT but not the registration taxes the consumer must pay (in certain countries) upon first acquiring the car, and is expressed in harmonized 2015 euro.

Vector **X** includes weight, engine size, horsepower, a proxy for acceleration (horsepower divided by weight), number of doors, body type, fuel type, range (kilometers driven on a full battery) if electric, and depending on the specification and subject to careful sample construction (see below), whether hybrid, plug-in hybrid or all-electric.[13] Equation (1) includes make-model fixed effects, plus time fixed effects to capture effects (e.g., regulations, the global economy, etc.) common to all countries and vehicles. We weight the observations by the number of units sold—sometimes over several months—at that price. The standard errors are clustered at the make-model level.

We emphasize that our observations are prices, and so there may be several observations for very same car—over time within a country, in different countries—and across somewhat different variants of the same make and model. The dataset used for estimating equation (1) is both a panel and a clustered dataset, but the observations are not collected necessarily at regular intervals over time.[14]

3.3 Supplementary Sample

We form a second sample by pooling the price observations from the different countries and using an exact matching approach. Specifically, we construct strata based on all of the possible combinations of market segment, number of doors, whether an SUV, and quintile of the

[13] We also have market segment, which is purely length-based for five categories (mini, small, lower midsize, midsize, upper midsize) and based on performance, size and manufacturer designation for the sixth (“roadster”). However the market segment doesn’t change within make-model and for that reason its effect cannot be identified in this regression. We include market segment in the regressions that use the sample described in section 3.C.

[14] This implies that if one were to represent the price using a continuous-time process, the variance of the observations would be proportional to the time between consecutive observations. We do not attempt to explicitly model this, and rely on the fact that clustering the standard errors renders them robust to correlation and heteroscedasticity.

distribution of horsepower for each year of the study.[15] We place cars (all-electric, PHEV and HEV, and conventional) as appropriate in these strata. Although 1680 combinations are possible, in practice only 799 are observed in our data. On dropping strata that contain no battery cars, or conversely only such cars, the number of "matched" strata—by which we mean strata that contain both battery and conventional fuel vehicles—dwindles down to 202.

A stratum thus defines relatively homogeneous vehicles. We can now fit the regression

$$P_{ijsct} = \alpha_s' + \tau_t' + \theta_c + \mathbf{X}_{ijc}\boldsymbol{\beta}' + F_{ijt}\gamma' + e_{ijsct} \quad (2)$$

where the subscript *s* denotes the stratum, and the inclusion of the stratum fixed effects mean that we exploit the difference in fuel economy across the otherwise relatively homogeneous cars within a stratum. Year fixed effects, country fixed effects and make fixed effects are also included. The purpose of this exercise is to broaden the set of vehicles beyond the 94 make-models used to construct sample 1, check for heterogeneity in the valuation of the fuel economy, and examine the sensitivity of results to the construction of the sample. A summary of the sample constructed in the above described fashion, plus our main sample, is presented in table 3.

4. The Data

4.1 Description of the Samples

As mentioned, for our first estimation approach we select a total of 94 make-models that come in all-electric and/or hybrid versions, and often (in 70 out of 94 cases) in both conventional and hybrid (and/or all electric) variants. We estimate equation (1) using a total of some 54,000 observations, less than 10% of which are from all-electric or hybrid cars.

[15] The 20th, 40th, 60th, and 80th percentile of the distribution of engine horsepower are 99, 120, 150 and 184 hp.

Table 4 compares this sample (also referred to as "sample 1") with the universe of new cars. The sample overrepresents diesel and battery cars, and slightly underrepresents gasoline cars, but is reasonable close to the universe in terms of price, horsepower, weight and most other characteristics. It boasts, as expected, somewhat lower CO_2 emissions rates and better fuel economy, and contains more lower-midsize cars than the universe.

Table 5 present descriptive statistics for the cost per kilometer, showing that it is lowest among battery electric cars, and that, among the conventional fuel versions, diesel is less expensive to drive than gasoline. Hybrids are generally less expensive to drive than gasoline vehicles and are competitive with diesel cars, while plug-in hybrids have the broadest range (the highest minimum and maximum cost per kilometer), but their mean and median costs per kilometer are lower than those of gasoline cars. Taken together, this information suggests that, all else the same, hybrids and battery-electric vehicles do indeed fall in the best fuel economy range.

On further breaking down HEVs and PHEVs by whether the conventional fuel is diesel or gasoline (table 6), we find that diesel HEV cars have the second lowest price per kilometer (after BEVs; € 0.0577/km), followed by gasoline HEV and conventional diesel cars (which are virtually identical in terms of cost per kilometer, € 0.068/km), with gasoline plug-ins ranking fifth (€ 0.0726/km), conventional gasoline sixth (€ 0.0896/km), and diesel plug-ins seventh at some 10 eurocents/km.

This hierarchy is in part explained by the size, weight and horsepower of the car, as shown in table 6. The PHEVs in sample 1 are heavier, have more horsepower, and are more likely to be SUVs than the cars in the other categories. It remains to be seen whether the significantly higher prices of plug-ins compared to other battery and conventional fuel cars are explained away by their heavier weight, size and horsepower.

Table 7 shows that our matched sample (also called “sample 2”) is reasonably similar to the universe of new cars, even though it contains a slightly smaller share of SUVs and more sedans.

4.2. Are Battery Cars Energy Efficient?

Given our interest in battery vehicles, it is important to check whether they truly are more efficient compared to most conventional cars, not just those in our samples. To check that this is the case, we use the full dataset (2,404,190 observations at monthly frequency and thousands of make-models).

We begin with plotting the average fuel consumption rate in liters per 100 km for conventional and hybrid cars over time, as shown in figure 3.[16] The fuel economy of conventional cars has improved over time, but so has that of regular hybrids, which usually falls in the second quintile (between the 20th and 30th percentile) of the distribution of fuel consumption rate. If one were to judge PHEVs solely on the efficiency of the internal combustion engine, without considering the cost of charging the battery, PHEVs would soundly outperform the other types of cars: They have continued to improve dramatically and their average diesel or gasoline consumption rate falls in the first quintile of the overall distribution.

BEVs have zero tailpipe emissions of CO_2, while for the other cars the CO_2 emissions rates are proportional to the (liquid fuel) consumption rate, and so are lowest for PHEVs, especially diesel PHEVs. They are highest for regular gasoline cars.

Figure 4 does a similar exercise as figure 3, but with cost/km and includes BEVs. It shows that BEVs have by far the lowest cost per km (about 3 euro-cents), which has remained stable over

[16] Although diesel cars typically have lower consumption rates than gasoline cars, we not separate them here. We note that the overall fuel economy reflects the introduction of new vehicles and any changes in the shares of gasoline and diesel cars.

time. Conventional cars and regular hybrids are more expensive to drive (the latter being less expensive than the former), but their cost/km has declined over time, in part due to actual fuel efficiency improvement and in part because of the falling prices of gasoline and diesel. It is thus surprising that the same conclusion does not apply to PHEVs, a finding that would appear to be caused by the sluggish improvement in battery efficiency. In spite of this, battery vehicles are generally fuel efficient.

5. Results and Discussion

5.1 Does the Price Reflect the Fuel Economy?

Table 8 displays selected coefficients from estimating equation (1) using the sample described in section 3.B (or subsets thereof). This specification does not include BEV, PHEV or HEV dummies, and thus attributes any difference in price across cars to the characteristics of the vehicles and the fuel economy, but not to the powertrain per se. We generally find that the price of a car is positively associated with horsepower and weight, and first declines and then rises with acceleration. It is also almost €4800 higher for four-wheel drives and some €2400 higher when a car has automatic transmissions. A station wagon is some €1180 pricier than a sedan, and a hatchback about €600 more. Surprisingly, the range of an all-electric vehicle enters with a negative sign and is insignificant. Overall, the R^2 of the regression is 0.96, implying excellent fit.[17]

As shown in table 8, the coefficient on price per kilometer is about -65,000 and is strongly significant: All else the same, the more fuel-efficient a car is, the higher the price. This entails that

[17] We experimented with further including the number of cylinders (when available) and the footprint of the vehicle (length times width), despite their strong correlation with weight and horsepower, but adding them left the coefficients on the other covariates virtually unchanged.

hybrids and electrics are generally more expensive than a conventional car with similar characteristics.

Columns (2)-(4) of Table 8 present robustness checks. For example, we drop BEVs, HEVs and PHEVs one group at a time, finding results similar to that of the base equation.[18] Column (5) restricts the sample to BEVs and hybrids, showing *less* pronounced sensitivity of vehicle price to the fuel economy among these cars. Perhaps consumers who purchase these cars have already indicated their concern for fuel costs by buying one of them, and let their final choice be dictated by other attributes of the car. Only in this regression is the coefficient on the all-electric battery range positive—but still insignificant at the conventional levels.

The magnitude of the coefficient in columns (1)-(4) of table 8 implies that if we assume that drivers drive on average 14,000 kilometers a year and the expected lifetime of the vehicle is 13 years, they would be discounting future fuel costs at a rate of 20% per year.[19, 20] An alternative interpretation is that consumers (and automakers) appear to be using a payback period of 4.64 years (see Greene, 2018).

Allcott and Wozny (2014) and Greene (2018) suggest that a more appropriate discount rate, based on the actual rates charged on car loans, is approximately 6%, and in recent years automakers, dealerships and banks in Europe have charged less than that (current rates are some

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[18] The regressions reported in this paper do not include country fixed effects. In specifications not reported in the paper, we further entered country dummies. While six out of seven country coefficients are statistically significant, the coefficients on fuel cost per km and BEV range are virtually unchanged.

[19] This calculation assumes that the distance driven each year is $M \cdot p_{km}$, where M is annual kilometers driven and p_{km} is the cost per kilometer driven. These are incurred every year over an expected lifetime of 13 years, and must be discounted back to the present. The expression is thus $M \cdot (1-\exp(-13 \cdot \delta))/\delta$, where δ is the discount rate. We assume 13 years because this is consistent with the most detailed vehicle registration data we were able to obtain for gasoline and diesel cars (those in veh0207 by the UK Department for Transport). Registration summaries are available for battery vehicles, but they are simply insufficient to estimate a credible expected lifetime, as sales and registration of battery vehicles started only in recent years.

[20] We obtained information about the annual mileage driven by passenger cars in different countries in Europe from the MURE-Odyssee project. These data indicate that during our sample period and in the eight countries covered by our sample the average passenger car was driven 14,000 kilometer a year.

3-4% per annum or less). Were we to use the 6% per annum rate suggested by Greene (2018), we would conclude that only some 51% of the fuel costs are capitalized.[21] At a rate of 4% per annum, only 46% of the fuel costs would be capitalized.

It is also possible that consumers simply do not take literally the fuel economy information reported by manufacturers or the government, but rather use it a reference point, from which departures are expected (downward or upward) depending on individual driving styles, road type and traffic conditions. If so, the fuel economy is affected by measurement error, and if the measurement error is classical, then the coefficient on price per km would be affected by attenuation bias. We would expect this (or any other discrepancies between posted and perceived fuel economy) to become more pronounced after the Volkswagen scandal, which came to light in September 2015 in the US. But dropping observations on VW cars after September 2015 has a negligible effect on coefficient on cost per km (results available from the authors).

Alternatively, the low capitalization rate might be an artifact due to consumer heterogeneity (Bento et al., 2012). Dumorier et al. (2015) find that providing subjects with information about the full cost of car ownership over 5 years (inclusive of insurance, maintenance, and fuel expenses), has little effect on individuals who have expressed the intention to buy an SUV. Perhaps these persons are more interested in passenger and trunk space and performance. When we exclude SUVs from the sample, the coefficient on cost per kilometer gets only slightly stronger (-65,879.50; t statistic -10.03). Excluding Teslas from the sample, as these are expensive and high-performance electric vehicles with their own dedicated charging stations and equipment, the coefficient on cost per km remains virtually the same.

[21] We follow Greene's procedure to compute payback periods and capitalization rates. First, we take the coefficient on the cost per kilometer, and divided that by 14,000, yielding 4.64. Assuming a 13 year lifetime and 6% discount rate, the discount factor is 9.02. We finally divide 4.64 by 9.02, and obtain that the rate at which future fuel costs are capitalized into the price of a car is 51%.

In table 9 we re-rerun regression (1) for each of the quintiles of the distribution of car price. The negative association between cost per km exists in each quintile, but only in the priciest group is the magnitude of the coefficient comparable to that for column (1) of table 1. If we interpret this in the light of the traditional economic model—that the price mirrors discounted lifetime fuel costs—this finding seems consistent with either i) heterogeneity across consumers in discount rates and in the utility of money (lower among wealthier consumers), or ii) sorting of consumers who need to do a lot of driving and are mindful of fuel costs towards larger, more comfortable and better equipped cars.

5.2 Is There a Battery Premium?

Based on simple descriptive statistics, we wonder whether apparent differences in prices across conventional cars and BEVs, PHEVs and HEVs are explained away by their different fuel economy or other attributes, or whether consumers pay a premium to drive battery vehicles. To answer this question, we must compare the battery cars with cars that are reasonably similar to them.

As shown in table 4, the fuel economy figures for battery cars do not fully overlap with those of conventional cars. To avoid combinations of fuel economy, weight, size, and body types that exist for conventional cars but not among the battery cars (or viceversa), and thus undue extrapolation that relies completely on the specification and functional form of the regression, we construct three subsamples from our main sample.

The first sample contains all HEVs plus conventional cars with similar fuel economy, weight and horsepower and body type (price per km between 0.0295 and 0.1992; weigh between 1480 and 3402 kg; between 65 and 799 HP; no convertibles, estate high volume, or roadsters; price comprised between € 15,912 and € 250,000). The results from running regression (1), amended to include the HEV dummy, on this sample (table 10, column (1)) show that the coefficient on cost/km has the expected negative sign, but its absolute magnitude is less than those in table 8. The powertrain dummies are both significant at the 5% level or better, but their magnitudes—some €1440 for diesel and €1800 for HEV—are modest compared to the price premium associated with four-wheel drive (€4450) or automatic transmissions (some €2300). These results don't change if we add the CO_2 emissions rate (which is however highly correlated with the fuel consumption rate, and hence the cost per km) and/or country fixed effects.

We report the results from a similar exercise for PHEVs and conventional fuels in column (2) of table 10. This is our second subsample. This time we trim the sample to include only cars with price per km between 0.0447 and 0.14, with 48-737 HP, 1560-3185 kilograms, and no convertibles, estate high volume vehicles, mini or small cars, or roadsters. We also limit the range of price between €28,814 and €250,000. The coefficient on cost per km is similar to its counterpart in column (1) of table 10. Controlling for everything else, plug-in hybrids are some €10,000 more expensive than a gasoline car with otherwise comparable attributes. The PHEV premium remains when we further add the CO_2 emissions rates, country dummies, the squares of weight and horsepower, or replace all of the continuous variables (price, weight, etc.) with their logarithmic transformations. In the log-log model, the PHEV premium is 23% of price.

To compare BEVs with conventional fuels, we restrict attention to the cars that are either electric or conventional and whose cost/km falls in the € 0.0171-0.0843 range, have between 5 and 772 HP, weigh between 1150 and 3070 kilos, cost between €12,853 and €175,411, and rule out station wagons, coupes and roadsters. This time the regression results hint at a stronger responsiveness of price to the fuel economy—the coefficient on cost per km is -53,082—but also at a large BEV premium (over €13000), although the latter is not significant at the conventional levels. Adding the CO_2 emissions rate or country dummies raises the BEV premium to €15,830 (significant at the 10% level) and €17,000 (significant at the 1% level), respectively.[22]

In sum, we find large premiums for PHEVs and BEVs, but not for HEVs. These premiums are above and beyond the savings in fuel costs that would be delivered by these vehicles, and are observed even though these types of cars are "demanding" in that they require access to charging equipment and facilities, and have the potential for "range anxiety" (Dumorier et al., 2015).

There are three possible explanations for these premiums. First, the price differential might simply be due to car characteristics that are not documented in our dataset. For example, if the PHEV variant of a car offered luxury features, extra safety apps (automatic breaking, collision warning, lane departure warning), or simply functions that increase comfort and ease of driving (e.g., park assist) but these are not documented in the dataset, that would explain the premium. The coefficients on the fuel economy would however be unbiased if these features are uncorrelated with the fuel economy of the car.

The second possible explanation is that people are paying for "something else." They could, for example, derive satisfaction from knowing that they are among the first to use cars with newer technologies or with low emissions. Because the correlation between the CO_2 emissions rate and the cost per kilometer driven is very high (0.77), we cannot establish conclusively whether drivers are willing to pay for lower greenhouse gas emissions.

Another possible explanation is that the price premium exist, but is completely or partially made up for by government incentives and subsidies, which typically apply to battery and/or fuel-efficient and low-emissions conventional cars. Consider for example PHEVs, and suppose one

[22] Results available from the authors.

were to go from € 0.14/km to € 0.0447. At 14,000 kilometers a year, the annual savings would be € 1,334.2. Table 7 implies a payback period of 2.15 years, over which the fuel cost savings would account for only one-third of the PHEV premium. When and where incentives to plug-ins were provided, they averaged some € 3000 (€ 1500-1600 if provided in the form of "bonus," namely a reduction of the registration tax that must be paid upon registering a car for the first time), and were in some cases as high as €6156, which would seem sufficient to offset (much of) the premium. With BEVs, the government incentives in the countries in our sample can be as high as over € 36,000, which would more than offset the BEV premium.

A final possible explanation may lie in the salience of the fuel costs—or lack thereof. By salience, we mean the correct perception of the full price per kilometer. Salience is compromised when a consumer only perceives a portion of the total cost per km.[23] This might be the case with plug-ins, to the extent that automakers advertise, and specialized press tends to report, only the liters consumed per 100 km by the internal combustion engine, without adding the cost of the electricity from the battery.[24] We took both into account when computing the cost per kilometer, which is on average € 0.0610. The NEDC-based fuel consumption rate for the internal combustion engine alone results in a dramatically lower € 0.0344/km. But when we enter this corrected version of the price per km in the regression for PHEVs and conventional cars, the regression suggests even less responsiveness to fuel economy (the estimated coefficient is -24972.62, with a t statistic of -2.59), and the PHEV premium decreases only by € 1000, to € 9202 (t statistic 4.21).

[23] See Chetty et al. (2009) and Li, Linn and Muehlegger (2014) for salience of taxes in different contexts.
[24] This is shown in figure 3 and 4.

5.3 Robustness Checks

We used our "matched samples" to check our main findings. Briefly, we find that the coefficient on cost per km is stronger here than with the previous sample, but only when the observations are unweighted. In this case (column (1) of table 11), the coefficient suggests a discount rate of 16.5% per annum. If one assumes a discount rate of 6%, and infers from 74,523/14,000=5.23 that this is the approximate payback period required by the public, then only 57% of the discounted lifetime fuel costs are capitalized into the price of a car. The coefficient on fuel costs is weaker when we use sales weight.

To investigate heterogeneity across types of cars, we re-estimate the model separately for each stratum. The coefficient on cost per kilometer is negative for at least 90% of the some 200 such estimations and the median coefficient is -61,000. The histogram of the estimated coefficients from the individual runs (figure 5) shows that the bulk of the estimated coefficients is negative, and that the few positive values can be extremely large.

When we run separate regressions for the observations that fall in each quintile of the distribution of cost per km in the sample, we find that the coefficients on cost per km are negative with four out of the five samples, but, as shown in table 12, do not exhibit any particular pattern. Battery electric vehicles are present only for the sample based on the lowest cost per km values. The coefficient on the price per km is positive in the top group, as consistent with the notion that those cars attract people who care about car attributes that are negatively correlated with the fuel economy.

Finally, table 13 reports results when we split the observations into the quintiles of the distribution of vehicle price, and enter car attributes, cost per kilometer, stratum fixed effects, country fixed effects and year fixed effects as usual in the model. For the 20% most expensive cars, the relationship between the fuel economy and the price of the car is, all else the same, no longer significant, and the strongest association is for the least expensive vehicle, suggesting that they attract customers who are more cost-conscious. This is somewhat in contrast with our findings from the regressions by price quintile for sample 1.

6. Conclusions and policy implications

Electric and hybrid vehicles are a top priority within the European Union's decarbonization goals. At this time, they still account for relatively small, but growing, shares of the new car sales. Using data on electric vehicles for several EU countries (Austria, Belgium, France, Germany, Italy, the Netherlands, Spain and the UK) we check if the electric and hybrid vehicles (PHEV, BEV and HEV) have a better fuel economy than diesel and and gasoline vehicles.

We then ask three research questions. First, we check whether this fuel economy is reflected in these vehicles' prices. Second, we seek evidence that "range anxiety" is mirrored in the price of all-electrics. Third, we investigate the existence of a price premium for these vehicles. If such a premium exists, it may hinder the sales of these vehicles, unless sufficient incentives are offered to consumers to offset it. Government budget considerations however suggest that incentive programs are likely to be short-lived, and electric and hybrids must become competitive if they are to replace regular vehicles.

Is the public prepared to pay for fuel economy, and hence prepared to pay more for battery vehicles? We have found that, all else the same, the more efficient variants of a given car have higher prices. The magnitude of this effect however suggests that future fuel costs are discounted heavily, or people expect very short payback periods on fuel-efficient technologies. Our main model and main sample suggest that, under standard assumptions (6% discount rate, expected lifetime of a car 13 years), only 51% of the discounted fuel costs are capitalized into the price of the car.

Why such low capitalization rate? The capitalization reflects assumptions on the annual distance driven, the expected lifetime of the car, and expectations about future fuel and electricity prices. Specifically, we have assumed that consumers forecast the future prices of fuel and electricity to be equal to the most recent prices, as is consistent with a random walk model of fuel prices (or static expectations) and appears to be empirically supported (Anderson et al., 2013).

Holding the discount rate at 6%, if we assume that the average car is driven 10,000 km a year, the capitalization rate is 72%, whereas for 16,000 km a year, a distance typical of diesel or hybrid cars, it would be 45%. If the lifetime of the car is 17 years (Greene, 2018), under the same assumptions the capitalization rate would be 61% and 38%, respectively. Other studies have found similarly wide ranges of capitalization rates. For example, Allcott and Wozny (2014) find that 75% of fuel costs is capitalized into the price of used vehicles under a random walk assumption, but this figure falls to 55% when expectations about motor fuel prices are based on the price of oil futures (Greene, 2018). Consumer heterogeneity has been shown to give the appearance of low capitalization rates (Bento et al., 2012), and we do find evidence of different valuations of the fuel economy in different market segments.

We find evidence of large premiums for PHEVs and BEVs but not for HEVs. By premium, we mean an economically meaningful and statistically significant battery vehicle effect. Automakers claim that manufacturing the more efficient vehicles means higher production costs, but economic theory suggests that consumers' additional willingness to pay for such efficient technologies should be equal to the savings in discounted fuel costs. What causes the price differentials to exceed the fuel costs savings?

We conjecture that there may be three possible explanations. First, the price differentials between standard vehicles and battery cars may be due to characteristics not documented in our dataset, such as luxury features and/or advanced driving and safety technologies (e.g., "heads up" feature, park assist, collision warning, navigation, WiFi integration, etc.). The coefficients on the fuel economy should however be unbiased if, as we expect, these features are uncorrelated with the fuel economy of the car.

Second, automakers may set prices knowing or expecting that the premium will be completely (or partially) covered by government incentives and subsidies. Third, consumers may not perceive the full price per km correctly. In the case of plug-in hybrids, consumers may fail to consider the cost of charging the battery, making only the gasoline or diesel component of driving cost "salient" to them (Chetty et al., 2009). This argument however cannot possibly explain the large premium on all-electric cars. We conclude that, as seen with other energy-using durables (Alberini et al., 2016; Houde, 2018; Cohen et al., 2015), a small number of consumers appear to be willing to pay a premium for energy-efficient products that is not explained by the fuel economy differential.

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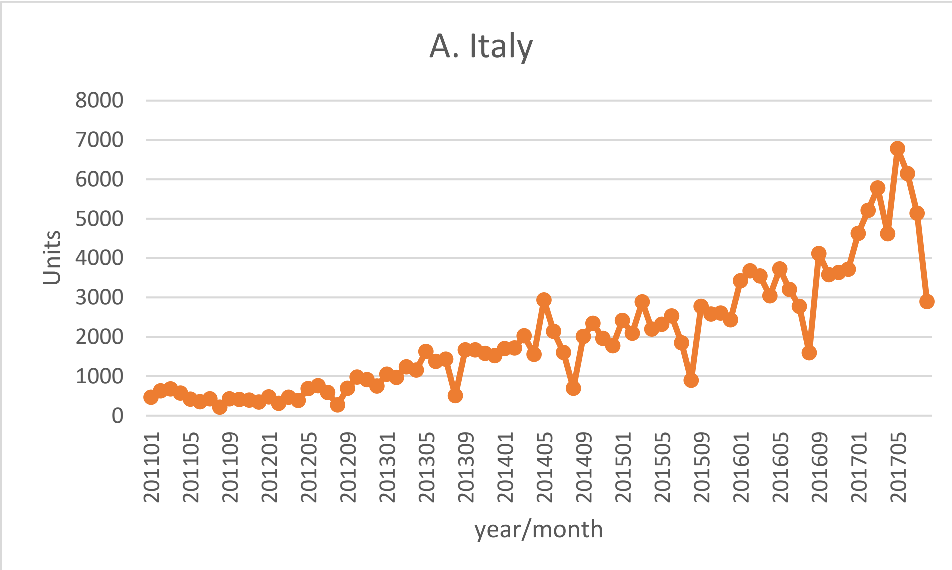
Figure 1. Sales of BEVs, PHEVs and HEVs by month in two European Union countries. Italy waived the annual registration fee on electric vehicles but did not offer any incentives upon purchase; Germany offered both.



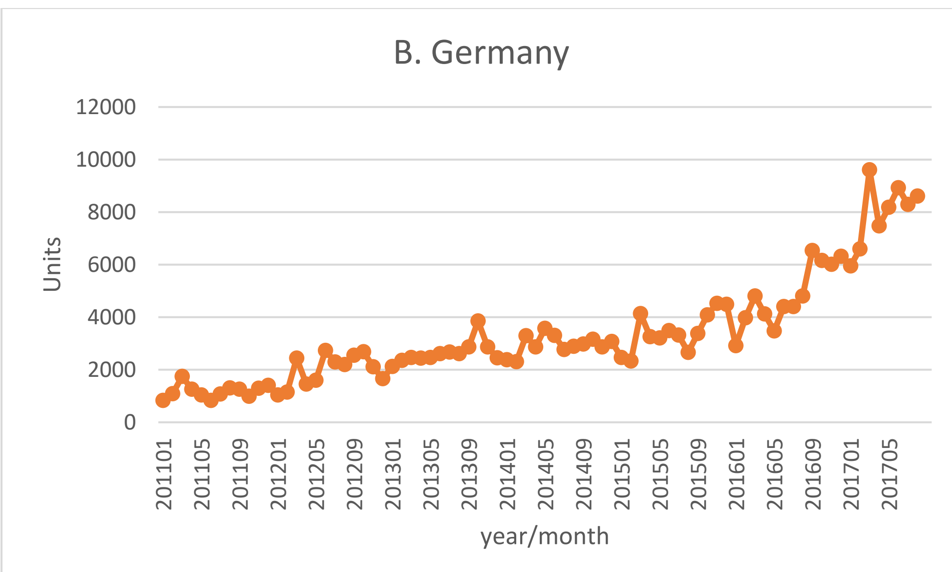


Figure 2. Gasoline prices in three large EU car markets over the study period.

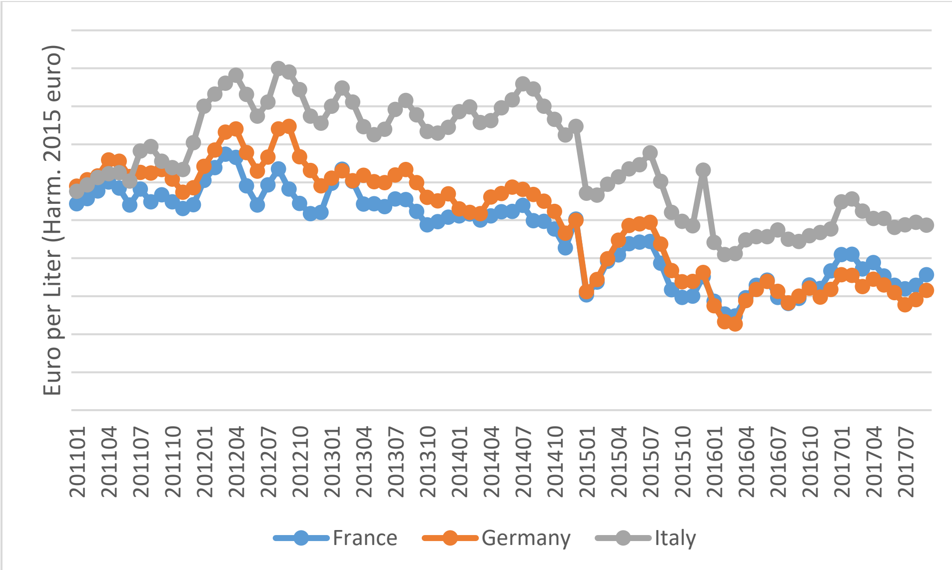


Figure 3. Fuel consumption rate (liters per 100 km) by powertrain and year.

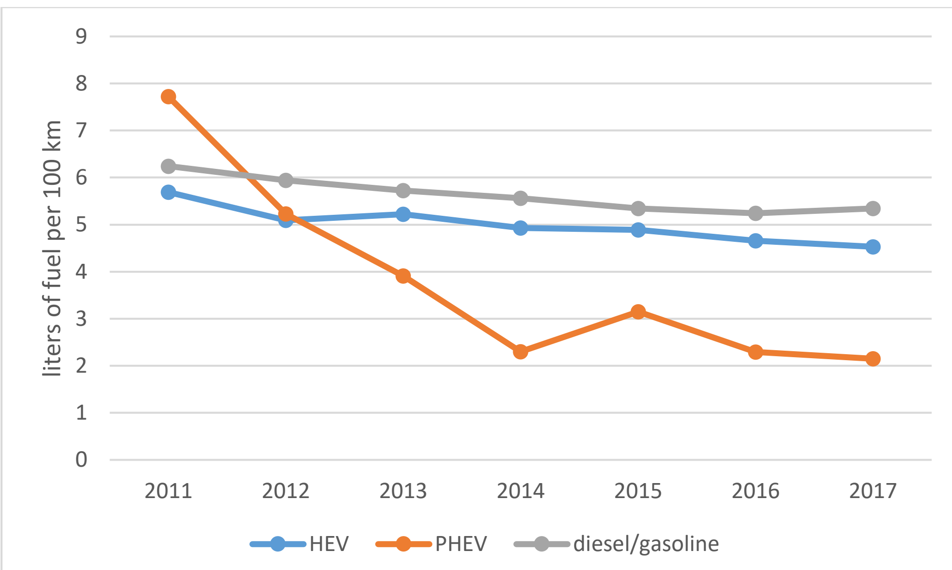


Figure 4. Average fuel/energy cost per kilometer driven by year and powertrain (based on sample 1).

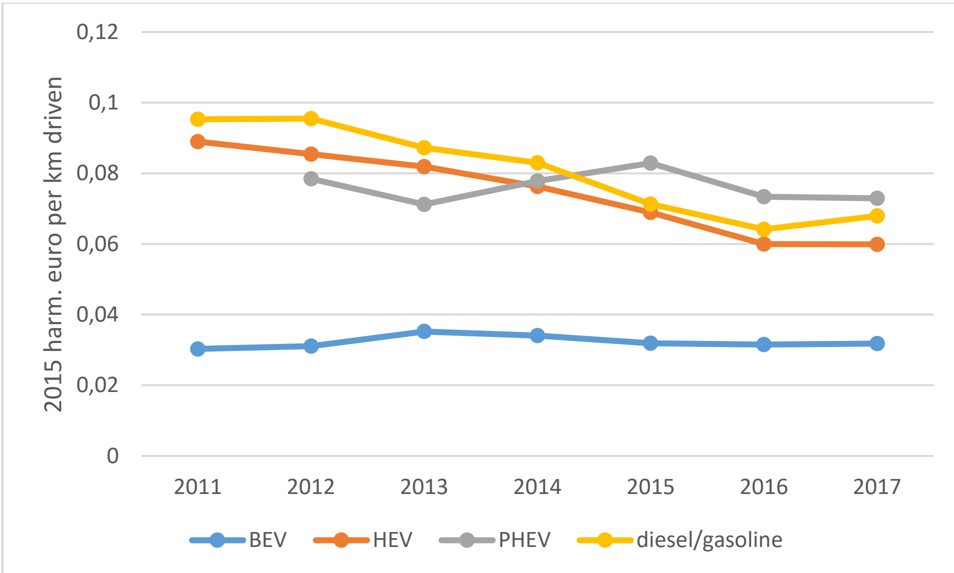


Figure 5. Estimated coefficients on price per kilometer from each matched stratum in sample 2: histogram.

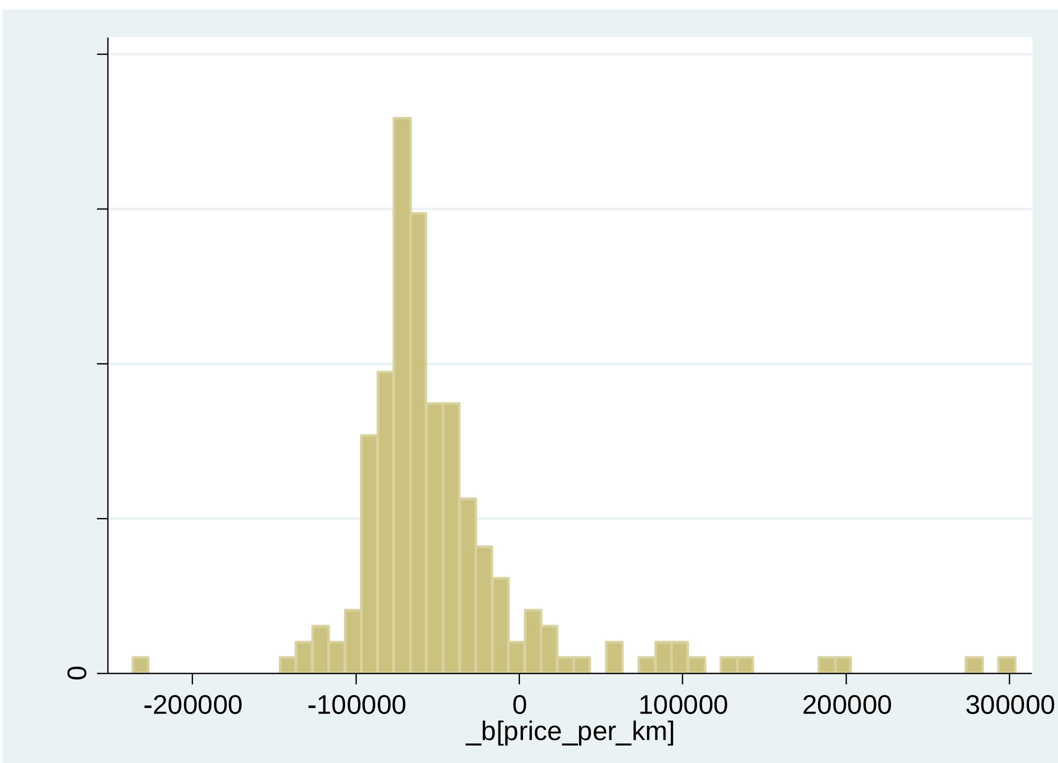


Table 1. Descriptive statistics of the five largest EU car markets for the year 2016.

	Germany	**United Kingdom**	**France**	**Italy**	**Spain**
New passenger cars sold	3,351,607	2,692,786	1,983,729	1,848,863	1,147,007
New passenger cars with battery (BEV, HEV, PHEV)	40,459	60,536	89,827	82,005	35,295
Share with battery out of total	1.21%	2.25%	4.53%	4.44%	3.08%

Table 2. Existing taxes, incentives and bonus/malus schemes for BEV and PHEV by country.

	Bonus/malus on registration tax (tax paid upon purchasing the car)	**Other Tax**	**Incentives**
Austria	Malus on pollutant vehicles and bonus for vehicles emitting less than 60g/km. Bonus in place until 2015. After 2015, deduction on taxation for hybrid and electric vehicles.	BEV=exempted from the registration tax; hybrids= reduction with respect to conventional cars	BEVs
France	Bonus for BEV and also for hybrids up to 110g/km of CO_2. Incentives to dismiss old conventional cars. Malus for cars polluting more than 110g/km.	BEV=exempted; hybrids=reduction if less than 190g CO_2/km	
Spain	Special tax equal to 0 for BEV. This tax increases up to 16% for vehicles emitting 200g/km co2.	Differs by region: in the Madrid region reduction up to 75% for hybrids and electric vehicles	BEVs in the Madrid region
Italy		Registration tax divided in two parts: 1) the amount that must be paid for registering the car in the public register (PRA, which includes the cost of tags, etc.), and 2) the Imposta Provinciale di Trascrizione (IPT), which individual provinces may increase up to 30% over the national base. An exemption of 100% from 1) is allowed for electric, LPG and CNG vehicles in the first 5 years from the first registration and an exemption of 75% thereafter is available in many regions. Some provinces offer reduced percentage increases of 2), the IPT, for BEVs, HEVs, PHEVs and CNGs or other alternative fuels.	Until 2015 incentives up to 20% of car total price (before taxes). In 2015 incentives reduced up to 15% of total price. Since 2016, incentives determined at the provincial level.
Germany	Bonus for BEVs and PHEVs since 2016	10 years of exemption from the annual registration for BEVs and PHEVs registered before 2016. 5 years of exemption if registered afterwards. Registration tax increases with CO_2 emitted for conventional cars.	Since 2016 for BEVs and PHEVs

UK		Annual registration tax is discounted or equal to zero for vehicles polluting less than a specified threshold. Both the threshold and the tax amount change over the years.	Since 2011 for BEVs and PHEVs
Belgium	Bonus/malus scheme in the Walloon region; vehicles with emissions lower than 145 g/km exempted from the payment of a fee starting in 2014	Tax on entry into service (TES): changes on a regional basis, depending on vehicle's fiscal horsepower and age. BEV are exempted only in specific years and not in all the regions. The annual circulation tax is also defined at the regional level. BEV and PHEV are exempted from circulation tax after 2016 in the Flemish region.	Income tax reduction for BEVs; Flemish region offers an additional incentive for BEVs
Netherlands		The registration tax (BPM) is equal to zero only for non-emitting vehicles and increases proportionally with emitted CO_2 for the other vehicles. From 2017, PHEVs pay a discounted BPM with respect to diesel and gasoline vehicles. Annual circulation tax: BEV and clean vehicles (less than 100g/km CO_2 if gasoline and less than 95g/km CO_2 if diesel) exempted before 2014. After 2014 they have a special regime.	

Table 3. Description of the universe and samples used in this paper.

	Description	Number of observations	Share of battery vehicles
Universe	Prices of thousands of unique cars from the eight European countries from Jan 2011 to Sept 2017	384,224	1.80%
Sample 1	Prices of 94 make-models in many variants for a total of 6734 unique vehicles	54,025	8.84%
Sample 2 ("matched sample")	Price observations from 202 groups of cars with common year, segment, SUV status, number of doors, engine horsepower range	246,072	2.67%

Table 4. Comparison between sample 1 and all passenger cars sold in the eight EU countries Jan 2011-Sept 2017.

	Sample 1 (prices of BEV, HEV, PHEV plus, if available, their diesel or gasoline counterparts within the same make and model)	**Universe** (prices of all new passenger cars sold in the eight EU countries during the same period; includes sample 1)
Nobs	54,025	384,224
SUV	17.71%	16.22%
Gasoline	39.11%	45.86%
Diesel	59.10%	53.78%
HEV	5.30%	1.13%
PHEV	1.75%	0.32%
BEV	1.79%	0.35%
Sedan	12.63%	12.27%
Engine HP	159.60	162.06
Weight (kilograms)	2074.59	2008.58
Market segment		
Mini	4.65%	4.49%
Small	3.91%	17.16%
Lower midsize	50.49%	39.27%
Midsize	24.34%	25.13%
Upper midsize	16.58%	13.54%
Roadster	0.03%	0.40%
Station wagon	22.92%	17.40%
Automatic transmission	51.12%	42.65%
AWD	21.92%	19.70%
Front wheel drive	69.91%	64.22%
CO2 emissions (grams per km)	128.03	138.23
Price per km (2015 harmonized euro)	0.074	0.085
Fuel consumption (liters per 100 km) if conventional fuels	5.50	5.93
Sale price inclusive of VAT and registration tax (2015 harmonized euro)	37,868	37,554

Table 5. Sample 1: Descriptive statistics of cost per km by powertrain. All figures in 2015 harmonized euro.

Powertrain	**Mean**	**Median**	**Min**	**Max**
BEV	0.033	0.031	0.017	0.084
Diesel	0.069	0.065	0.033	0.177
Gasoline	0.090	0.084	0.043	0.291
HEV	0.067	0.062	0.022	0.196
PHEV	0.076	0.071	0.045	0.140

Table 6. Sample 1: Selected characteristics of vehicles by powertrain.

Powertrain	**Average price per km (2015 harm. euro)**	**Average Weight (kg)**	**Average Engine HP**	**Share SUV**	**Average price (2015 harm. euro)**
BEV	0.033	1907	166.5	7.00%	47,501
Diesel	0.069	2179	160.3	20.75%	38,824
Gasoline	0.090	1872	154.4	11.05%	31,259
HEV (all)	0.067	2109	158.2	24.14%	44,772
HEV gasoline	0.068	2040	148.8	24.18%	
HEV diesel	0.058	2510	213.4	23.88%	
PHEV (all)	0.079	2462	209.0	34.06%	67,392
PHEV gasoline	0.076	2437	207.4	35.29%	
PHEV diesel	0.070	2668	221.5	26.92%	

Table 7. Sample 2: Descriptive statistics.

		Obs.	**Mean or share of the sample**
Car type	SUV	246,072	11.52%
	Gasoline	246,072	45.60%
	Diesel	246,072	53.89%
	BEV	246,072	0.05%
	PHEV	246,072	0.04%
	HEV	246,072	1.70%
	Sedan	246,072	15.62%
Car characteristics	Engine horsepower	246,072	164.39
	Weight (kilograms)	234,499	2023
	Station wagon	246,072	18.17%
	CO_2 emissions rate (g per km)	243,129	135.91
	Automatic transmission	246,072	45.55%
	AWD	246,072	19.79%
	Front wheel drive	246,072	65.08%
	price per km (2015 harm euro)	241,626	0.08
	Fuel consumption (liters/100 km.)	240,784	5.84
	Sale price inclusive of VAT and registration tax (2015 harm euro)	245,160	38,683
Market segment	Mini	246,072	5.88%
	Small	246,072	12.14%
	Lower midsize	246,072	41.72%
	Midsize	246,072	24.19%
	Upper midsize	246,072	15.71%
	Roadster	246,072	0.36%

Table 8. Sample 1: Results from the hedonic pricing model. Coefficients on selected regressors.

	(1) **All**	(2) **no BEVs**	(3) **No PHEVs**	(4) **No HEVs**	(5) **Only BEV, PHEV, HEV cars**
Range (BEV)	-29.359	--	-4.3637	-31.458	44.458
	(-1.59)		(-0.31)	(-1.64)	-1.85
Price per km in 2015 harm. Euro	-64,987.21***	-64,560.41***	-64,293.54***	-65,325.86***	-39,338.61
	(-12.08)	(-10.19)	(-11.13)	(-12.50)	(-1.59)
Observations	53697	52789	52777	50939	4586

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.010

Note: The dependent variable is price inclusive of VAT. All regressions include make-model fixed effects, other car attributes, and year dummies. Observations are weighted by sales. T statistics based on standard errors clustered at the make-model level.

Table 9. Sample 1: Robustness checks for the hedonic pricing model. Separate regressions by quintiles of distribution of price. Coefficients on selected regressors.

	(1) Prices in the 1st quintile (≤24,375.64)	(2) Prices in the 2nd quintile (24,375.64 to 29,124.04)	(3) Prices in the 3rd quintile (29,124.04 to 34,354.11)	(4) Prices in the 4th quintile (34,354.11 to 47,093.37)	(5) Prices in the 5th quintile (>47,093.37)
Price per km in 2015 harm. Euro	-43,364.76***	-32,372.07***	-25,037.71***	-35,791.51***	-71,162.25***
	(-16.04)	(-7.77)	(-7.14)	(-5.47)	(-5.10)
Observations	10,739	10,740`	10,739	10,740	10,739

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.010

Note: The dependent variable is price inclusive of VAT. All regressions include make-model fixed effects, other car attributes, and year dummies. Observations are weighted by sales. T statistics based on standard errors clustered at the make-model level.

Table 10. Sample 1: Results from the hedonic pricing model. Battery premium. Coefficients on selected regressors.

	(1) HEV plus conventional	**(2)PHEV plus conventional**	**(3) BEV plus conventional**
Price per km (2015 harm. euro)	-34,775.46*** (-4.70)	-31006.33*** (-2.99)	-56957.51*** (-6.57)
Diesel	1438.16*** (6.25)	1497.80*** (3.69)	1035.59*** (5.16)
HEV	1837.23** (2.26)		
PHEV		10236.36*** (9.00)	
BEV			13550.83 (1.51)
Observations	45631	26721	25,011
Make-models	66	50	67

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.010

Note: The dependent variable is price inclusive of VAT. All regressions include make-model fixed effects, other car attributes, and year dummies. Observations are weighted by sales. T statistics based on standard errors clustered at the make-model level. Samples are restricted to ranges of cost per km, weight, horsepower and price common to the HEV, PHEV or BEV and conventional fuel cars.

Table 11. Sample 2: Results from the hedonic pricing model. Coefficients on selected regressors.

	(1) Unweighted	**(2) Sales-weighted**
Price per km	-75358.8***	-56480.04***
	(-4.00)	(-8.17)
Range (BEV)	-20.2843*	-34.1459***
	(-1.93)	(-4.42)
Observations	243,940	243,940

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.010

Note: The dependent variable is price inclusive of VAT. All regressions include country fixed effects, make fixed effects, stratum fixed effects, and other car attributes. T statistics based on standard errors clustered at the make level. Samples are restricted to ranges of cost per km, weight, horsepower and price common to the HEV, PHEV or BEV and conventional fuel cars.

Table 12. Sample 2: Robustness checks for the hedonic pricing model. Separate regressions for each quintile of the distribution of price per km. Coefficients on selected regressors.

	(1)	(2)	(3)	(4)	(5)
	1st quintile (≤24,375.64)	2nd quintile (24,375.64 to 29,124.04)	3rd quintile (29,124.04 to 34,354.11)	4th quintile (34,354.11 to 47,093.37)	5th quintile (>47,093.37)
Price per km in 2015 harm. Euro	-44074.5***	-57131.91***	-72850.97***	-41132.2***	21195.19***
	(-3.93)	(-16.49)	(-20.62)	(-14.29)	(7.63)
Range (BEV)	-13.79*	-12.59	0	0	0
	(-1.71)	(-0.61)	(.)	(.)	(.)
Observations	47126	49203	49207	49186	49218

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.010

Note: The dependent variable is price inclusive of VAT. All regressions include country fixed effects, make fixed effects, stratum fixed effects, and other car attributes. Observations weighted by sales. T statistics based on standard errors clustered at the make level. Samples are restricted to ranges of cost per km, weight, horsepower and price common to the HEV, PHEV or BEV and conventional fuel cars.

Table 13. Sample 2: Robustness checks for the hedonic pricing model. Separate regressions for each quantile of the distribution of vehicle price. Coefficients on selected regressors.

	(1)	(2)	(3)	(4)	(5)
	1st quintile (≤24,375.64)	2nd quintile (24,375.64 to 29,124.04)	3rd quintile (29,124.04 to 34,354.11)	4th quintile (34,354.11 to 47,093.37)	5th quintile (>47,093.37)
Price per km in 2015 harm. Euro	-55072	-41976	-26010	-42549	-10694
	(-17.87)	(-15.67)	(-40.50)	(-52.65)	(-2.92)
Observations	48,789	48,789	48,787	48,788	48,788

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.010