# Electric Vehicles Are Driven Less:

selection or substitution?

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**Abstract**

A great deal of funding is spent in promoting electric vehicle adoption. The benefits of these subsidies depend not only on the cost effectiveness of the policy in terms of adoption, but also on how much mileage is actually substituted away from the traditional vehicles. Davis (2019) shows that electric vehicles are driven much less than traditional cars nationwide, which suggests much smaller environmental benefits than expected. Understanding the underlying mechanism can help improve policy design for promoting adoption and encourage electric vehicles usage. This paper investigates two potential explanations for lower mileage in electric vehicles by exploring the mileage changes in households purchasing electric vehicles. For average households purchasing an electric vehicle, there is no significant change in the mileage of the other cars. However, households incentivized to adopt electric vehicles substitute certain mileage away from other cars in their portfolio. The substitution mainly comes from households adding a car to their portfolio, but not households replacing a car.

JEL code: D12, L62, Q41, Q58

Key words: Electric Vehicles; Vehicle Miles Traveled; Substitution among Vehicle Portfolio

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# 1 Introduction

Electric vehicles (EVs) are advocated as an environmentally friendly substitute for the traditional gasoline cars. Large amounts of government funding, including rebate, tax credits, and charging station subsidies, are spent in promoting EVs adoption. The benefits of the spending depend not only on the cost effectiveness of the policy in terms of adoption, but also on how much mileage can be substituted away from traditional vehicles. Little is known about the driving pattern of households with electric vehicles. It is unclear who selects into owning an electric vehicle, how much they expect to use it ex ante, as well as the ex post mileage realization. Davis (2019) shows that electric vehicles are driven much less than traditional cars nationwide and discusses several potential reasons. The finding suggests much smaller environmental benefits than previously expected. However, the exact mechanism remains unclear. Improving the understanding about who chooses to purchase EVs and how consumers use EVs versus other cars in the portfolio can help improve policy design and promote clean energy adoption. To provide further evidence of the mechanism at work, this paper explores the potential underlying reasons that EVs are driven less than other cars. Two main explanations, selection into purchasing an EV and substitution among cars in the portfolio, are discussed.

The argument that EVs are expected to be driven more is mainly based on the cost analysis, in terms of the upfront capital cost and variable driving costs. The upfront cost of EVs, which usually comes with high-ranking attributes, is much higher than traditional cars. Meanwhile, the variable cost, dollars-per-mile (DPM), for EVs can be much smaller. Sivak and Schoettle (2018) report that, a gasoline powered vehicle needs to have around 60 miles per gallon (MPG) for it to be equally cost effective as an EV. But the average MPG is lower than 25. Doing the cost-benefit analysis will lead to the conclusion that people with higher driving demand can benefit the most from purchasing an EV and thus are the target consumers.

Consumer's mileage demand may also depend on the car characteristics, especially the variable cost of driving. The rebound effect is a well-known example of people using their cars more when fuel efficiency is higher and the unit driving cost is lower. Opposite to the rebound effect, consumers may drive less when hitting the mileage limit of EVs. EVs have the well-known disadvantages of high capital cost, limited range, long charging times, and limited charging places ( S. Li, Tong, et al., 2017). It is possible that people purchasing EVs cannot utilize them as much as they planned, due to these restrictions. If this is the case, it is likely that people have to utilize other cars more than before to make up for the low mileage in EVs. This motivates the investigation of mileage substitution among the vehicles in the vehicle portfolio.

This paper relates to the literature of car usage, mileage substitution within household vehicle portfolio and Electric Vehicles.

Discrete choice models are usually employed to study the trade off between capital costs and car attributes. Goldberg (1995) uses a nested logit model to study the substitution among domestic and foreign cars. Berry et al. (1995) and McFadden et al. (1973) use a mixed logit model, or random coefficient logit model, to allow for consumer heterogeneity. Goldberg (1998) combines a discrete choice model of car purchase with continuous mileage usage. This paper uses the discrete choice model to illustrate the selection mechanism and extends the mileage model to multiple car usage to analyze the impact of the new car on other cars in the portfolio.

Substitution of mileage within cars in the same household has been documented by

Archsmith et al. (2017). One type of the instrumental variables used is the gasoline price at the time of car purchase. This type of IV is adopted in this paper.

One stream of the recent research about EVs is the network effect of charging stations. S. Li, Tong, et al. (2017) study the indirect network effect of charging stations on EV penetration. J. Li (2018) explores the efficiency improvement of unifying three incompatible charging standards in the U.S. This paper borrows the insight from these paper in using charging stations as an IV for EV purchase. Another stream of research focuses on the usage ( Davis, 2019) and transportation choice associated with consumer's environmental ideology ( M. E. Kahn, 2007). The goal of this paper is to provide supports for explaining the findings in Davis (2019).

The main finding of this paper is that selection is the main reason that EVs are on average driven less than gasoline cars. Substitution is heterogeneous. Households with EVs do not show much changes in their driving of other cars. However, households that are induced to purchase an EV substitute mileage away from traditional cars. The substitution mainly comes from households purchasing EVs to add to their portfolio, while there is almost no substitution effect when households purchase an EV to replace an old car.

As for policy implications, Davis (2019) suggests implementing gasoline tax to reduce gasoline consumption. Langer et al. (2017) and S. Li, Linn, et al. (2014) discuss different taxing strategies. Currently the most important barrier for EV adoption still lies in the high capital cost. Therefore, providing subsidies for EV purchases along with incentives to lower the price of an EV is a direct and intuitive approach. However, for the consideration of revenue neutral, supplementing subsidies with different taxing strategies may be a better balance.

The remainder of the paper is organized as follows. Section 2 introduces a model to explain the selection and substitution mechanism. Section 3 describes the data and summarizes the characteristics of four categories of cars by fuel type. Section 4 discusses the regression design to analyze the substitution pattern. Section 5 presents estimation results. Section 6 concludes. Other specifications are in the appendix.

# 2 A Model for Decision Making

## 2.1 Selection Decision

Consider household $h$ make decisions over which vehicle to purchase. The utility of choosing vehicle i is

$$u_i^h = -\alpha P_i^h(m_i^h) + s_i'\delta + w_h'\gamma_i + \xi_{i=EV}^h + \varepsilon_{hi}$$

Where $P_i^h(m_i^h) = \sum_{t=0}^{T} \beta^t (c_{it} m_{it}^h + r_{it}) - F_i$ is the discounted present cost of driving car $i$, given discount factor $\beta$, mileage demand $m_{it}$, variable cost for each mile $c_{it}$, capital cost $r_{it}$ of purchasing the car, from the time of purchase to the end of usage $T$, and possible subsidy $F_i$. $\alpha > 0$ for the distaste of paying. $s_i'$ is the vehicle attributes of car $i$ that people generally value. $w_h'$ is the household characteristics and the preference conditional on household characteristics, $\gamma_i$, is specific to the car $i$. $\xi_{i=EV}^h$ is one example of this term, which represents household specific preference for having an electric vehicle.

The probability of choosing an electric vehicle $i = EV$ is $P(u_{i=EV}^h > u_j^h \, \forall j \neq i)$:

$$P\left(-\alpha P_{\text{EV}}^h(m_{\text{EV}}^h) + s_{\text{EV}}'\delta + w_h'\gamma_{\text{EV}} + \xi_{EV}^h + \varepsilon_{hi} > -\alpha P_j^h(m_j^h) + s_j'\delta + w_h'\gamma_j + \varepsilon_{hj}, \, \forall j \neq \text{EV}\right)$$

First of all, assume there is no special preference for electric vehicle ($\xi = 0$). The decision for which car to purchase is completely based on monetary cost-benefit analysis and utility gain from vehicle attributes. In this case, household $h$ compares the monetary difference in purchasing and utilizing car $i$ versus car $j$, and consider whether this difference outweighs the difference in car attributes. That is, whether $\alpha\left(P_j^h(m_j^h) - P_{\text{EV}}^h(m_{\text{EV}}^h)\right)$ is larger than the difference in the characteristics $(s_j' - s_{\text{EV}}')\delta$. To simplify it more, assume no substitution effect or rebound effect, that the household plan to drive the same mileage independent of the car chosen. Let $m_t^h = m_{it}^h = m_{jt}^h$. Then the household choose an EV with probability:

$$P\left(\xi_{EV}^h + \alpha \sum_{t=0}^{T} \beta^t [(c_{jt} - c_{\text{EV},t})m_t^h] > \Delta_{j,i} + \varepsilon_{hj} - \varepsilon_{hi},\ \forall j \neq i\right)$$

Where $\Delta_{j,i} = \alpha\left(F_j - F_{\text{EV}} + \sum_{t=0}^{T} \beta^t (r_{\text{EV},t} - r_{jt})\right) + (s_j' - s_{\text{EV}}')\delta + w_h'(\gamma_j - \gamma_{\text{EV}})$. With the term $\Delta_{j,i}$ fixed, and assume the driving cost for an EV is always lower than an alternative car, $c_{jt} - c_{\text{EV},t} > 0\,\forall t$, then the higher is the mileage demand, the more beneficial it is to purchase an EV, and the higher is the probability of choosing an EV. Therefore, we expect people purchasing an EV to have a higher mileage demand ex ante. If this is true, observing a lower usage ex post may suggest that households with high mileage demand have to substitute mileage towards other cars in their portfolio. This implies households do not have complete understanding of the cost of utilizing an EV and make mistake in choosing an EV ex ante.

However, the above analysis is based on the assumption $m_t^h \perp\!\!\!\perp \xi_{i=EV}^h$, that mileage demand is independent of household characteristics. Assume mileage demand is negatively correlated with the preference for an EV, $cov(m_t^h, \xi_{i=EV}^h) < 0$, we can have higher probability of observing EV purchase from households with lower mileage demand while larger $\xi_{i=EV}^h$. This can be one explanation for observing the lower mileage driven in EV from the selection aspect.

## 2.2 Range Limit

Another potential explanation is the limited range and the long charging time of EV. People can only drive the EV for a certain distance and have to charge it. The charging process often takes longer than two hours and the charging locations are usually limited to at home and workplace. These together constrain the usage. To model the substitution among the vehicle portfolio, we build on the model by Goldberg (1998). [1]

Assume household $h$ with a car portfolio of $J^h$ chooses to purchase vehicle $i$ to maximize a conditional indirect utility function of the form:

$$V_i^h = (\beta(y - r_i + F_i) + \frac{\beta}{\varphi}\left[f(p., J^h, i) + \psi_i + w'\gamma_i + \eta_h\right])e^{-\varphi \sum_j p_j} + 1_{\text{i=EV}}\xi^h + \epsilon_h$$

Where $J^h, i$ denotes the new portfolio, and $k, j, l \in J^h, i$ are subscripts that index the vehicles in the household $h$. The term $f(p., J^h, i) = -\alpha \sum_j p_j - \theta \sum_{k<l} p_k p_l - \sum_j p_j s_j' \phi$ represents the burden from fuel costs of the cars in the portfolio. $-\alpha \sum_j p_j - \theta \sum_{k<l} p_k p_l$

[1] The model is not necessary or not good enough for this problem. I'm putting it here due to sunk cost fallacy.

represents the burden from having different costs for driving, while $-\sum_j p_j s_j'\phi$ is the interaction between vehicle attributes and the driving cost for each of the car. [2]

$p_j$ is the dollar per vehicle mile for car $j$, which is price per gallon divided by Miles Per Gallon. $s_j$ is a vector of vehicle attributes, $w$ is a vector of household characteristics, $y$ for income, $r_i$ represents the capital cost of vehicle $i$ and $F_i$ for subsidy for that type of car.

The term $\psi_i$ represents special preference for vehicle type $i$. $\eta_h$ for consumer characteristics that are unobserved. Finally, the last term $1_{\mathrm{i=EV}}$ is an indicator for car $i$ is an electric, $\xi^h$ represents the special preference for having an electric vehicle.

Denote TPP for the sum of all price interaction pairs, TP for the sum of all prices, $\mathrm{OP}_j$ for the sum of all prices other than vehicle $j$ as follows:

$$\begin{cases} \mathrm{TPP}^h & = \sum_{k<l} p_k p_l \\ \mathrm{TP}^h & = \sum_{j \in J^h} p_j \\ \mathrm{OP}_k^h & = \mathrm{TP}^h - p_k \end{cases}$$

Rewrite $f_k(p.) = -\alpha \mathrm{OP}_k^h - \alpha p_k - \theta \mathrm{TPP}^h + \sum_j p_j s_j' \phi$

Apply Roy's Identity and get mileage for vehicle $k$ in the portfolio:

$$\begin{aligned} m_k^h &= -\frac{\partial V_h / \partial p_k}{\partial V_h / \partial y} \\ &= (\theta/\varphi - \alpha)\mathrm{OP}_k^h - \alpha p_k + s_k' \phi/\varphi - \theta \mathrm{TPP}^h + \sum_j p_j s_j' \phi \\ &+ \psi_i + w' \gamma_i + \varphi(y_h - r_i + F_i) + \eta_h \end{aligned}$$

The coefficients for own price and cross price are as follows:

$$\begin{cases} \frac{\partial m_k}{\partial p_k} & = -\alpha - \theta \mathrm{OP}_k + s_k' \phi \\ \frac{\partial m_k}{\partial p_j} & = \theta/\varphi - \alpha - \theta \mathrm{OP}_j + s_j' \phi \end{cases}$$

The range limit problem can be modeled as a special attribute for an EV, denote this as $s_{\mathrm{EV}}^1$ with coefficient $\phi^1 < 0$, and a sudden increase in the price per mileage for the EV to represent customers realizing the extra cost associated with charging. Assume other terms for characteristics, $s_k^{-1}\phi^{-1}$, are small, $\frac{\partial m_{\mathrm{EV}}}{\partial p_{\mathrm{EV}}} = -\alpha - \theta \mathrm{OP}_{\mathrm{EV}} + s_{\mathrm{EV}}' \phi < 0$, mileage on an EV will decrease. Let $k$ denote another car in the portfolio, and $j$ denote the EV, $\frac{\partial m_k}{\partial p_{\mathrm{EV}}} = \theta/\varphi + \frac{\partial m_{\mathrm{EV}}}{\partial p_{\mathrm{EV}}}$, an increase in the price of an EV has a similar reduction effect on other car's mileage, but with an additional term $\theta/\beta$ as substitution towards other cars. If the substitution term is large enough, the increase in the cost of driving an EV due to the limited range and extra charging cost will lead to increase of mileage in other cars in the household.

[2]Adding an interaction term between price and vehicle attributes $\sum_j p_j s_j' \phi$ will lead to over-identification problem in the empirical estimation. However, without this term, there won't be asymmetric own car attribute effect on mileage.

# 3 Data

## 3.1 Data Set Construction

We identify car ownership and group households[3] according to the registration record from the Texas Department of Transportation (DOT). It covers 2009 - 2016. There are around 24 million cars registered in 2016, we have around one eighth of the records for each year. We focus on the five main cities in Texas, which includes Austin, Dallas, El Paso, Fort Worth and Houston. These five main cities have around half of the registration records of the whole Texas. Addresses were submitted to Census geocoder provided by the US Census Bureau to geocode and standardize the address. Due to the large number of data, only a subset of these registration is taken. We first choose vehicles with electricity as one of the fuel types,[4] then take all the cars that ever registered under the same addresses as these cars, repeat this step of taking cars from the same addresses until no more cars can be added. Similar to Hoekstra et al. (2017), potential commercial addresses are dropped. This data set is then used to group and track households overtime.

The outcome of interest is the mileage from each car in each year. The mileage is calculated from odometer reading data gathered during smog check.[5] Data are available from 2007 to 2016. The earliest and the latest odometer readings in each year are used to interpolate to get the mileage on the first date of each year. Subtracting the mileage in two consecutive years give the mileage increase in each year. Year 2017 and 2007 is extrapolated with the most recent two records if appropriate. Only the mileage increase from 2009 to 2016 is used, divided by total number of days in each year to get daily mileage. The odometer data are then matched to the administrative records according to the VIN number and year. Around 79% of the VIN in the selected registration data set can get matches from the odometer data, 70% of the records (VIN-year) in the registration data are matched without missing odometer. Follow West et al. (2017), raw odometer readings that are likely out of range are adjusted. For the calculated daily mileage, negative values and extreme values that lie beyond 95% of the fuel type in the whole data set were dropped.[6]Sometimes mileage can be lower than last observed. A robustness check with only cars that never have negative mileage increase is in the appendix. The result does not change by much.

Supplementary information about car characteristics, mainly car make, model, model year, primary and secondary fuel type and vehicle type are obtained through VIN decoding. NHTSA provides Vehicle API to decode VIN. Mileage per gallon information is provided by the US Environment Protection Agency (EPA), matched to the make, model, model year and possibly more details of the car whenever possible. Whenever the information of a specific model is not available, the average of the closest models is taken.

Fuel prices are from several online resources. energy.gov provides quarterly average US retail fuel prices for Gasoline, E85, CNG and Diesel. Gas prices for the five main cities in Texas were obtained from austingasprices.com,[7]

Information about regional demographic is taken at the block group level. The American Community Survey (ACS) provides 5-year estimates for some block group level

[3] See details in the appendix.

[4] Or equivalently, either EV, plug-in EV or not plug-in EV.

[5] In Texas, gasoline vehicle owners living in one of the 17 counties need to pass an annual smog check if the car is between 2 to 24 model years old. Most of these counties fall in the five main cities. Source

[6] Daily mileage above 74 miles are dropped.

[7] Chart data points converted into number using online graph digitizer automeris.

demographics. The most recent one available from Topologically Integrated Geographic Encoding and Referencing (TIGER) is for 2007-2011. TIGER provides the estimates along with the geographic shape file.

For the regression, only households ever have more than 1 cars are kept.[8] Each zip code - year with less than 5 observations and households with less than 10 observations are dropped to avoid singleton in the IV regression.

The 2017 National Household Travel Survey (NHTS) from the U.S. Department of Transportation is used for comparison. The most recent one other than 2017 is 2009. There were almost no electric vehicles in 2009 but the amount grew substantially since 2016.

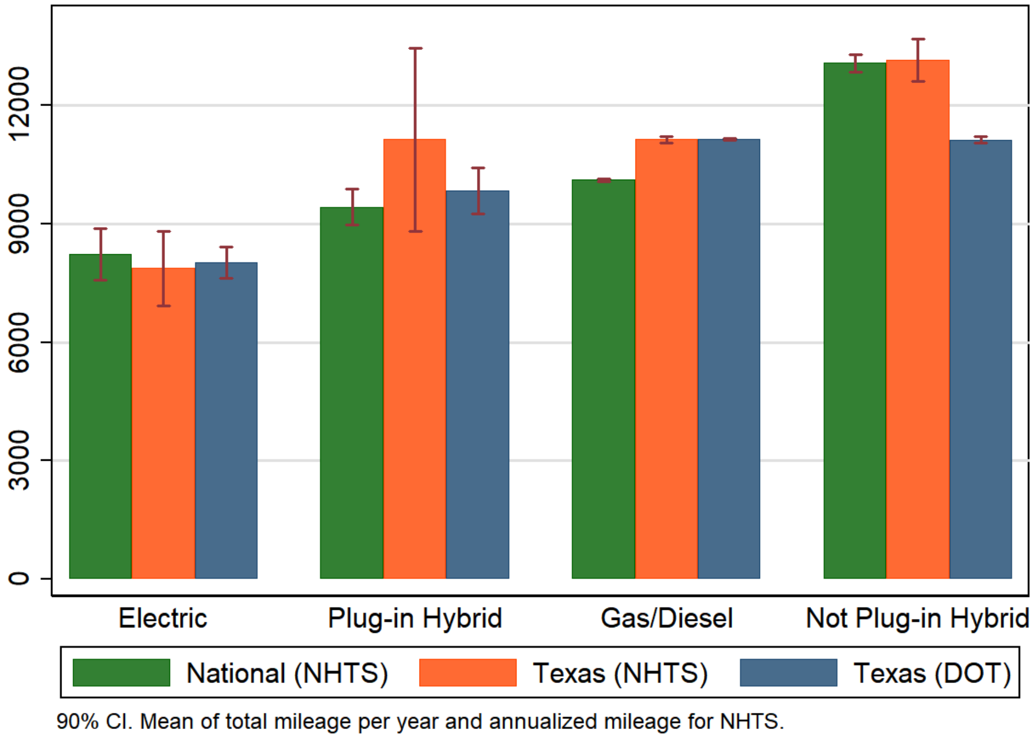
There are some problems with the registration data. There are around 3 million unique VIN each year in the registration data, but 8 million in the smog check data each year. Around 30% of the VIN in the smog check data ever shown up in the registration data. Since only 17 counties in Texas require smog check for a subset of vehicles, The VINs that appear in the registration data are probably less than a quarter of the whole data set. The missing data problem leads to the following problems: 1) We may not be observing all vehicles in each household; if the missing registration is not random across households with EV and households without, this will lead to certain estimation bias. For example, if the less frequently used cars in households with a new EV are missing from the registration, the estimation will be attenuated. Estimated substitution effect tends to be zero. 2) The observation of adding a new car may be later than actual. If a new EV is added to the household in 2011 but first observed in 2013, the estimated substitution effect may also be smaller. 3) The number of events may be smaller. If a new EV is added to the household in 2011 but first observed in 2015, this will not be considered as a new purchase and counted as an event. The direction of the bias is uncertain, though probably attenuating the effect. For this problem, we are contacting to see if we can get the whole record.

Another problem is with VIN decoding. The number of EV is too small and the percentage of unidentified primary fuel type is too high, around 20%. The information provided by EPA is probably the most official and the only approach for batch decoding. However, we need to be able to identify EV, PHEV and traditional hybrid cars from traditional internal combustion engine cars. We plan to manually collect a list of all makes and models for EV and PHEV to group the vehicles.

[8] This drops around half of the data set, the result is similar to without this restriction.

## 3.2 Summary Statistics

Figure 1: Annual mileage by fuel type




*Note*: The first two from NHTS. The last one is from the registration data. NHTS annual mileage estimated with weight.

Figure 1 follows Davis (2019) to show the annual mileage for each type of vehicles. Slightly different from Davis (2019), which takes the total mileage and divide by the age of the car, the annual mileage here is the mean of that metric and the annualized mileage calculated by NHTS. The first two bars, green and orange, are data from NHTS 2017, with sample weight. The last bar in blue is from the Texas DOT data in year 2016.[9] For the Texas data from the Texas DOT, the information in the primary and secondary fuel type is used to classify cars. A car is classified as electric if the only fuel used is electric. A car is classified as a Plug-in Hybrid if electric is the primary fuel type but not the only one. The rest using electric fuel is classified as not Plug-in Hybrids. Vehicles powered by Gasoline, Diesel, both or Gasoline with CNG are classified as Gas/Diesel. Those powered by gasoline with FFV (flexible fuel vehicle) or E85 are grouped into "Gas with FFV/E85". The rest are classified as "Other Fuel", mainly contains CNG, LPG, E85, FFV and natural gas. The annual mileage calculated from the Texas smog check data is comparable with NHTS data, though probably mis-classifying some of the Plug-in Hybrid into Not Plug-in Hybrid, which drives the mileage from the not plug-in hybrid down by a lot.

Table 1 shows the characteristics of the vehicles and the demographics of the region that these vehicles belong to. Although the data set is not a random sub-sample of the five main cities, the associated characteristics have the intuitive pattern. Gas and diesel powered vehicles are being driven the most, followed by Hybrid, and pure electric vehicles

[9] In theory, electric vehicles are not required to have smog check.

the least. Electric vehicles on average have a model year at around 2013, Gas/Diesel and conventional Hybrid cars are generally older. In terms of number of cars, households with EVs on average have 2 cars, while households with Gas/Diesel or conventional Hybrids usually have less cars.[10] EVs are from regions with higher percentage of white and households generally have higher income. They are also associated with regions that drivers prefer to drive alone to work, though lower percentage of both using private cars or public transportation. People in these regions are less likely to travel more than 30 minutes to work. Overall, EVs are concentrated in regions that do not have a high demand for driving. This is a suggestive evidence of selection leading to lower mileage in EV. The national average number of cars in households with electric vehicle or plug-in hybrid is 2.5 while 1.97 for all households with at least one car. The lower number of cars in the data set is probably due to sub-sampling data in the Texas DOT registration records.

[10] The result is consistent with Davis (2019), but cars from households with EVs are less.

Table 1: Characteristics Comparison by vehicle fuel types (Registrated in 2016)

| | **Electric** | **PHEV** | **Gas/Diesel** | **Hybrid** |
|---|---|---|---|---|
| *Daily Mileage* | 22.159 | 26.916 | 30.402 | 30.465 |
| | [0.663] | [0.972]*** | [0.045]*** | [0.149]*** |
| *Model Year* | 2013 | 2013 | 2008 | 2010 |
| | [0.078] | [0.076]*** | [0.013]*** | [0.028]*** |
| *# Cars in Household* | 2.076 | 1.952 | 1.774 | 1.892 |
| | [0.062] | [0.072] | [0.003]*** | [0.011]** |
| *Block Group Level Demographics* | | | | |
| *Male (%)* | 50.327 | 51.033 | 49.544 | 49.425 |
| | [0.355] | [0.428] | [0.019]* | [0.056]* |
| *White (%)* | 80.736 | 76.007 | 64.404 | 75.119 |
| | [0.878] | [1.193]** | [0.066]*** | [0.198]*** |
| *Black or* | 5.246 | 7.906 | 15.533 | 8.953 |
| *African American (%)* | [0.553] | [0.761]** | [0.057]*** | [0.151]*** |
| *Below Poverty Level (%)* | 7.462 | 10.268 | 16.109 | 10.057 |
| | [0.480] | [0.820]** | [0.040]*** | [0.111]*** |
| *Households Income* | 31.381 | 19.772 | 9.589 | 19.218 |
| $\geq$ *150k (%)* | [1.249] | [1.186]*** | [0.040]*** | [0.189]*** |
| *Median Income* | 112.967 | 81.542 | 57.843 | 82.723 |
| *(2011 Thousands)* | [3.458] | [3.070]*** | [0.102]*** | [0.468]*** |
| *Housing Units* | 831.685 | 903.321 | 869.710 | 799.689 |
| | [32.392] | [44.240] | [1.416] | [5.119] |
| *Means of Transportation to Work* | | | | |
| *Drive Alone (%)* | 79.566 | 78.069 | 77.337 | 79.377 |
| | [0.587] | [0.736] | [0.036]*** | [0.107] |
| *Private (%)* | 86.335 | 86.661 | 88.799 | 88.475 |
| | [0.509] | [0.662] | [0.026]*** | [0.086]*** |
| *Public (%)* | 1.607 | 2.340 | 3.345 | 2.250 |
| | [0.183] | [0.276]* | [0.015]*** | [0.042]*** |
| *Taxicab (%)* | 0.078 | 0.078 | 0.083 | 0.077 |
| | [0.029] | [0.033] | [0.002] | [0.005] |
| *Travel* $\geq$ *30min* | 26.883 | 29.698 | 36.495 | 33.329 |
| *to work (%)* | [0.819] | [1.054]* | [0.043]*** | [0.159]*** |
| *PM 2.5* | 7.658 | 7.714 | 7.683 | 7.669 |
| | [0.048] | [0.062] | [0.003] | [0.009] |
| *Obs* | 317 | 209 | 117,616 | 9,609 |

Two-sample t-test relative to EV with unequal variances.

Standard errors in parenthesis.

PHEV for Plug-in Hybrid, Hybrid for Conventional Hybrid.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

# 4 Empirical Design

## 4.1 Individual mileage for each car in the portfolio

The daily mileage for a car $k$ in household $h$ in year $y$ is modeled as follows:

$$m^h_{ky} = \psi 1_{i=\text{EV},y} + \alpha p_{k,y} + \varphi \text{OP}^h_{k,y} + s'_{k,y}\phi + w'_{h,y}\zeta + \rho_h + \gamma_y + \eta_{h,y}$$

Where $1_{i=\text{EV}}$ is an indicator for having an EV in the portfolio. $p_k$ is the dollar-per-mile driving cost of car $k$, $\text{OP}^h_k$ is the sum of the driving costs from other cars in the portfolio. $s'_k$ is a vector of car $k$ attributes, including car make, fuel type, age and age square. $w'_h$ is a vector of regional demographics,[11] either at the block group level or the zip code level. $\rho_h$ for region fixed effects, either at the zip code level or the city level, corresponding to demographics. $\gamma_y$ for year fixed effects.

The number of cars in the household is added to control for the effect of having an additional car versus replacing a car in the portfolio. However, this is not enough to capture the heterogeneous effect of adding a car versus replacing a car, as will be shown in Section 5.3.

The linear specification may not fit the data well, especially for daily mileage closer to zero. A semi-log specification with log mileage as the outcome variable is also tested.

## 4.2 Average mileage in each household

$$m^h_y = \tilde{\psi} 1_{i=\text{EV},y} + \tilde{\alpha}\frac{1}{J}\text{TP}^h_y + \frac{1}{J}\sum_j s'_{j,y}\tilde{\phi} + w'_{h,y}\tilde{\zeta} + \tilde{\rho}_h + \tilde{\gamma}_y + \tilde{\eta}_{h,y}$$

This specification provides a supplementary analysis to the above specification. This specification gives each household equal weight , while the individual car specification gives each household the weight proportional to the observed number of car-year in the household portfolio. The disadvantage of this specification is that covariates such as price and car age are not as meaningful to be incorporated into the covariates.

## 4.3 Instrument for purchasing an EV

The decision of which car to purchase is very likely to be correlated with how often the other cars in the portfolio will be used. The external margin is whether the older car will be kept or dropped when households decide to purchase a new car. The internal margin is how much mileage from the old car will be substituted by the new car. The OLS results will show the optimized mileage distribution, while using an IV can provide some information regarding the direction of bias of the joint decision and suggest what could happen when households are exogenously given an electric vehicle.

To instrument for having an EV, three sets of instrument variables (IV) are used in the main results.

The first set is subsidies. From May 13, 2014 to June 26, 2015, the Texas state provided a \$2,500 rebate for purchasing a plug in vehicle.[12] We define a variable TX2000 as an indicator for cars first purchased during this time frame. Between Oct, 2010 and

[11] Including dummies for number of cars in the household, and other variables in the summary statistics in Table 1.

[12] Online Reference and AFDC.

Jul, 2012, Coulomb Technologies' ChargePoint America program provided free EVSE to individuals who purchased a qualified plug-in electric vehicle in the Austin Metropolitan Statistical Area (MSA), in exchange for anonymous data collection. Austin Energy in the city of Austin offers rebates of 50% or up to $1,500 for the purchase of ChargePoint home charging station. We define a variable AE for cars first purchased during this time frame and households living in Austin MSA according to the zip code.[13] An experiment led by ECOtality[14] during Jul, 2012 - Mar, 2013 provided Electric Vehicle Supply Equipment (EVSE) Incentive, including free equipment and installation to people purchasing a qualified electric car and in selected region in exchange for consumer driving data. We define a variable ECOtality as an indicator for cars purchased in this time frame and households living in MSA of Dallas, Fort Worth and Houston.

We assume the purchase date to be the date the car is registered, this is probably accurate at the monthly level. Besides, we consider new cars purchased, defined as if the first observed registration is within 3 years of the vehicle's model year.

Similar to the IV used by S. Li, Tong, et al. (2017), the second IV is the number of charging station in each zip code region, defined as "stations".[15] A preferred control is the number at the time of purchase, so it is less correlated with the driving decision afterwards. However, only around one third of the stations have opening dates and there is not enough variation.

Also similar to the IV used by Archsmith et al. (2017), the third IV is the gasoline price at the time of purchasing a new car, define this variable as "GP". It varies by city by month.

An extra fourth set of IV is the EV/PHEV percentage in the previous year in the same zip code region, estimated from the registration data. This IV is not used in the main specification, results in the appendix for robustness check.

For the instrument variables to be valid, it has to be correlated with the endogenous variable, which is the household PHEV purchase dummy, but should not affect the post purchase mileage through any other channels. All these IVs are potentially relevant for adoption decision. The relevance will be tested in the empirical work below. For the exclusion restriction, the subsidies are one shot payment, do not have a long duration, and probably not large enough to have any general equilibrium effect. This makes it less likely to violate the exclusion restriction. The gasoline price at the time of purchase could be serially correlated in each region, but future variable costs are controlled. There is not much variation in the charging station variable, this may lead to identifying regional differences. Regional fixed effects at either the zip code level or household level are both tested.

However, there are concerns about the IVs. The instrument using the number of charging stations in each zip code can be problematic in that it has only geographical variation and household can move in and out of different regions. If households move into regions with more charging stations and then adopt an EV, the difference in the driving pattern will not be just from adding an EV, but also from the new environment that changes the driving demand, mainly the distance to work. This can be attenuated by adding some approximation for the local environment. A set of block group level demographics, including travel time to work, percentage of private driving, number of housing units and the intensity of PM 2.5 are added to help control for the moving. The

[13] Need to update to use longitude & latitude, the zip code shape file is for ZCTA, not exactly zip code.
[14] Later held by Idaho National Lab.
[15] Downloaded from AFDC.

subsidies instruments can be problematic in a similar way. In addition to the concern that people may move to be qualified for the incentives, it is also possible that people sensitive to the incentives may have different adjustment in their driving behavior, from people that are not paying much attention to such incentives. In this case, the estimated effect is local to the population that is sensitive to subsidies.

# 5 Results

For the rest of the analysis, PHEV is used to indicate either an EV or a plug-in Hybrid and nPHEV represents not Plug-in Hybrids. The main data set used is the households ever had at least one PHEV or nPHEV. Results for using two other control groups are in the appendix. The smallest data set includes only households ever had a PHEV, while the other one is the largest which consists of all households ever registered their car in the same addresses as the PHEV or nPHEV households. All PHEV cars are excluded from the regressions.

## 5.1 First Stage

The following is the first stage results for using five instrument variables. The combination of these five instrumental variables pass the under-identification, and weak instrument test, although this does not guarantee a valid instrument. The null hypothesis of over-identification is that the instruments are orthogonal to the error term and the excluded instruments are correctly excluded from the estimated equation. Rejecting the null means the IVs are potentially correlated with unobserved variables that are correlated with mileage. The over-identification test rejects the null when only controlling for region fixed effects, but not when controlling for household fixed effects under individual mileage. This may suggest adding more controls at the household level can help improve the model.

The sign of each variable is positive, with the exception of ECOtality under zip code or city fixed effect and AE under household fixed effect, though not significant for the latter. The higher the gasoline prices at the time of purchase increases the likelihood of purchasing a PHEV, households from regions with more charging stations are more likely to purchase PHEV and subsidies are positively correlated with PHEV purchase. In the robustness check in the appendix, excluding charging stations or including EV/PHEV percentage in the previous year gives similar results. The first stage is the same for linear and semi-log specification, only results for individual mileage and average mileage are shown.

Table 2: First Stage for PHEV purchase

| | Individual | | Average | |
|---|---|---|---|---|
| GP | 0.00215*** | 0.00156*** | 0.00318*** | 0.00289*** |
| | (0.00038) | (0.0003) | (0.00079) | (0.00076) |
| stations | 0.00144*** | 0.00174*** | 0.00315** | 0.00419*** |
| | (0.00037) | (0.00032) | (0.00095) | (0.00103) |
| TX2000 | 0.01092** | 0.01199*** | 0.00673 | 0.01021* |
| | (0.00317) | (0.00246) | (0.00424) | (0.00422) |
| AE | 0.00488 | -0.00078 | 0.01053 | 0.00892 |
| | (0.00518) | (0.00316) | (0.01427) | (0.01288) |
| ECOtality | -0.00139 | 1e-05 | -0.00315 | -0.0005 |
| | (0.00229) | (0.00196) | (0.00445) | (0.00519) |
| Under Id | 67.30*** | 144.98*** | 51.43*** | 91.38*** |
| ARW F | 19.92*** | 4.89*** | 11.68*** | 4.21*** |
| ARW $\chi^2$ | 100.06*** | 24.46*** | 58.63*** | 21.05*** |
| SW $\chi^2$ | 68.58*** | 24.54*** | 41.30*** | 21.20*** |
| Over Id | 26.709*** | 7.194 | 31.107*** | 15.687** |
| Obs | 381,388 | 381,377 | 189,499 | 189,077 |
| Num Cluster | 243 | 33,062 | 243 | 32,459 |
| FE | Zipcode | Household | Zipcode | Household |

Robust standard errors clustered by region in parentheses
Under Id for under-identification test (Kleibergen-Paap rk LM statistic)
ARW stands for Anderson-Rubin Wald test
SW stands for Stock-Wright LM S statistic
Over Id stands for over-identification test (Hansen J statistic)
$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

## 5.2 Mileage effect on other cars in the same household

Table 3 shows the result for the linear specification.[16] Other controls not shown in the table include block group level demographic and household characteristics. Households after purchasing their first PHEV have on average 2 miles per day lower mileage on other cars in their portfolio under the specification with zip code fixed effect, the effect goes away once household fixed effects are included. For the IV specification, when household fixed effects are included, the estimated substitution is 30 miles per day, with a wide 95% confidence interval in the range of [-46.01, -15.24]. Given that the mean of driving a Gasoline powered vehicle is around 30 miles per day, and that the estimation only captures the internal margin of substitution, this point estimate is neither reasonable nor accurate. For the IV specification, going from controlling zip code fixed effects to controlling for household fixed effects significantly reduce the magnitude of the coefficient. Maybe adding more controls can help pin down a better coefficient.[17]

[16] Block group level demographics are included also for specification with household fixed effects. Household may move to another region and thus not perfectly colineared.

[17] PM 2.5 intensity in each block group region varies by year, data created by van Donkelaar et al. (2018). It is added for the hope of getting a better estimate, but without much improvement.

Table 3: Mileage on other cars when purchase a new PHEV

| | OLS | IV | OLS | IV |
|---|---|---|---|---|
| Post(PHEV) elec=1 | -2.0807** | -73.9492*** | -0.3641 | -30.6211*** |
| | (0.7267) | (11.2276) | (0.6179) | (7.8490) |
| Own Price | -0.0099*** | -0.0098*** | -0.0068** | -0.0089* |
| | (0.0028) | (0.0027) | (0.0024) | (0.0036) |
| Other Price | -0.0094 | -0.0770* | -0.0253 | -0.0647 |
| | (0.0578) | (0.0382) | (0.0321) | (0.0414) |
| Age | -0.7117*** | -0.7283*** | -0.8907*** | -0.8861*** |
| | (0.0360) | (0.0378) | (0.0314) | (0.0300) |
| Age Sq | -0.0182*** | -0.0166*** | -0.0092*** | -0.0094*** |
| | (0.0016) | (0.0018) | (0.0015) | (0.0015) |
| PM 2.5 | -0.2338* | -0.2337* | -0.1155* | -0.1262** |
| | (0.1112) | (0.1115) | (0.0463) | (0.0445) |
| Region FE | Zip Code | Zip Code | Household | Household |
| Year FE | Yes | Yes | Yes | Yes |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1457 | 0.0106 | 0.4435 | 0.0677 |
| adj.R-squared | 0.1449 | 0.0103 | 0.3904 | 0.0674 |

Standard errors clustered by region in parentheses.

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4 shows the result for the semi-log specification. The coefficient for the IV specification with household fixed effects translates into 18%, which means having an PHEV on average reduces the mileage on other cars by about 82%, with a 95% confidence interval [61%,91%]. Similar results as the linear specification, and the point estimation is similarly not reliable. The main takeaway is the sign of the coefficient is negative. If exogenously given a PHEV, household will use the PHEV instead of other traditional cars.

Table 4: Percentage Mileage Change on other cars when purchase a new PHEV

| | OLS | IV | OLS | IV |
|---|---|---|---|---|
| Post(PHEV) elec=1 | -0.1378*** | -3.2804*** | -0.0778* | -1.7057*** |
| | (0.0403) | (0.5567) | (0.0326) | (0.3861) |
| Own Price | -0.0004* | -0.0004* | -0.0003 | -0.0004 |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Other Price | 0.0020 | -0.0010 | 0.0001 | -0.0021 |
| | (0.0026) | (0.0017) | (0.0014) | (0.0024) |
| Age | -0.0005 | -0.0012 | -0.0093*** | -0.0093*** |
| | (0.0026) | (0.0026) | (0.0022) | (0.0021) |
| Age Sq | -0.0029*** | -0.0029*** | -0.0025*** | -0.0025*** |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| PM 2.5 | -0.0075 | -0.0068 | -0.0065** | -0.0072*** |
| | (0.0052) | (0.0053) | (0.0022) | (0.0021) |
| Region FE | Zip Code | Zip Code | Household | Household |
| Year FE | Yes | Yes | Yes | Yes |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1808 | 0.0565 | 0.4523 | 0.0907 |
| adj.R-squared | 0.1801 | 0.0563 | 0.4002 | 0.0905 |

Standard errors clustered by region in parentheses.
With demographic.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

### 5.3 Replacement versus Addition

Table 5 and 6 shows the results for semi-log specification with the data set being restricted to households only replacing cars or only adding a new car, all other controls are the same as above. For replacement, the number 1 or 2 after OLS or IV indicates whether the most recent car is dropped within one year or two. For example, a household dropping a car A within one year of buying a new car B in 2013 has the car A last registered in some day of year 2013. Similar for addition, the number indicates that no car in the household is dropped within the corresponding window. There is almost no effect on other cars when restrict to replacement. Meanwhile, there is substantial substitution away from other cars, at around 74% for not dropping a car within a year of new purchase and 95% for not dropping a car within two years of new purchase, with OLS estimates going in the same direction but at a much smaller magnitude. Together this suggests that people adding a PHEV will reduce the usage of other cars while replacing an older car with a PHEV will not make people substitute mileage to other cars. This implies substitution effect is small, and indirectly suggest selection is at work. Combining the demographics summary statistics, rich people with mild mileage demand select to purchase PHEV.

Table 5: Mileage effect with replacement

| | OLS 1 | IV 1 | OLS 2 | IV 2 |
|---|---|---|---|---|
| Post(PHEV) elec=1 | 0.0225 | 0.3343 | 0.0087 | -0.0803 |
| | (0.0455) | (0.6657) | (0.0404) | (0.5044) |
| Own Price | 0.0001* | 0.0001* | -0.0001 | -0.0001 |
| | (0.0001) | (0.0000) | (0.0002) | (0.0001) |
| Other Price | -0.0003 | -0.0001 | 0.0005 | 0.0004 |
| | (0.0015) | (0.0015) | (0.0013) | (0.0013) |
| Age | -0.0016 | -0.0014 | -0.0025 | -0.0023 |
| | (0.0038) | (0.0037) | (0.0033) | (0.0031) |
| Age Sq | -0.0030*** | -0.0030*** | -0.0029*** | -0.0029*** |
| | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| PM 2.5 | -0.0048 | -0.0048 | -0.0034 | -0.0036 |
| | (0.0038) | (0.0037) | (0.0032) | (0.0031) |
| Region FE | Household1 | Household1 | Household2 | Household2 |
| Year FE | Yes 1 | Yes 1 | Yes 2 | Yes 2 |
| Observations | 113,499 | 113,499 | 153,586 | 153,584 |
| R-squared | 0.4314 | 0.1060 | 0.4289 | 0.1051 |
| adj.R-squared | 0.3870 | 0.1054 | 0.3834 | 0.1046 |

Standard errors clustered by region in parentheses.

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Mileage effect with addition

| | OLS 1 | IV 1 | OLS 2 | IV 2 |
|---|---|---|---|---|
| Post(PHEV) elec=1 | -0.1326* | -1.3364* | -0.2502*** | -2.9736** |
| | (0.0570) | (0.6392) | (0.0703) | (1.0401) |
| Own Price | 0.0565 | 0.0677 | -0.1059 | -0.0621 |
| | (0.1571) | (0.1509) | (0.2146) | (0.2102) |
| Other Price | -0.0465 | -0.1416 | -0.0231 | -0.2951* |
| | (0.0616) | (0.0738) | (0.0981) | (0.1352) |
| Age | -0.0052 | -0.0048 | -0.0014 | -0.0022 |
| | (0.0055) | (0.0053) | (0.0075) | (0.0073) |
| Age Sq | -0.0027*** | -0.0027*** | -0.0030*** | -0.0029*** |
| | (0.0003) | (0.0003) | (0.0004) | (0.0004) |
| PM 2.5 | -0.0104* | -0.0122* | -0.0151* | -0.0179** |
| | (0.0053) | (0.0051) | (0.0070) | (0.0068) |
| Region FE | Household1 | Household1 | Household2 | Household2 |
| Year FE | Yes 1 | Yes 1 | Yes 2 | Yes 2 |
| Observations | 52,984 | 52,982 | 28,286 | 28,286 |
| R-squared | 0.4683 | 0.0958 | 0.4935 | 0.0367 |
| adj.R-squared | 0.4172 | 0.0944 | 0.4441 | 0.0341 |

Standard errors clustered by region in parentheses.
With demographic.
$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

## 5.4 Emission implications

The above estimations show the impact of purchasing an EV on the usage of the other cars in the household's portfolio. The substitution effect mainly comes from households adding a new car. Around 38.8% of the new purchased PHEV are classified as adding to the households without dropping a car in one year, which on average reduces the usage of other cars by 73.7% in each year. There are 1.86 cars in each of such households, the average annual mileage is 9,672 miles and the average fuel economy is 22.7 mpg. [18] There were 109,449 EVs sold in the US in 2014, according to Xing et al. (2019). The estimated reduction of gasoline consumption is 24.8 million gallons, equivalent to 0.49 million pounds of $CO_2$in a year. [19]

The above calculation can be interpreted as the saving from shortening the lifetime of other vehicles in the household portfolio when the household purchases an EV.

The current setting is not suitable for estimating the counterfactual of selection effect.

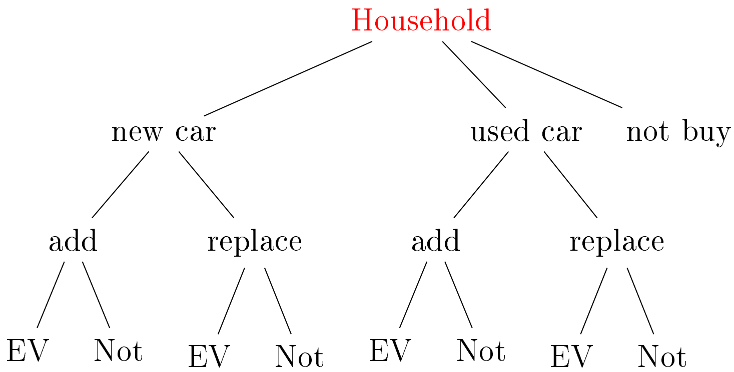
[18]The fuel economy information is from EPA, combined for city and highway. The information is available for 70% of the observations. According to Xing et al. (2019), the average fuel economy is 23 mpg, but it is 21.5 in our data set.

[19]Using a fuel economy of 28.9 mpg results in 19.5 million gallons, 0.38 million pounds of $CO_2$in a year.

A recent working paper by Xing et al. (2019) focus on the selection effect. According to their results, around 78.7% of the EV replaced conventional gasoline vehicles, with an average fuel economy of 28.9 mpg. Assume the lifetime vehicle miles traveled (VMT) is 195,264, the lifetime gasoline consumption saved from purchasing EVs in 2014 for the whole US is 0.51 billion gallons, equivalent to 9.94 million pounds of $CO_2$. The estimation based heavily on the number of EVs sold. Since the adoption of EVs surges in 2016, the environmental benefits in 2016 and after will be much higher than this calculation.

We tend to believe that the low mileage in EVs are mainly due to household selection. However, in the case of adding an EV without dropping any other cars in one year, the estimation of mileage reduction proportion on other cars is large and the average fuel economy of other cars is low. Because of these, the aggregate emission saving is at a magnitude similar to the saving from purchasing an EV instead of a conventional gasoline car in each year.

The future plan is to incorporate the portfolio choice and mileage usage, similar to Goldberg (1998). This will include estimating the choice of portfolio similar to the following structure, and use the estimated probability as weights to instrument for the car choice. The coefficients can be interacted with car attributes to provide more detailed estimations, though the computation complexity may increase quickly. To allow for multiple purchase, we are considering changing the dependent variable from daily mileage to the difference of average annual mileage before and after each year. The specification is still under discussion.




# 6 Conclusions and Discussions

Electric vehicle is a new clean energy technique to reduce emissions. Governments are spending a lot of funding in promoting EVs. However, the efficiency of various promotions and the benefits of employing EV are still under examination. EVs have the advantage of low driving cost, lower emissions and other nice features. However, EVs are subject to high capital cost, limited mileage, long charging time and not enough charging places. All else the same, it is more beneficial if people with higher mileage demand choose to drive EVs. However, Davis (2019) finds that EVs are much driven less than gasoline or diesel powered vehicles. On the one hand, this could be due to selection, people aware of the limited usage of EVs and only select to purchase an EV when they do not have high demand for mileage. On the other hand, substitution to other cars can be another potential explanation if people did not recognize the limited usage of EVs ex ante.

This paper tries to figure out the underlying mechanism that EVs are driven less. By comparing the block group demographics for different fuel types, it is suggestive that people that are rich and with lower demand for long distance travel choose to purchase EVs.

The OLS estimates show that households with a PHEV on average do not significantly change their driving behavior in other cars in the portfolio. However, the IV estimates show that households induced to purchase a PHEV significantly reduce their usage in other cars. Splitting the data into households adding a new car and households replacing an old car show that the substitution mainly comes from households adding a PHEV to their portfolio. For households replacing their old cars with a PHEV, there is almost no substitution effect on other cars.

The main takeaway may be that selection is the main reason that EVs are driven less, while there is few evidence of substitution. With EVs getting improvement in its range limit, more charging stations being built and possibly lower capital costs in the future, it is expected that EVs will be driven more. In such context, subsidies to encourage EV adoption may be a direct approach.

Regarding the policy design, we lack of detailed information about who actually adopted an EV and received the subsidies. Besides, we do not have information about the capital cost for each car. The noisy usage of credit incentives may not provide good estimation for policy design. Further research may gather such information and compare policy instruments as in Xing et al. (2019).

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# 7 Appendix

## 7.1 Data Construction

### 7.1.1 Identifying Households

Addresses are geocoded and standardized, this gives the longitude and latitude. PM 2.5 values are the average of the grid point value within each block group region, and added to the demographics data. The demographics data are matched according to whether the address point locates in the block group region.

To group vehicles into households, first we track each vehicle across years and make use of the addresses and owner's name to classify them into 1) the same household moving to another place; 2) car sold to another household; 3) staying in the same place. Then from each vehicle, we take all other vehicles ever in the same address with an overlapping time frame as the targeted vehicle, choose if first four characters and last four characters of the owner's name match with the target. After including this new set of vehicles, we repeat the same process for all vehicles, until no more vehicles can be added, and assign a household id for this group. We need to do this for each vehicle as the grouping may not be transitive. After each vehicle has its household group, we then merge and clean up duplicates. The final data set has unique vehicle-year.

### 7.1.2 Interpolating Annual Mileage

For each vehicle in each calendar year, we keep the first and the last odometer reading. Extremely small or large odometer values are multiplied or divided by 10 respectively. Extreme values after previous operation are dropped. For each year 20xx other than 2007 and 2017, we take the last odometer reading before January 1st, 20xx and the first odometer reading in 20xx and take linear interpolation to get the odometer on Jan 1st, 20xx. For 2007, take the two observations in 2008, if available, and do extrapolation, missing if not available. Similarly use 2016 for 2017. The annual mileage for 20xx is the difference between Jan 1st, 20xx and Jan 1st 20xx+1. The daily mileage is the annual mileage divided by the number of days in each year. This data set is then matched to the registration data according to VIN and year.

## 7.2 Other Controls

Each column shows different specification, OLS or IV, with different region fixed effect, zip code or household level. Each row shows different data set. Post(EV) means the indicator is only for purchasing an EV while Post(PHEV) means the indicator is for either an EV or a plug-in hybrid. The rows with "elec=1" represent the main data set used. The rows without such indication are using the most restricted data set, with only households ever had PHEV. Finally, the rows with "all=1" are for the whole data set.

### 7.2.1 Linear specification

Table 7: Mileage on other cars when purchase a new (PH)EV

| | OLS Zip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| Post(EV)=1 | -0.3491 | -1.8261 | 0.4325 | 1.7003 |
| | (0.9401) | (2.4533) | (0.8667) | (2.5540) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3342 | 0.1015 | 0.5286 | 0.0659 |
| adj.R-squared | 0.3022 | 0.0875 | 0.4717 | 0.0513 |
| Post(EV) elec=1 | -1.7516* | -98.1811*** | -0.3288 | -40.0829*** |
| | (0.8642) | (15.6111) | (0.7487) | (10.6516) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1457 | -0.0121 | 0.4435 | 0.0654 |
| adj.R-squared | 0.1449 | -0.0124 | 0.3904 | 0.0651 |
| Post(EV) all=1 | -1.4743 | -2.0e+02*** | -0.4056 | -66.1024*** |
| | (0.8644) | (28.2118) | (0.7483) | (15.3470) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1372 | -0.1361 | 0.4614 | 0.0517 |
| adj.R-squared | 0.1367 | -0.1363 | 0.4051 | 0.0515 |
| Post(PHEV)=1 | -1.0402 | -1.3683 | 0.0724 | 0.3910 |
| | (0.9401) | (1.4744) | (0.7236) | (1.4327) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3347 | 0.1033 | 0.5285 | 0.0665 |
| adj.R-squared | 0.3028 | 0.0893 | 0.4717 | 0.0519 |
| Post(PHEV) elec=1 | -2.0807** | -73.9492*** | -0.3641 | -30.6211*** |
| | (0.7267) | (11.2276) | (0.6179) | (7.8490) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1457 | 0.0106 | 0.4435 | 0.0677 |
| adj.R-squared | 0.1449 | 0.0103 | 0.3904 | 0.0674 |
| Post(PHEV) all=1 | -1.8567* | -1.2e+02*** | -0.5334 | -40.5407*** |
| | (0.7182) | (15.1511) | (0.5513) | (8.6105) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1372 | -0.0512 | 0.4614 | 0.0576 |
| adj.R-squared | 0.1368 | -0.0513 | 0.4051 | 0.0575 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

### 7.2.2 Log specification

Table 8: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLS Zip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| Post(EV)=1 | -0.0236 | -0.1747 | 0.0078 | -0.0539 |
| | (0.0491) | (0.1198) | (0.0435) | (0.1326) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3916 | 0.1615 | 0.5594 | 0.1155 |
| adj.R-squared | 0.3624 | 0.1484 | 0.5063 | 0.1017 |
| Post(EV) elec=1 | -0.1204* | -4.4676*** | -0.0523 | -2.2985*** |
| | (0.0481) | (0.7973) | (0.0369) | (0.5306) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1808 | 0.0342 | 0.4523 | 0.0867 |
| adj.R-squared | 0.1800 | 0.0339 | 0.4001 | 0.0864 |
| Post(EV) all=1 | -0.1138* | -9.0279*** | -0.0553 | -4.2527*** |
| | (0.0484) | (1.3087) | (0.0369) | (0.7822) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1673 | -0.0803 | 0.4625 | 0.0635 |
| adj.R-squared | 0.1669 | -0.0804 | 0.4063 | 0.0633 |
| Post(PHEV)=1 | -0.0691 | -0.1119 | -0.0409 | -0.0448 |
| | (0.0470) | (0.0708) | (0.0387) | (0.0746) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3924 | 0.1666 | 0.5596 | 0.1165 |
| adj.R-squared | 0.3632 | 0.1535 | 0.5065 | 0.1026 |
| Post(PHEV) elec=1 | -0.1378*** | -3.2804*** | -0.0778* | -1.7057*** |
| | (0.0403) | (0.5567) | (0.0326) | (0.3861) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1808 | 0.0565 | 0.4523 | 0.0907 |
| adj.R-squared | 0.1801 | 0.0563 | 0.4002 | 0.0905 |
| Post(PHEV) all=1 | -0.1218** | -5.2044*** | -0.0717* | -2.4726*** |
| | (0.0366) | (0.6917) | (0.0283) | (0.4245) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1673 | 0.0003 | 0.4625 | 0.0758 |
| adj.R-squared | 0.1669 | 0.0001 | 0.4063 | 0.0756 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

## 7.3 Average mileage of the household

### 7.3.1 Linear specification

Table 9: Mileage on other cars when purchase a new (PH)EV

| | OLSZip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| PostEV=1 | -0.1967 | -1.7276 | -0.7336 | 0.9102 |
| | (1.7181) | (2.8129) | (1.6243) | (2.7184) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4186 | 0.1221 | 0.7028 | 0.0825 |
| adj.R-squared | 0.3713 | 0.1110 | 0.6257 | 0.0709 |
| PostEV elec=1 | -0.9764 | -47.0620*** | -0.6417 | -29.7738* |
| | (1.5333) | (13.0519) | (1.3686) | (12.1106) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1307 | 0.0736 | 0.6224 | 0.0572 |
| adj.R-squared | 0.1294 | 0.0734 | 0.5431 | 0.0571 |
| PostEV all=1 | -0.9183 | -63.1089*** | -0.7765 | -33.6335* |
| | (1.5363) | (18.5176) | (1.3743) | (15.7343) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1255 | 0.0702 | 0.6377 | 0.0518 |
| adj.R-squared | 0.1249 | 0.0702 | 0.5584 | 0.0517 |
| PostPHEV=1 | -1.2979 | -1.2923 | -1.5803 | -0.0352 |
| | (1.5199) | (1.6975) | (1.5142) | (1.4785) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4193 | 0.1242 | 0.7033 | 0.0837 |
| adj.R-squared | 0.3720 | 0.1131 | 0.6263 | 0.0721 |
| PostPHEV elec=1 | -1.4689 | -31.2983*** | -0.4091 | -18.3043* |
| | (1.3018) | (9.1591) | (1.2046) | (8.2896) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1307 | 0.0802 | 0.6224 | 0.0603 |
| adj.R-squared | 0.1295 | 0.0801 | 0.5431 | 0.0601 |
| PostPHEV all=1 | -1.5854 | -36.2289*** | -1.0600 | -16.8387 |
| | (1.1962) | (10.4899) | (1.1152) | (8.7803) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1255 | 0.0768 | 0.6377 | 0.0544 |
| adj.R-squared | 0.1249 | 0.0767 | 0.5584 | 0.0544 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

### 7.3.2 Log specification

Table 10: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLSZip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| PostEV=1 | -0.0841 | -0.2611* | -0.1048 | -0.1254 |
| | (0.0788) | (0.1263) | (0.0760) | (0.1355) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4720 | 0.1874 | 0.7079 | 0.1615 |
| adj.R-squared | 0.4290 | 0.1771 | 0.6322 | 0.1508 |
| PostEV elec=1 | -0.1513 | -4.1774*** | -0.1372 | -3.6790*** |
| | (0.0862) | (0.7812) | (0.0738) | (0.6770) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1311 | 0.0376 | 0.6068 | 0.0214 |
| adj.R-squared | 0.1298 | 0.0375 | 0.5242 | 0.0213 |
| PostEV all=1 | -0.1576 | -6.0186*** | -0.1411 | -5.3587*** |
| | (0.0871) | (1.0618) | (0.0748) | (0.9122) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1280 | 0.0327 | 0.6154 | 0.0079 |
| adj.R-squared | 0.1274 | 0.0327 | 0.5312 | 0.0078 |
| PostPHEV=1 | -0.1456* | -0.1496* | -0.1569* | -0.0747 |
| | (0.0718) | (0.0725) | (0.0757) | (0.0733) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4747 | 0.1980 | 0.7096 | 0.1643 |
| adj.R-squared | 0.4320 | 0.1878 | 0.6343 | 0.1537 |
| PostPHEV elec=1 | -0.1699* | -2.9748*** | -0.1464* | -2.3202*** |
| | (0.0737) | (0.5523) | (0.0657) | (0.4350) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1311 | 0.0577 | 0.6068 | 0.0438 |
| adj.R-squared | 0.1299 | 0.0575 | 0.5242 | 0.0436 |
| PostPHEV all=1 | -0.1659* | -3.6321*** | -0.1495* | -2.6937*** |
| | (0.0648) | (0.5942) | (0.0585) | (0.4599) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1281 | 0.0585 | 0.6154 | 0.0397 |
| adj.R-squared | 0.1275 | 0.0584 | 0.5313 | 0.0396 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Longer appendix available upon request.

## 7.4 Replacement

### 7.4.1 First Stage

Table 11: First Stage Summary

| | 1 | 2 | 1 | 2 |
|---|---|---|---|---|
| GP | 0.00206*** | 0.00159*** | 0.00121** | 0.00079* |
| | (0.00051) | (0.00041) | (0.00042) | (0.00035) |
| stations | 0.00091* | 0.00115** | 0.0014** | 0.00174*** |
| | (0.00036) | (0.00039) | (0.00042) | (0.00037) |
| TX2000 | 0.01032** | 0.01211*** | 0.00944** | 0.01115*** |
| | (0.00353) | (0.00335) | (0.00326) | (0.00275) |
| AE | -0.00231 | -0.00389 | -0.00201 | -0.00354 |
| | (0.0051) | (0.00456) | (0.00376) | (0.00303) |
| ECOtality | -0.0011 | -0.00031 | 0.00031 | 0.0013 |
| | (0.00341) | (0.00268) | (0.00276) | (0.00228) |
| Under Id | 42.94*** | 48.18*** | 58.25*** | 70.93*** |
| ARW F | 1.54 | 2.27* | 1.04 | 2.45* |
| ARW $\chi^2$ | 7.76 | 11.38* | 5.22 | 12.26* |
| SW $\chi^2$ | 7.53 | 10.69 | 5.24 | 12.26* |
| Over Id | 7.463 | 9.293 | 4.867 | 8.783 |
| Obs | 113,486 | 153,572 | 113,499 | 153,584 |
| Num Cluster | 240 | 242 | 8,141 | 11,233 |
| FE | Zipcode | Zipcode | Household | Household |

Robust standard errors clustered by region in parentheses

Under Id for under-identification test (Kleibergen-Paap rk LM statistic)

ARW stands for Anderson-Rubin Wald test

SW stands for Stock-Wright LM S statistic

Over Id stands for over-identification test (Hansen J statistic)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

### 7.4.2 Linear specification

Table 12: Mileage on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | 1.6899 | -2.1116 | 1.6580 | -15.2385 | 1.1896 | -15.5978 | 1.6215 | -25.5655 |
| | (1.1250) | (18.8637) | (1.0793) | (19.4414) | (0.9260) | (14.4249) | (0.9357) | (14.1440) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.1527 | 0.0830 | 0.4039 | 0.0733 | 0.1483 | 0.0785 | 0.4063 | 0.0683 |
| adj.R-squared | 0.1502 | 0.0822 | 0.3574 | 0.0726 | 0.1464 | 0.0779 | 0.3590 | 0.0678 |
| Post(EV) all=1 | 1.8629 | 62.9739* | 1.5941 | 23.8823 | 1.3012 | 19.2800 | 1.5312 | -18.0658 |
| | (1.1425) | (26.7583) | (1.0812) | (25.5311) | (0.9656) | (18.4971) | (0.9364) | (18.4003) |
| Observations | 197,335 | 197,335 | 197,354 | 197,354 | 275,639 | 275,639 | 275,669 | 275,667 |
| R-squared | 0.1366 | 0.0439 | 0.4203 | 0.0640 | 0.1352 | 0.0730 | 0.4254 | 0.0644 |
| adj.R-squared | 0.1351 | 0.0434 | 0.3701 | 0.0636 | 0.1341 | 0.0727 | 0.3740 | 0.0641 |
| Post(PHEV) elec=1 | 1.1614 | 0.7903 | 1.5151 | -7.9389 | 0.5687 | -11.7766 | 1.4399 | -19.3817 |
| | (1.0069) | (13.3914) | (0.8779) | (13.8787) | (0.8918) | (11.2204) | (0.7775) | (10.9058) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.1527 | 0.0832 | 0.4039 | 0.0750 | 0.1482 | 0.0792 | 0.4063 | 0.0697 |
| adj.R-squared | 0.1502 | 0.0824 | 0.3574 | 0.0743 | 0.1464 | 0.0787 | 0.3590 | 0.0692 |
| Post(PHEV) all=1 | 0.4687 | 31.8141* | 0.9356 | 17.5015 | -0.0159 | 9.4522 | 0.8403 | -10.5720 |
| | (0.8527) | (13.1348) | (0.7503) | (13.9359) | (0.7904) | (11.0433) | (0.6878) | (10.9130) |
| Observations | 197,342 | 197,342 | 197,361 | 197,361 | 275,646 | 275,646 | 275,676 | 275,674 |
| R-squared | 0.1365 | 0.0584 | 0.4203 | 0.0637 | 0.1351 | 0.0742 | 0.4254 | 0.0653 |
| adj.R-squared | 0.1351 | 0.0580 | 0.3701 | 0.0633 | 0.1341 | 0.0738 | 0.3740 | 0.0650 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

### 7.4.3 Log specification

Table 13: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | 0.0562 | 1.0075 | 0.0494 | 0.1158 | 0.0338 | 0.4570 | 0.0421 | -0.2717 |
| | (0.0692) | (0.9720) | (0.0520) | (0.9333) | (0.0563) | (0.6753) | (0.0445) | (0.6512) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.2044 | 0.1112 | 0.4314 | 0.1067 | 0.1966 | 0.1130 | 0.4289 | 0.1047 |
| adj.R-squared | 0.2021 | 0.1105 | 0.3870 | 0.1060 | 0.1948 | 0.1124 | 0.3834 | 0.1041 |
| Post(EV) all=1 | 0.0576 | 3.8260** | 0.0483 | 2.0917 | 0.0344 | 1.8004* | 0.0382 | 0.2797 |
| | (0.0714) | (1.4632) | (0.0523) | (1.2480) | (0.0586) | (0.8695) | (0.0446) | (0.8489) |
| Observations | 197,335 | 197,335 | 197,354 | 197,354 | 275,639 | 275,639 | 275,669 | 275,667 |
| R-squared | 0.1812 | 0.0570 | 0.4383 | 0.0861 | 0.1752 | 0.0958 | 0.4364 | 0.0943 |
| adj.R-squared | 0.1798 | 0.0566 | 0.3897 | 0.0857 | 0.1742 | 0.0954 | 0.3860 | 0.0940 |
| Post(PHEV) elec=1 | 0.0251 | 0.7487 | 0.0225 | 0.3343 | -0.0014 | 0.4136 | 0.0087 | -0.0803 |
| | (0.0608) | (0.6643) | (0.0455) | (0.6657) | (0.0517) | (0.5085) | (0.0404) | (0.5044) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.2044 | 0.1118 | 0.4314 | 0.1060 | 0.1966 | 0.1125 | 0.4289 | 0.1051 |
| adj.R-squared | 0.2020 | 0.1110 | 0.3870 | 0.1054 | 0.1948 | 0.1119 | 0.3834 | 0.1046 |
| Post(PHEV) all=1 | 0.0032 | 1.8852** | 0.0122 | 1.4725* | -0.0212 | 1.0260* | -0.0040 | 0.2824 |
| | (0.0499) | (0.6977) | (0.0370) | (0.6700) | (0.0436) | (0.5187) | (0.0346) | (0.5058) |
| Observations | 197,342 | 197,342 | 197,361 | 197,361 | 275,646 | 275,646 | 275,676 | 275,674 |
| R-squared | 0.1812 | 0.0824 | 0.4383 | 0.0860 | 0.1752 | 0.0991 | 0.4364 | 0.0940 |
| adj.R-squared | 0.1798 | 0.0820 | 0.3897 | 0.0856 | 0.1742 | 0.0988 | 0.3860 | 0.0937 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

## 7.5 Adding

### 7.5.1 First Stage

Table 14: First Stage Summary

| | 1 | 2 | 1 | 2 |
|---|---|---|---|---|
| GP | 0.00247** | 0.00385** | 0.00097 | 0.00259** |
| | (0.00087) | (0.00127) | (0.00058) | (0.00087) |
| stations | 0.0016* | 0.00074 | 0.00194** | 0.00101 |
| | (0.00071) | (0.00082) | (0.00059) | (0.00069) |
| TX2000 | 0.01971* | 0.02295 | 0.02192** | 0.02152 |
| | (0.00837) | (0.01611) | (0.00721) | (0.01488) |
| AE | 0.0183 | 0.03693 | 0.00696 | 0.01976 |
| | (0.01237) | (0.01949) | (0.00738) | (0.01194) |
| ECOtality | 0.00194 | -0.00167 | 0.00279 | -0.00077 |
| | (0.00645) | (0.00913) | (0.00504) | (0.00655) |
| Under Id | 32.26*** | 24.64*** | 39.94*** | 30.24*** |
| ARW F | 3.79** | 3.21** | 5.40*** | 3.74** |
| ARW $\chi^2$ | 19.05** | 16.18** | 27.06*** | 18.74** |
| SW $\chi^2$ | 15.94** | 15.55** | 27.05*** | 18.65** |
| Over Id | 9.768* | 5.818 | 13.421** | 5.203 |
| Obs | 52,983 | 28,286 | 52,982 | 28,286 |
| Num Cluster | 237 | 233 | 4,569 | 2,438 |
| FE | Zipcode | Zipcode | Household | Household |

Robust standard errors clustered by region in parentheses

Under Id for under-identification test (Kleibergen-Paap rk LM statistic)

ARW stands for Anderson-Rubin Wald test

SW stands for Stock-Wright LM S statistic

Over Id stands for over-identification test (Hansen J statistic)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

### 7.5.2 Linear specification

Table 15: Mileage on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | -2.3298 | -38.9763** | -1.5959 | -59.1556** | -2.5752 | -53.6259** | -4.0691** | -89.9867** |
| | (1.2063) | (14.5740) | (1.2630) | (19.0406) | (1.4168) | (16.6502) | (1.4151) | (30.1457) |
| Observations | 52,956 | 52,955 | 52,956 | 52,954 | 28,273 | 28,273 | 28,273 | 28,273 |
| R-squared | 0.1797 | 0.0563 | 0.4707 | 0.0196 | 0.2177 | 0.0049 | 0.4968 | -0.0739 |
| adj.R-squared | 0.1746 | 0.0546 | 0.4198 | 0.0181 | 0.2088 | 0.0018 | 0.4478 | -0.0769 |
| Post(EV) all=1 | -1.9907 | -1.4e+02*** | -1.5676 | -1.7e+02*** | -2.6309 | -1.7e+02*** | -4.0154** | -2.5e+02*** |
| | (1.2630) | (30.6878) | (1.2555) | (35.8520) | (1.3614) | (36.1930) | (1.4075) | (58.8577) |
| Observations | 125,566 | 125,566 | 125,573 | 125,571 | 72,259 | 72,259 | 72,259 | 72,259 |
| R-squared | 0.1579 | -0.1574 | 0.4892 | -0.1945 | 0.1726 | -0.3273 | 0.5046 | -0.4707 |
| adj.R-squared | 0.1557 | -0.1583 | 0.4339 | -0.1953 | 0.1688 | -0.3289 | 0.4513 | -0.4723 |
| Post(PHEV) elec=1 | -3.2688** | -25.5929* | -1.7264 | -47.0011** | -4.0180** | -38.2865** | -4.3193*** | -63.2649** |
| | (1.0722) | (11.1649) | (1.0981) | (14.9051) | (1.2386) | (12.1369) | (1.2672) | (20.8949) |
| Observations | 52,984 | 52,983 | 52,984 | 52,982 | 28,286 | 28,286 | 28,286 | 28,286 |
| R-squared | 0.1797 | 0.0777 | 0.4706 | 0.0343 | 0.2178 | 0.0494 | 0.4968 | -0.0086 |
| adj.R-squared | 0.1746 | 0.0762 | 0.4196 | 0.0328 | 0.2089 | 0.0465 | 0.4477 | -0.0113 |
| Post(PHEV) all=1 | -2.9355** | -87.8466*** | -1.1870 | -1.2e+02*** | -3.8741*** | -1.2e+02*** | -3.5240** | -1.7e+02*** |
| | (1.0843) | (19.2003) | (1.0703) | (22.3413) | (1.1543) | (24.2011) | (1.2866) | (35.7228) |
| Observations | 125,614 | 125,614 | 125,621 | 125,619 | 72,283 | 72,283 | 72,283 | 72,283 |
| R-squared | 0.1579 | -0.0603 | 0.4891 | -0.1258 | 0.1726 | -0.2309 | 0.5046 | -0.3067 |
| adj.R-squared | 0.1557 | -0.0611 | 0.4338 | -0.1265 | 0.1689 | -0.2324 | 0.4513 | -0.3081 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

### 7.5.3 Log specification

Table 16: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | -0.1218 | -0.8803 | -0.1093 | -1.7750* | -0.1374 | -2.5076** | -0.2163** | -4.1213** |
| | (0.0662) | (0.6874) | (0.0654) | (0.8039) | (0.0796) | (0.8640) | (0.0765) | (1.4643) |
| Observations | 52,956 | 52,955 | 52,956 | 52,954 | 28,273 | 28,273 | 28,273 | 28,273 |
| R-squared | 0.2130 | 0.1205 | 0.4683 | 0.0879 | 0.2563 | 0.0507 | 0.4934 | -0.0128 |
| adj.R-squared | 0.2081 | 0.1190 | 0.4172 | 0.0865 | 0.2478 | 0.0477 | 0.4440 | -0.0156 |
| Post(EV) all=1 | -0.1164 | -5.3872*** | -0.1134 | -7.2567*** | -0.1458 | -7.0480*** | -0.2252** | -10.6391*** |
| | (0.0685) | (1.3373) | (0.0652) | (1.6154) | (0.0796) | (1.6411) | (0.0757) | (2.6989) |
| Observations | 125,566 | 125,566 | 125,573 | 125,571 | 72,259 | 72,259 | 72,259 | 72,259 |
| R-squared | 0.1829 | -0.0523 | 0.4769 | -0.1119 | 0.2030 | -0.2136 | 0.4948 | -0.3217 |
| adj.R-squared | 0.1807 | -0.0531 | 0.4203 | -0.1126 | 0.1994 | -0.2151 | 0.4404 | -0.3232 |
| Post(PHEV) elec=1 | -0.1713** | -0.4033 | -0.1326* | -1.3364* | -0.2132** | -1.7463** | -0.2502*** | -2.9736** |
| | (0.0596) | (0.5250) | (0.0570) | (0.6392) | (0.0720) | (0.6282) | (0.0703) | (1.0401) |
| Observations | 52,984 | 52,983 | 52,984 | 52,982 | 28,286 | 28,286 | 28,286 | 28,286 |
| R-squared | 0.2132 | 0.1272 | 0.4683 | 0.0958 | 0.2566 | 0.0930 | 0.4935 | 0.0367 |
| adj.R-squared | 0.2083 | 0.1257 | 0.4172 | 0.0944 | 0.2481 | 0.0902 | 0.4441 | 0.0341 |
| Post(PHEV) all=1 | -0.1514** | -3.3607*** | -0.1059 | -4.8988*** | -0.2006** | -5.1776*** | -0.2113** | -7.0980*** |
| | (0.0549) | (0.8393) | (0.0543) | (0.9966) | (0.0648) | (1.1082) | (0.0694) | (1.6185) |
| Observations | 125,614 | 125,614 | 125,621 | 125,619 | 72,283 | 72,283 | 72,283 | 72,283 |
| R-squared | 0.1829 | 0.0207 | 0.4769 | -0.0498 | 0.2032 | -0.1283 | 0.4949 | -0.1838 |
| adj.R-squared | 0.1808 | 0.0200 | 0.4202 | -0.0505 | 0.1996 | -0.1297 | 0.4405 | -0.1851 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

## 7.6 Results for using four IVs

### 7.6.1 Individual Mileage

Table 17: First Stage for PHEV purchase

| | Individual | | Average | |
|---|---|---|---|---|
| GP | 0.00307*** | 0.00269*** | 0.0051*** | 0.00545*** |
| | (0.00037) | (0.00029) | (0.00077) | (0.00076) |
| TX2000 | 0.01089** | 0.01203*** | 0.00687 | 0.01054* |
| | (0.00316) | (0.00246) | (0.00425) | (0.00422) |
| AE | 0.00792 | 0.00224 | 0.01982 | 0.01667 |
| | (0.00522) | (0.00307) | (0.01395) | (0.01266) |
| ECOtality | -0.00208 | -0.00067 | -0.00527 | -0.00262 |
| | (0.00229) | (0.00196) | (0.00446) | (0.00522) |
| Under Id | 66.93*** | 143.14*** | 51.00*** | 91.38*** |
| ARW F | 24.80*** | 6.09*** | 12.29*** | 5.01*** |
| ARW $\chi^2$ | 99.66*** | 24.38*** | 49.38*** | 20.05*** |
| SW $\chi^2$ | 66.98*** | 24.46*** | 41.30*** | 20.16*** |
| Over Id | 17.982*** | 3.196 | 13.883** | 7.862* |
| Obs | 381,388 | 381,377 | 189,499 | 189,077 |
| Num Cluster | 243 | 33,062 | 243 | 32,459 |
| FE | Zipcode | Household | Zipcode | Household |

Robust standard errors clustered by region in parentheses

Under Id for under-identification test (Kleibergen-Paap rk LM statistic)

ARW stands for Anderson-Rubin Wald test

SW stands for Stock-Wright LM S statistic

Over Id stands for over-identification test (Hansen J statistic)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**First stage**

Table 18: Mileage on other cars when purchase a new (PH)EV

| | OLS Zip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| Post(EV)=1 | -0.3491 | -1.6783 | 0.4325 | 1.7242 |
| | (0.9401) | (2.4841) | (0.8667) | (2.5565) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3342 | 0.1018 | 0.5286 | 0.0659 |
| adj.R-squared | 0.3022 | 0.0877 | 0.4717 | 0.0513 |
| Post(EV) elec=1 | -1.7516* | -1.3e+02*** | -0.3288 | -54.9217*** |
| | (0.8642) | (19.7370) | (0.7487) | (13.1097) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1457 | -0.0871 | 0.4435 | 0.0545 |
| adj.R-squared | 0.1449 | -0.0874 | 0.3904 | 0.0543 |
| Post(EV) all=1 | -1.4743 | -2.5e+02*** | -0.4056 | -97.1765*** |
| | (0.8644) | (35.7907) | (0.7483) | (19.1001) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1372 | -0.2733 | 0.4614 | 0.0303 |
| adj.R-squared | 0.1367 | -0.2735 | 0.4051 | 0.0301 |
| Post(PHEV)=1 | -1.0402 | -1.3415 | 0.0724 | 0.3922 |
| | (0.9401) | (1.4859) | (0.7236) | (1.4330) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3347 | 0.1034 | 0.5285 | 0.0665 |
| adj.R-squared | 0.3028 | 0.0893 | 0.4717 | 0.0519 |
| Post(PHEV) elec=1 | -2.0807** | -90.5799*** | -0.3641 | -39.0301*** |
| | (0.7267) | (13.1529) | (0.6179) | (9.1610) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1457 | -0.0305 | 0.4435 | 0.0614 |
| adj.R-squared | 0.1449 | -0.0308 | 0.3904 | 0.0611 |
| Post(PHEV) all=1 | -1.8567* | -1.4e+02*** | -0.5334 | -56.8927*** |
| | (0.7182) | (17.7781) | (0.5513) | (10.2533) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1372 | -0.1025 | 0.4614 | 0.0455 |
| adj.R-squared | 0.1368 | -0.1026 | 0.4051 | 0.0453 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Linear specification**

Table 19: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLS Zip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| Post(EV)=1 | -0.0236 | -0.1663 | 0.0078 | -0.0498 |
| | (0.0491) | (0.1201) | (0.0435) | (0.1328) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3916 | 0.1621 | 0.5594 | 0.1156 |
| adj.R-squared | 0.3624 | 0.1490 | 0.5063 | 0.1018 |
| Post(EV) elec=1 | -0.1204* | -5.8992*** | -0.0523 | -3.2822*** |
| | (0.0481) | (0.9886) | (0.0369) | (0.6695) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1808 | -0.0297 | 0.4523 | 0.0703 |
| adj.R-squared | 0.1800 | -0.0300 | 0.4001 | 0.0701 |
| Post(EV) all=1 | -0.1138* | -11.2101*** | -0.0553 | -5.7233*** |
| | (0.0484) | (1.6200) | (0.0369) | (0.9625) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1673 | -0.1862 | 0.4625 | 0.0385 |
| adj.R-squared | 0.1669 | -0.1863 | 0.4063 | 0.0383 |
| Post(PHEV)=1 | -0.0691 | -0.1097 | -0.0409 | -0.0447 |
| | (0.0470) | (0.0709) | (0.0387) | (0.0746) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3924 | 0.1667 | 0.5596 | 0.1164 |
| adj.R-squared | 0.3632 | 0.1537 | 0.5065 | 0.1026 |
| Post(PHEV) elec=1 | -0.1378*** | -4.0215*** | -0.0778* | -2.2449*** |
| | (0.0403) | (0.6419) | (0.0326) | (0.4576) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1808 | 0.0243 | 0.4523 | 0.0820 |
| adj.R-squared | 0.1801 | 0.0241 | 0.4002 | 0.0818 |
| Post(PHEV) all=1 | -0.1218** | -5.9145*** | -0.0717* | -3.2023*** |
| | (0.0366) | (0.7907) | (0.0283) | (0.5012) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1673 | -0.0332 | 0.4625 | 0.0631 |
| adj.R-squared | 0.1669 | -0.0334 | 0.4063 | 0.0630 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Log specification**

### 7.6.2 Average mileage

Table 20: Mileage on other cars when purchase a new (PH)EV

| | OLSZip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| PostEV=1 | -0.1967 | -1.8304 | -0.7336 | 0.9092 |
| | (1.7181) | (2.8306) | (1.6243) | (2.7191) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4186 | 0.1220 | 0.7028 | 0.0825 |
| adj.R-squared | 0.3713 | 0.1109 | 0.6257 | 0.0709 |
| PostEV elec=1 | -0.9764 | -96.0628*** | -0.6417 | -53.4060*** |
| | (1.5333) | (20.2156) | (1.3686) | (15.6018) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1307 | 0.0228 | 0.6224 | 0.0421 |
| adj.R-squared | 0.1294 | 0.0226 | 0.5431 | 0.0419 |
| PostEV all=1 | -0.9183 | -1.4e+02*** | -0.7765 | -81.5719*** |
| | (1.5363) | (30.2547) | (1.3743) | (21.6508) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1255 | 0.0135 | 0.6377 | 0.0299 |
| adj.R-squared | 0.1249 | 0.0134 | 0.5584 | 0.0298 |
| PostPHEV=1 | -1.2979 | -1.3362 | -1.5803 | 0.0182 |
| | (1.5199) | (1.7153) | (1.5142) | (1.4851) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4193 | 0.1242 | 0.7033 | 0.0836 |
| adj.R-squared | 0.3720 | 0.1131 | 0.6263 | 0.0720 |
| PostPHEV elec=1 | -1.4689 | -66.9395*** | -0.4091 | -32.2622** |
| | (1.3018) | (13.4846) | (1.2046) | (10.1538) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1307 | 0.0458 | 0.6224 | 0.0526 |
| adj.R-squared | 0.1295 | 0.0456 | 0.5431 | 0.0525 |
| PostPHEV all=1 | -1.5854 | -79.1412*** | -1.0600 | -40.9459*** |
| | (1.1962) | (15.2254) | (1.1152) | (11.1282) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1255 | 0.0468 | 0.6377 | 0.0451 |
| adj.R-squared | 0.1249 | 0.0467 | 0.5584 | 0.0450 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Linear specification**

Table 21: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLSZip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| PostEV=1 | -0.0841 | -0.2649* | -0.1048 | -0.1243 |
| | (0.0788) | (0.1279) | (0.0760) | (0.1360) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4720 | 0.1871 | 0.7079 | 0.1615 |
| adj.R-squared | 0.4290 | 0.1768 | 0.6322 | 0.1508 |
| PostEV elec=1 | -0.1513 | -6.3210*** | -0.1372 | -4.8324*** |
| | (0.0862) | (1.1136) | (0.0738) | (0.8580) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1311 | -0.0437 | 0.6068 | -0.0148 |
| adj.R-squared | 0.1298 | -0.0439 | 0.5242 | -0.0149 |
| PostEV all=1 | -0.1576 | -9.4707*** | -0.1411 | -7.2301*** |
| | (0.0871) | (1.6190) | (0.0748) | (1.2284) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1280 | -0.0657 | 0.6154 | -0.0377 |
| adj.R-squared | 0.1274 | -0.0657 | 0.5312 | -0.0378 |
| PostPHEV=1 | -0.1456* | -0.1534* | -0.1569* | -0.0732 |
| | (0.0718) | (0.0744) | (0.0757) | (0.0736) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4747 | 0.1980 | 0.7096 | 0.1642 |
| adj.R-squared | 0.4320 | 0.1879 | 0.6343 | 0.1535 |
| PostPHEV elec=1 | -0.1699* | -4.5429*** | -0.1464* | -3.0963*** |
| | (0.0737) | (0.7355) | (0.0657) | (0.5292) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1311 | -0.0001 | 0.6068 | 0.0224 |
| adj.R-squared | 0.1299 | -0.0003 | 0.5242 | 0.0222 |
| PostPHEV all=1 | -0.1659* | -5.4762*** | -0.1495* | -3.8378*** |
| | (0.0648) | (0.7925) | (0.0585) | (0.5834) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1281 | 0.0062 | 0.6154 | 0.0152 |
| adj.R-squared | 0.1275 | 0.0061 | 0.5313 | 0.0151 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

### Log specification

### 7.6.3 Replacement

Table 22: First Stage Summary

| | 1 | 2 | 1 | 2 |
|---|---|---|---|---|
| GP | 0.00261*** | 0.0023*** | 0.00208*** | 0.00185*** |
| | (0.00045) | (0.00036) | (0.00038) | (0.00032) |
| TX2000 | 0.01029** | 0.01211*** | 0.00946** | 0.01118*** |
| | (0.00353) | (0.00335) | (0.00327) | (0.00276) |
| AE | -0.00092 | -0.00216 | 0.0004 | -0.00066 |
| | (0.00501) | (0.00441) | (0.00363) | (0.0029) |
| ECOtality | -0.00143 | -0.00074 | -0.00029 | 0.00053 |
| | (0.00341) | (0.00268) | (0.00277) | (0.00228) |
| Under Id | 39.22*** | 45.19*** | 56.74*** | 67.12*** |
| ARW F | 1.47 | 2.47* | 0.97 | 2.84* |
| ARW $\chi^2$ | 5.89 | 9.91* | 3.88 | 11.36* |
| SW $\chi^2$ | 5.95 | 9.87* | 3.88 | 11.37* |
| Over Id | 5.452 | 6.849 | 1.897 | 2.536 |
| Obs | 113,486 | 153,572 | 113,499 | 153,584 |
| Num Cluster | 240 | 242 | 8,141 | 11,233 |
| FE | Zipcode | Zipcode | Household | Household |

Robust standard errors clustered by region in parentheses

Under Id for under-identification test (Kleibergen-Paap rk LM statistic)

ARW stands for Anderson-Rubin Wald test

SW stands for Stock-Wright LM S statistic

Over Id stands for over-identification test (Hansen J statistic)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

#### First Stage

Table 23: Mileage on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | 1.6899 | -13.8985 | 1.6580 | -33.8159 | 1.1896 | -28.1485 | 1.6215 | -50.2427** |
| | (1.1250) | (20.6142) | (1.0793) | (22.9027) | (0.9260) | (16.6487) | (0.9357) | (18.6819) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.1527 | 0.0797 | 0.4039 | 0.0625 | 0.1483 | 0.0700 | 0.4063 | 0.0452 |
| adj.R-squared | 0.1502 | 0.0789 | 0.3574 | 0.0618 | 0.1464 | 0.0694 | 0.3590 | 0.0447 |
| Post(EV) all=1 | 1.8629 | 51.5343 | 1.5941 | 5.0293 | 1.3012 | 14.0064 | 1.5312 | -40.0069 |
| | (1.1425) | (30.0606) | (1.0812) | (27.9392) | (0.9656) | (22.6958) | (0.9364) | (22.7374) |
| Observations | 197,335 | 197,335 | 197,354 | 197,354 | 275,639 | 275,639 | 275,669 | 275,667 |
| R-squared | 0.1366 | 0.0545 | 0.4203 | 0.0673 | 0.1352 | 0.0743 | 0.4254 | 0.0550 |
| adj.R-squared | 0.1351 | 0.0541 | 0.3701 | 0.0669 | 0.1341 | 0.0740 | 0.3740 | 0.0547 |
| Post(PHEV) elec=1 | 1.1614 | -9.0330 | 1.5151 | -22.4290 | 0.5687 | -21.6508 | 1.4399 | -39.3764** |
| | (1.0069) | (15.1370) | (0.8779) | (16.5989) | (0.8918) | (12.9370) | (0.7775) | (14.3866) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.1527 | 0.0809 | 0.4039 | 0.0671 | 0.1482 | 0.0718 | 0.4063 | 0.0487 |
| adj.R-squared | 0.1502 | 0.0801 | 0.3574 | 0.0664 | 0.1464 | 0.0712 | 0.3590 | 0.0482 |
| Post(PHEV) all=1 | 0.4687 | 26.4820 | 0.9356 | 4.8949 | -0.0159 | 4.3626 | 0.8403 | -27.2474 |
| | (0.8527) | (17.1668) | (0.7503) | (16.8821) | (0.7904) | (14.3751) | (0.6878) | (14.0942) |
| Observations | 197,342 | 197,342 | 197,361 | 197,361 | 275,646 | 275,646 | 275,676 | 275,674 |
| R-squared | 0.1365 | 0.0636 | 0.4203 | 0.0672 | 0.1351 | 0.0754 | 0.4254 | 0.0565 |
| adj.R-squared | 0.1351 | 0.0632 | 0.3701 | 0.0668 | 0.1341 | 0.0750 | 0.3740 | 0.0562 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Linear specification**

Table 24: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | 0.0562 | 0.3665 | 0.0494 | -0.6490 | 0.0338 | -0.1712 | 0.0421 | -1.2131 |
| | (0.0692) | (1.0576) | (0.0520) | (1.0717) | (0.0563) | (0.8069) | (0.0445) | (0.8295) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.2044 | 0.1160 | 0.4314 | 0.1045 | 0.1966 | 0.1138 | 0.4289 | 0.0974 |
| adj.R-squared | 0.2021 | 0.1152 | 0.3870 | 0.1038 | 0.1948 | 0.1132 | 0.3834 | 0.0969 |
| Post(EV) all=1 | 0.0576 | 3.6396* | 0.0483 | 1.6175 | 0.0344 | 1.8665 | 0.0382 | -0.2157 |
| | (0.0714) | (1.6084) | (0.0523) | (1.3601) | (0.0586) | (1.1030) | (0.0446) | (1.0210) |
| Observations | 197,335 | 197,335 | 197,354 | 197,354 | 275,639 | 275,639 | 275,669 | 275,667 |
| R-squared | 0.1812 | 0.0620 | 0.4383 | 0.0910 | 0.1752 | 0.0949 | 0.4364 | 0.0942 |
| adj.R-squared | 0.1798 | 0.0615 | 0.3897 | 0.0906 | 0.1742 | 0.0946 | 0.3860 | 0.0939 |
| Post(PHEV) elec=1 | 0.0251 | 0.2185 | 0.0225 | -0.1962 | -0.0014 | -0.0920 | 0.0087 | -0.7679 |
| | (0.0608) | (0.7567) | (0.0455) | (0.7791) | (0.0517) | (0.6243) | (0.0404) | (0.6420) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.2044 | 0.1162 | 0.4314 | 0.1064 | 0.1966 | 0.1140 | 0.4289 | 0.1009 |
| adj.R-squared | 0.2020 | 0.1154 | 0.3870 | 0.1057 | 0.1948 | 0.1134 | 0.3834 | 0.1004 |
| Post(PHEV) all=1 | 0.0032 | 1.8819* | 0.0122 | 1.3762 | -0.0212 | 1.0925 | -0.0040 | -0.0004 |
| | (0.0499) | (0.8618) | (0.0370) | (0.8119) | (0.0436) | (0.6934) | (0.0346) | (0.6403) |
| Observations | 197,342 | 197,342 | 197,361 | 197,361 | 275,646 | 275,646 | 275,676 | 275,674 |
| R-squared | 0.1812 | 0.0825 | 0.4383 | 0.0875 | 0.1752 | 0.0981 | 0.4364 | 0.0944 |
| adj.R-squared | 0.1798 | 0.0821 | 0.3897 | 0.0871 | 0.1742 | 0.0977 | 0.3860 | 0.0941 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Log specification**

### 7.6.4 Adding

Table 25: First Stage Summary

| | 1 | 2 | 1 | 2 |
|---|---|---|---|---|
| GP | 0.00353*** | 0.00436*** | 0.00228*** | 0.00328*** |
| | (0.00083) | (0.00121) | (0.00056) | (0.00084) |
| TX2000 | 0.01976* | 0.02309 | 0.02194** | 0.02179 |
| | (0.00837) | (0.01608) | (0.00723) | (0.01486) |
| AE | 0.02086 | 0.03838* | 0.01146 | 0.02278* |
| | (0.01247) | (0.01931) | (0.00716) | (0.01159) |
| ECOtality | 0.00149 | -0.00182 | 0.00196 | -0.00105 |
| | (0.00646) | (0.00913) | (0.00507) | (0.00657) |
| Under Id | 32.26*** | 24.61*** | 37.78*** | 29.46*** |
| ARW F | 4.08** | 3.15* | 6.21*** | 4.23** |
| ARW $\chi^2$ | 16.43** | 12.71* | 24.89*** | 16.95** |
| SW $\chi^2$ | 14.58** | 12.86* | 25.03*** | 17.02** |
| Over Id | 9.783* | 5.331 | 12.778** | 5.226 |
| Obs | 52,983 | 28,286 | 52,982 | 28,286 |
| Num Cluster | 237 | 233 | 4,569 | 2,438 |
| FE | Zipcode | Zipcode | Household | Household |

Robust standard errors clustered by region in parentheses

Under Id for under-identification test (Kleibergen-Paap rk LM statistic)

ARW stands for Anderson-Rubin Wald test

SW stands for Stock-Wright LM S statistic

Over Id stands for over-identification test (Hansen J statistic)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**First Stage**

Table 26: Mileage on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | -2.3298 | -44.0916* | -1.5959 | -85.6007** | -2.5752 | -50.1184** | -4.0691** | -1.1e+02** |
| | (1.2063) | (18.3987) | (1.2630) | (26.5046) | (1.4168) | (18.6025) | (1.4151) | (35.5516) |
| Observations | 52,956 | 52,955 | 52,956 | 52,954 | 28,273 | 28,273 | 28,273 | 28,273 |
| R-squared | 0.1797 | 0.0442 | 0.4707 | -0.0572 | 0.2177 | 0.0178 | 0.4968 | -0.1359 |
| adj.R-squared | 0.1746 | 0.0426 | 0.4198 | -0.0588 | 0.2088 | 0.0148 | 0.4478 | -0.1390 |
| Post(EV) all=1 | -1.9907 | -1.6e+02*** | -1.5676 | -2.7e+02*** | -2.6309 | -1.8e+02*** | -4.0154** | -3.0e+02*** |
| | (1.2630) | (36.6368) | (1.2555) | (51.9315) | (1.3614) | (40.0194) | (1.4075) | (72.7947) |
| Observations | 125,566 | 125,566 | 125,573 | 125,571 | 72,259 | 72,259 | 72,259 | 72,259 |
| R-squared | 0.1579 | -0.2415 | 0.4892 | -0.5889 | 0.1726 | -0.4288 | 0.5046 | -0.7357 |
| adj.R-squared | 0.1557 | -0.2424 | 0.4339 | -0.5899 | 0.1688 | -0.4306 | 0.4513 | -0.7376 |
| Post(PHEV) elec=1 | -3.2688** | -24.1289 | -1.7264 | -52.8625** | -4.0180** | -33.9645** | -4.3193*** | -62.8397** |
| | (1.0722) | (12.9984) | (1.0981) | (17.3832) | (1.2386) | (13.0266) | (1.2672) | (22.0255) |
| Observations | 52,984 | 52,983 | 52,984 | 52,982 | 28,286 | 28,286 | 28,286 | 28,286 |
| R-squared | 0.1797 | 0.0801 | 0.4706 | 0.0196 | 0.2178 | 0.0620 | 0.4968 | -0.0072 |
| adj.R-squared | 0.1746 | 0.0786 | 0.4196 | 0.0182 | 0.2089 | 0.0591 | 0.4477 | -0.0099 |
| Post(PHEV) all=1 | -2.9355** | -92.6962*** | -1.1870 | -1.6e+02*** | -3.8741*** | -1.3e+02*** | -3.5240** | -1.9e+02*** |
| | (1.0843) | (21.5115) | (1.0703) | (28.3958) | (1.1543) | (26.1054) | (1.2866) | (38.6460) |
| Observations | 125,614 | 125,614 | 125,621 | 125,619 | 72,283 | 72,283 | 72,283 | 72,283 |
| R-squared | 0.1579 | -0.0775 | 0.4891 | -0.2881 | 0.1726 | -0.2552 | 0.5046 | -0.4078 |
| adj.R-squared | 0.1557 | -0.0783 | 0.4338 | -0.2889 | 0.1689 | -0.2568 | 0.4513 | -0.4093 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Linear specification**

Table 27: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | -0.1218 | -1.0893 | -0.1093 | -2.7579* | -0.1374 | -2.5493** | -0.2163** | -4.9383** |
| | (0.0662) | (0.8249) | (0.0654) | (1.1575) | (0.0796) | (0.9330) | (0.0765) | (1.7582) |
| Observations | 52,956 | 52,955 | 52,956 | 52,954 | 28,273 | 28,273 | 28,273 | 28,273 |
| R-squared | 0.2130 | 0.1159 | 0.4683 | 0.0520 | 0.2563 | 0.0476 | 0.4934 | -0.0721 |
| adj.R-squared | 0.2081 | 0.1144 | 0.4172 | 0.0505 | 0.2478 | 0.0447 | 0.4440 | -0.0751 |
| Post(EV) all=1 | -0.1164 | -5.8853*** | -0.1134 | -10.5146*** | -0.1458 | -7.3071*** | -0.2252** | -12.1447*** |
| | (0.0685) | (1.5353) | (0.0652) | (2.2020) | (0.0796) | (1.7456) | (0.0757) | (3.1412) |
| Observations | 125,566 | 125,566 | 125,573 | 125,571 | 72,259 | 72,259 | 72,259 | 72,259 |
| R-squared | 0.1829 | -0.0855 | 0.4769 | -0.3463 | 0.2030 | -0.2388 | 0.4948 | -0.4538 |
| adj.R-squared | 0.1807 | -0.0863 | 0.4203 | -0.3472 | 0.1994 | -0.2403 | 0.4404 | -0.4554 |
| Post(PHEV) elec=1 | -0.1713** | -0.3954 | -0.1326* | -1.5247* | -0.2132** | -1.6791* | -0.2502*** | -3.0313** |
| | (0.0596) | (0.5787) | (0.0570) | (0.7659) | (0.0720) | (0.6609) | (0.0703) | (1.1158) |
| Observations | 52,984 | 52,983 | 52,984 | 52,982 | 28,286 | 28,286 | 28,286 | 28,286 |
| R-squared | 0.2132 | 0.1273 | 0.4683 | 0.0906 | 0.2566 | 0.0967 | 0.4935 | 0.0333 |
| adj.R-squared | 0.2083 | 0.1258 | 0.4172 | 0.0892 | 0.2481 | 0.0939 | 0.4441 | 0.0307 |
| Post(PHEV) all=1 | -0.1514** | -3.3924*** | -0.1059 | -6.0909*** | -0.2006** | -5.1410*** | -0.2113** | -7.5015*** |
| | (0.0549) | (0.9175) | (0.0543) | (1.2111) | (0.0648) | (1.1668) | (0.0694) | (1.7055) |
| Observations | 125,614 | 125,614 | 125,621 | 125,619 | 72,283 | 72,283 | 72,283 | 72,283 |
| R-squared | 0.1829 | 0.0189 | 0.4769 | -0.1321 | 0.2032 | -0.1247 | 0.4949 | -0.2186 |
| adj.R-squared | 0.1808 | 0.0181 | 0.4202 | -0.1329 | 0.1996 | -0.1261 | 0.4405 | -0.2199 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Log specification**

## 7.7 Results for using six IVs

### 7.7.1 Individual Mileage

Table 28: First Stage for PHEV purchase

| | Individual | | Average | |
|---|---|---|---|---|
| newPHEVperc | 0.50879 | 0.82504** | 0.23681 | 0.29573 |
| | (0.63243) | (0.29983) | (0.71785) | (0.57408) |
| GP | 0.0021*** | 0.00149*** | 0.00315*** | 0.00285*** |
| | (0.00038) | (0.0003) | (0.00079) | (0.00076) |
| stations | 0.00141*** | 0.00167*** | 0.00313** | 0.00415*** |
| | (0.00036) | (0.00032) | (0.00094) | (0.00104) |
| TX2000 | 0.01067** | 0.01159*** | 0.00663 | 0.01009* |
| | (0.00316) | (0.00245) | (0.0042) | (0.00418) |
| AE | 0.00502 | -0.00044 | 0.01063 | 0.00919 |
| | (0.00511) | (0.00315) | (0.01415) | (0.01288) |
| ECOtality | -0.00149 | -0.00015 | -0.00317 | -0.00053 |
| | (0.0023) | (0.00196) | (0.00446) | (0.0052) |
| Under Id | 67.41*** | 146.15*** | 52.26*** | 91.91*** |
| ARW F | 17.61*** | 4.72*** | 9.77*** | 3.52** |
| ARW $\chi^2$ | 106.10*** | 28.35*** | 58.85*** | 21.12** |
| SW $\chi^2$ | 68.73*** | 28.13*** | 41.41*** | 21.26** |
| Over Id | 26.733*** | 7.798 | 31.428*** | 15.848** |
| Obs | 381,388 | 381,377 | 189,499 | 189,077 |
| Num Cluster | 243 | 33,062 | 243 | 32,459 |
| FE | Zipcode | Household | Zipcode | Household |

Robust standard errors clustered by region in parentheses

Under Id for under-identification test (Kleibergen-Paap rk LM statistic)

ARW stands for Anderson-Rubin Wald test

SW stands for Stock-Wright LM S statistic

Over Id stands for over-identification test (Hansen J statistic)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**First stage**

Table 29: Mileage on other cars when purchase a new (PH)EV

| | OLS Zip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| Post(EV)=1 | -0.3491 | -1.6211 | 0.4325 | 1.9200 |
| | (0.9401) | (2.4522) | (0.8667) | (2.5530) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3342 | 0.1019 | 0.5286 | 0.0656 |
| adj.R-squared | 0.3022 | 0.0878 | 0.4717 | 0.0510 |
| Post(EV) elec=1 | -1.7516* | -97.0350*** | -0.3288 | -42.3660*** |
| | (0.8642) | (15.3722) | (0.7487) | (10.1523) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1457 | -0.0097 | 0.4435 | 0.0639 |
| adj.R-squared | 0.1449 | -0.0099 | 0.3904 | 0.0637 |
| Post(EV) all=1 | -1.4743 | -1.9e+02*** | -0.4056 | -69.1660*** |
| | (0.8644) | (27.4205) | (0.7483) | (14.6911) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1372 | -0.1278 | 0.4614 | 0.0499 |
| adj.R-squared | 0.1367 | -0.1279 | 0.4051 | 0.0498 |
| Post(PHEV)=1 | -1.0402 | -1.5549 | 0.0724 | 0.3760 |
| | (0.9401) | (1.4517) | (0.7236) | (1.4170) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3347 | 0.1033 | 0.5285 | 0.0665 |
| adj.R-squared | 0.3028 | 0.0892 | 0.4717 | 0.0519 |
| Post(PHEV) elec=1 | -2.0807** | -73.7773*** | -0.3641 | -32.1419*** |
| | (0.7267) | (11.1283) | (0.6179) | (7.6685) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1457 | 0.0110 | 0.4435 | 0.0666 |
| adj.R-squared | 0.1449 | 0.0107 | 0.3904 | 0.0664 |
| Post(PHEV) all=1 | -1.8567* | -1.2e+02*** | -0.5334 | -42.2426*** |
| | (0.7182) | (15.0150) | (0.5513) | (8.4373) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1372 | -0.0521 | 0.4614 | 0.0565 |
| adj.R-squared | 0.1368 | -0.0522 | 0.4051 | 0.0564 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Linear specification**

Table 30: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLS Zip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| Post(EV)=1 | -0.0236 | -0.1694 | 0.0078 | -0.0406 |
| | (0.0491) | (0.1197) | (0.0435) | (0.1322) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3916 | 0.1620 | 0.5594 | 0.1157 |
| adj.R-squared | 0.3624 | 0.1489 | 0.5063 | 0.1019 |
| Post(EV) elec=1 | -0.1204* | -4.3514*** | -0.0523 | -2.3487*** |
| | (0.0481) | (0.7789) | (0.0369) | (0.5037) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1808 | 0.0386 | 0.4523 | 0.0860 |
| adj.R-squared | 0.1800 | 0.0383 | 0.4001 | 0.0857 |
| Post(EV) all=1 | -0.1138* | -8.7864*** | -0.0553 | -4.2805*** |
| | (0.0484) | (1.2680) | (0.0369) | (0.7443) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1673 | -0.0700 | 0.4625 | 0.0631 |
| adj.R-squared | 0.1669 | -0.0701 | 0.4063 | 0.0629 |
| Post(PHEV)=1 | -0.0691 | -0.1132 | -0.0409 | -0.0453 |
| | (0.0470) | (0.0707) | (0.0387) | (0.0744) |
| Observations | 5,132 | 5,130 | 5,132 | 5,132 |
| R-squared | 0.3924 | 0.1666 | 0.5596 | 0.1165 |
| adj.R-squared | 0.3632 | 0.1536 | 0.5065 | 0.1026 |
| Post(PHEV) elec=1 | -0.1378*** | -3.2309*** | -0.0778* | -1.7666*** |
| | (0.0403) | (0.5435) | (0.0326) | (0.3765) |
| Observations | 381,388 | 381,388 | 381,388 | 381,377 |
| R-squared | 0.1808 | 0.0584 | 0.4523 | 0.0899 |
| adj.R-squared | 0.1801 | 0.0582 | 0.4002 | 0.0896 |
| Post(PHEV) all=1 | -0.1218** | -5.1976*** | -0.0717* | -2.5409*** |
| | (0.0366) | (0.6828) | (0.0283) | (0.4146) |
| Observations | 744,192 | 744,192 | 744,192 | 744,176 |
| R-squared | 0.1673 | 0.0006 | 0.4625 | 0.0747 |
| adj.R-squared | 0.1669 | 0.0004 | 0.4063 | 0.0746 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

### Log specification

### 7.7.2 Average mileage

Table 31: Mileage on other cars when purchase a new (PH)EV

| | OLSZip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| PostEV=1 | -0.1967 | -0.4584 | -0.7336 | 1.5821 |
| | (1.7181) | (2.6670) | (1.6243) | (2.6742) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4186 | 0.1233 | 0.7028 | 0.0809 |
| adj.R-squared | 0.3713 | 0.1122 | 0.6257 | 0.0692 |
| PostEV elec=1 | -0.9764 | -47.0431*** | -0.6417 | -29.1277* |
| | (1.5333) | (13.0503) | (1.3686) | (11.9204) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1307 | 0.0736 | 0.6224 | 0.0575 |
| adj.R-squared | 0.1294 | 0.0735 | 0.5431 | 0.0573 |
| PostEV all=1 | -0.9183 | -63.6751*** | -0.7765 | -36.6201* |
| | (1.5363) | (18.6411) | (1.3743) | (15.7392) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1255 | 0.0700 | 0.6377 | 0.0510 |
| adj.R-squared | 0.1249 | 0.0699 | 0.5584 | 0.0509 |
| PostPHEV=1 | -1.2979 | -1.2263 | -1.5803 | 0.0278 |
| | (1.5199) | (1.6953) | (1.5142) | (1.4744) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4193 | 0.1242 | 0.7033 | 0.0836 |
| adj.R-squared | 0.3720 | 0.1131 | 0.6263 | 0.0720 |
| PostPHEV elec=1 | -1.4689 | -30.9306*** | -0.4091 | -18.0541* |
| | (1.3018) | (9.1356) | (1.2046) | (8.2636) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1307 | 0.0804 | 0.6224 | 0.0604 |
| adj.R-squared | 0.1295 | 0.0803 | 0.5431 | 0.0602 |
| PostPHEV all=1 | -1.5854 | -36.2930*** | -1.0600 | -17.4014* |
| | (1.1962) | (10.4901) | (1.1152) | (8.7825) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1255 | 0.0768 | 0.6377 | 0.0543 |
| adj.R-squared | 0.1249 | 0.0767 | 0.5584 | 0.0542 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

### Linear specification

Table 32: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLSZip | IV Zip | OLS HH | IV HH |
|---|---|---|---|---|
| PostEV=1 | -0.0841 | -0.2105 | -0.1048 | -0.0926 |
| | (0.0788) | (0.1192) | (0.0760) | (0.1330) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4720 | 0.1907 | 0.7079 | 0.1616 |
| adj.R-squared | 0.4290 | 0.1805 | 0.6322 | 0.1509 |
| PostEV elec=1 | -0.1513 | -4.1676*** | -0.1372 | -3.5976*** |
| | (0.0862) | (0.7750) | (0.0738) | (0.6682) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1311 | 0.0379 | 0.6068 | 0.0236 |
| adj.R-squared | 0.1298 | 0.0378 | 0.5242 | 0.0234 |
| PostEV all=1 | -0.1576 | -6.0217*** | -0.1411 | -5.4417*** |
| | (0.0871) | (1.0622) | (0.0748) | (0.9127) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1280 | 0.0327 | 0.6154 | 0.0062 |
| adj.R-squared | 0.1274 | 0.0326 | 0.5312 | 0.0061 |
| PostPHEV=1 | -0.1456* | -0.1516* | -0.1569* | -0.0604 |
| | (0.0718) | (0.0723) | (0.0757) | (0.0712) |
| Observations | 2,404 | 2,400 | 2,404 | 2,393 |
| R-squared | 0.4747 | 0.1980 | 0.7096 | 0.1636 |
| adj.R-squared | 0.4320 | 0.1879 | 0.6343 | 0.1530 |
| PostPHEV elec=1 | -0.1699* | -2.9430*** | -0.1464* | -2.3021*** |
| | (0.0737) | (0.5507) | (0.0657) | (0.4337) |
| Observations | 189,499 | 189,499 | 189,499 | 189,077 |
| R-squared | 0.1311 | 0.0586 | 0.6068 | 0.0442 |
| adj.R-squared | 0.1299 | 0.0584 | 0.5242 | 0.0441 |
| PostPHEV all=1 | -0.1659* | -3.6339*** | -0.1495* | -2.7168*** |
| | (0.0648) | (0.5929) | (0.0585) | (0.4604) |
| Observations | 385,206 | 385,206 | 385,206 | 383,899 |
| R-squared | 0.1281 | 0.0584 | 0.6154 | 0.0393 |
| adj.R-squared | 0.1275 | 0.0584 | 0.5313 | 0.0392 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Log specification**

### 7.7.3 Replacement

Table 33: First Stage Summary

| | 1 | 2 | 1 | 2 |
|---|---|---|---|---|
| newPHEVperc | 0.61691 | 0.70813 | 1.11576 | 1.20594* |
| | (0.75718) | (0.68641) | (0.58747) | (0.47923) |
| GP | 0.00201*** | 0.00154*** | 0.00113** | 0.00071* |
| | (0.00051) | (0.00042) | (0.00041) | (0.00035) |
| stations | 0.00087* | 0.00111** | 0.00131** | 0.00163*** |
| | (0.00036) | (0.00039) | (0.00042) | (0.00037) |
| TX2000 | 0.01004** | 0.0118*** | 0.00894** | 0.01062*** |
| | (0.00356) | (0.00335) | (0.00326) | (0.00274) |
| AE | -0.00214 | -0.00362 | -0.0017 | -0.00313 |
| | (0.00501) | (0.00445) | (0.00373) | (0.00302) |
| ECOtality | -0.00121 | -0.00045 | 0.00015 | 0.0011 |
| | (0.00343) | (0.0027) | (0.00278) | (0.00228) |
| Under Id | 43.12*** | 49.43*** | 58.26*** | 72.93*** |
| ARW F | 1.35 | 2.06 | 1.60 | 2.76* |
| ARW $\chi^2$ | 8.16 | 12.44 | 9.60 | 16.56* |
| SW $\chi^2$ | 7.76 | 11.20 | 9.21 | 15.88* |
| Over Id | 7.679 | 9.440 | 7.654 | 9.796 |
| Obs | 113,486 | 153,572 | 113,499 | 153,584 |
| Num Cluster | 240 | 242 | 8,141 | 11,233 |
| FE | Zipcode | Zipcode | Household | Household |

Robust standard errors clustered by region in parentheses

Under Id for under-identification test (Kleibergen-Paap rk LM statistic)

ARW stands for Anderson-Rubin Wald test

SW stands for Stock-Wright LM S statistic

Over Id stands for over-identification test (Hansen J statistic)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**First Stage**

Table 34: Mileage on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | 1.6899 | -4.8026 | 1.6580 | -27.7009 | 1.1896 | -17.7699 | 1.6215 | -31.4252* |
| | (1.1250) | (17.0159) | (1.0793) | (17.2791) | (0.9260) | (13.3126) | (0.9357) | (12.4472) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.1527 | 0.0826 | 0.4039 | 0.0669 | 0.1483 | 0.0773 | 0.4063 | 0.0641 |
| adj.R-squared | 0.1502 | 0.0818 | 0.3574 | 0.0662 | 0.1464 | 0.0768 | 0.3590 | 0.0636 |
| Post(EV) all=1 | 1.8629 | 70.9373** | 1.5941 | 8.9114 | 1.3012 | 21.3123 | 1.5312 | -26.5222 |
| | (1.1425) | (24.7777) | (1.0812) | (22.9801) | (0.9656) | (16.6078) | (0.9364) | (16.6043) |
| Observations | 197,335 | 197,335 | 197,354 | 197,354 | 275,639 | 275,639 | 275,669 | 275,667 |
| R-squared | 0.1366 | 0.0352 | 0.4203 | 0.0670 | 0.1352 | 0.0724 | 0.4254 | 0.0616 |
| adj.R-squared | 0.1351 | 0.0347 | 0.3701 | 0.0666 | 0.1341 | 0.0720 | 0.3740 | 0.0612 |
| Post(PHEV) elec=1 | 1.1614 | -0.5163 | 1.5151 | -15.4647 | 0.5687 | -12.8642 | 1.4399 | -23.8110* |
| | (1.0069) | (13.1008) | (0.8779) | (13.3203) | (0.8918) | (10.9333) | (0.7775) | (10.2489) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.1527 | 0.0831 | 0.4039 | 0.0717 | 0.1482 | 0.0786 | 0.4063 | 0.0662 |
| adj.R-squared | 0.1502 | 0.0824 | 0.3574 | 0.0710 | 0.1464 | 0.0780 | 0.3590 | 0.0657 |
| Post(PHEV) all=1 | 0.4687 | 35.9989** | 0.9356 | 12.0748 | -0.0159 | 11.1000 | 0.8403 | -14.3144 |
| | (0.8527) | (12.8702) | (0.7503) | (13.3463) | (0.7904) | (10.7949) | (0.6878) | (10.4241) |
| Observations | 197,342 | 197,342 | 197,361 | 197,361 | 275,646 | 275,646 | 275,676 | 275,674 |
| R-squared | 0.1365 | 0.0537 | 0.4203 | 0.0657 | 0.1351 | 0.0736 | 0.4254 | 0.0640 |
| adj.R-squared | 0.1351 | 0.0532 | 0.3701 | 0.0653 | 0.1341 | 0.0733 | 0.3740 | 0.0637 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Linear specification**

Table 35: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | 0.0562 | 0.6304 | 0.0494 | -0.5882 | 0.0338 | 0.2304 | 0.0421 | -0.7902 |
| | (0.0692) | (0.8354) | (0.0520) | (0.8449) | (0.0563) | (0.5759) | (0.0445) | (0.5791) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.2044 | 0.1146 | 0.4314 | 0.1048 | 0.1966 | 0.1138 | 0.4289 | 0.1017 |
| adj.R-squared | 0.2021 | 0.1138 | 0.3870 | 0.1042 | 0.1948 | 0.1133 | 0.3834 | 0.1012 |
| Post(EV) all=1 | 0.0576 | 3.9566** | 0.0483 | 1.1405 | 0.0344 | 1.8618* | 0.0382 | -0.3741 |
| | (0.0714) | (1.3241) | (0.0523) | (1.1039) | (0.0586) | (0.7384) | (0.0446) | (0.7493) |
| Observations | 197,335 | 197,335 | 197,354 | 197,354 | 275,639 | 275,639 | 275,669 | 275,667 |
| R-squared | 0.1812 | 0.0534 | 0.4383 | 0.0946 | 0.1752 | 0.0950 | 0.4364 | 0.0939 |
| adj.R-squared | 0.1798 | 0.0529 | 0.3897 | 0.0942 | 0.1742 | 0.0946 | 0.3860 | 0.0936 |
| Post(PHEV) elec=1 | 0.0251 | 0.6538 | 0.0225 | 0.0029 | -0.0014 | 0.3037 | 0.0087 | -0.3937 |
| | (0.0608) | (0.6447) | (0.0455) | (0.6411) | (0.0517) | (0.4795) | (0.0404) | (0.4777) |
| Observations | 113,486 | 113,486 | 113,499 | 113,499 | 153,572 | 153,572 | 153,586 | 153,584 |
| R-squared | 0.2044 | 0.1130 | 0.4314 | 0.1067 | 0.1966 | 0.1132 | 0.4289 | 0.1040 |
| adj.R-squared | 0.2020 | 0.1122 | 0.3870 | 0.1060 | 0.1948 | 0.1126 | 0.3834 | 0.1035 |
| Post(PHEV) all=1 | 0.0032 | 2.1627** | 0.0122 | 1.1492 | -0.0212 | 1.1668* | -0.0040 | 0.0141 |
| | (0.0499) | (0.6710) | (0.0370) | (0.6377) | (0.0436) | (0.4927) | (0.0346) | (0.4787) |
| Observations | 197,342 | 197,342 | 197,361 | 197,361 | 275,646 | 275,646 | 275,676 | 275,674 |
| R-squared | 0.1812 | 0.0741 | 0.4383 | 0.0907 | 0.1752 | 0.0968 | 0.4364 | 0.0944 |
| adj.R-squared | 0.1798 | 0.0737 | 0.3897 | 0.0903 | 0.1742 | 0.0965 | 0.3860 | 0.0941 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Log specification**

### 7.7.4 Adding

Table 36: First Stage Summary

| | 1 | 2 | 1 | 2 |
|---|---|---|---|---|
| newPHEVperc | 0.69274 | 0.02708 | 1.17627 | 0.3065 |
| | (0.98912) | (0.7323) | (0.66226) | (0.50761) |
| GP | 0.00241** | 0.00385** | 0.00087 | 0.00256** |
| | (0.00086) | (0.00127) | (0.00059) | (0.00087) |
| stations | 0.00156* | 0.00074 | 0.00185** | 0.00098 |
| | (0.00071) | (0.00081) | (0.00058) | (0.00068) |
| TX2000 | 0.01937* | 0.02294 | 0.02135** | 0.02139 |
| | (0.00842) | (0.0161) | (0.00721) | (0.0149) |
| AE | 0.01857 | 0.03694 | 0.00729 | 0.01982 |
| | (0.01226) | (0.0194) | (0.00737) | (0.01192) |
| ECOtality | 0.00181 | -0.00167 | 0.00267 | -0.00079 |
| | (0.00649) | (0.00914) | (0.00506) | (0.00655) |
| Under Id | 32.28*** | 24.86*** | 44.54*** | 30.26*** |
| ARW F | 3.16** | 2.74* | 4.67*** | 3.24** |
| ARW $\chi^2$ | 19.05** | 16.57* | 28.05*** | 19.52** |
| SW $\chi^2$ | 16.08* | 16.43* | 27.91*** | 19.36** |
| Over Id | 10.318 | 6.778 | 13.458* | 5.306 |
| Obs | 52,983 | 28,286 | 52,982 | 28,286 |
| Num Cluster | 237 | 233 | 4,569 | 2,438 |
| FE | Zipcode | Zipcode | Household | Household |

Robust standard errors clustered by region in parentheses

Under Id for under-identification test (Kleibergen-Paap rk LM statistic)

ARW stands for Anderson-Rubin Wald test

SW stands for Stock-Wright LM S statistic

Over Id stands for over-identification test (Hansen J statistic)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

#### First Stage

Table 37: Mileage on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | -2.3298 | -33.3381* | -1.5959 | -55.6693** | -2.5752 | -47.6787** | -4.0691** | -90.3163** |
| | (1.2063) | (13.5546) | (1.2630) | (17.3964) | (1.4168) | (15.9767) | (1.4151) | (29.8482) |
| Observations | 52,956 | 52,955 | 52,956 | 52,954 | 28,273 | 28,273 | 28,273 | 28,273 |
| R-squared | 0.1797 | 0.0677 | 0.4707 | 0.0276 | 0.2177 | 0.0263 | 0.4968 | -0.0752 |
| adj.R-squared | 0.1746 | 0.0661 | 0.4198 | 0.0261 | 0.2088 | 0.0232 | 0.4478 | -0.0781 |
| Post(EV) all=1 | -1.9907 | -1.3e+02*** | -1.5676 | -1.5e+02*** | -2.6309 | -1.6e+02*** | -4.0154** | -2.5e+02*** |
| | (1.2630) | (28.9569) | (1.2555) | (30.9421) | (1.3614) | (35.6767) | (1.4075) | (57.5419) |
| Observations | 125,566 | 125,566 | 125,573 | 125,571 | 72,259 | 72,259 | 72,259 | 72,259 |
| R-squared | 0.1579 | -0.1276 | 0.4892 | -0.1274 | 0.1726 | -0.3099 | 0.5046 | -0.4630 |
| adj.R-squared | 0.1557 | -0.1285 | 0.4339 | -0.1281 | 0.1688 | -0.3115 | 0.4513 | -0.4646 |
| Post(PHEV) elec=1 | -3.2688** | -23.5988* | -1.7264 | -46.4273** | -4.0180** | -36.1892** | -4.3193*** | -64.1697** |
| | (1.0722) | (10.7701) | (1.0981) | (14.2076) | (1.2386) | (11.9437) | (1.2672) | (20.8345) |
| Observations | 52,984 | 52,983 | 52,984 | 52,982 | 28,286 | 28,286 | 28,286 | 28,286 |
| R-squared | 0.1797 | 0.0810 | 0.4706 | 0.0356 | 0.2178 | 0.0557 | 0.4968 | -0.0116 |
| adj.R-squared | 0.1746 | 0.0794 | 0.4196 | 0.0341 | 0.2089 | 0.0528 | 0.4477 | -0.0143 |
| Post(PHEV) all=1 | -2.9355** | -89.4690*** | -1.1870 | -1.2e+02*** | -3.8741*** | -1.2e+02*** | -3.5240** | -1.7e+02*** |
| | (1.0843) | (19.1306) | (1.0703) | (21.1980) | (1.1543) | (24.1158) | (1.2866) | (35.6513) |
| Observations | 125,614 | 125,614 | 125,621 | 125,619 | 72,283 | 72,283 | 72,283 | 72,283 |
| R-squared | 0.1579 | -0.0660 | 0.4891 | -0.1141 | 0.1726 | -0.2254 | 0.5046 | -0.3146 |
| adj.R-squared | 0.1557 | -0.0668 | 0.4338 | -0.1148 | 0.1689 | -0.2269 | 0.4513 | -0.3160 |

Standard errors in parentheses

With demographic.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Linear specification**

Table 38: Percentage Mileage Change on other cars when purchase a new (PH)EV

| | OLS Zip1 | IV Zip1 | OLS HH1 | IV HH1 | OLS Zip2 | IV Zip2 | OLS HH2 | IV HH2 |
|---|---|---|---|---|---|---|---|---|
| Post(EV) elec=1 | -0.1218 | -0.5905 | -0.1093 | -1.6691$^{*}$ | -0.1374 | -2.2573$^{**}$ | -0.2163$^{**}$ | -4.0232$^{**}$ |
| | (0.0662) | (0.6132) | (0.0654) | (0.7066) | (0.0796) | (0.8423) | (0.0765) | (1.4235) |
| Observations | 52,956 | 52,955 | 52,956 | 52,954 | 28,273 | 28,273 | 28,273 | 28,273 |
| R-squared | 0.2130 | 0.1251 | 0.4683 | 0.0908 | 0.2563 | 0.0676 | 0.4934 | -0.0065 |
| adj.R-squared | 0.2081 | 0.1236 | 0.4172 | 0.0894 | 0.2478 | 0.0647 | 0.4440 | -0.0092 |
| Post(EV) all=1 | -0.1164 | -4.9844$^{***}$ | -0.1134 | -6.1045$^{***}$ | -0.1458 | -6.9180$^{***}$ | -0.2252$^{**}$ | -10.4219$^{***}$ |
| | (0.0685) | (1.2544) | (0.0652) | (1.3610) | (0.0796) | (1.6226) | (0.0757) | (2.6128) |
| Observations | 125,566 | 125,566 | 125,573 | 125,571 | 72,259 | 72,259 | 72,259 | 72,259 |
| R-squared | 0.1829 | -0.0276 | 0.4769 | -0.0498 | 0.2030 | -0.2013 | 0.4948 | -0.3042 |
| adj.R-squared | 0.1807 | -0.0284 | 0.4203 | -0.0505 | 0.1994 | -0.2027 | 0.4404 | -0.3056 |
| Post(PHEV) elec=1 | -0.1713$^{**}$ | -0.3064 | -0.1326$^{*}$ | -1.3487$^{*}$ | -0.2132$^{**}$ | -1.6482$^{**}$ | -0.2502$^{***}$ | -2.9723$^{**}$ |
| | (0.0596) | (0.4979) | (0.0570) | (0.5920) | (0.0720) | (0.6231) | (0.0703) | (1.0247) |
| Observations | 52,984 | 52,983 | 52,984 | 52,982 | 28,286 | 28,286 | 28,286 | 28,286 |
| R-squared | 0.2132 | 0.1278 | 0.4683 | 0.0955 | 0.2566 | 0.0983 | 0.4935 | 0.0368 |
| adj.R-squared | 0.2083 | 0.1263 | 0.4172 | 0.0941 | 0.2481 | 0.0955 | 0.4441 | 0.0342 |
| Post(PHEV) all=1 | -0.1514$^{**}$ | -3.3817$^{***}$ | -0.1059 | -4.7060$^{***}$ | -0.2006$^{**}$ | -4.9827$^{***}$ | -0.2113$^{**}$ | -7.1457$^{***}$ |
| | (0.0549) | (0.8400) | (0.0543) | (0.9327) | (0.0648) | (1.0942) | (0.0694) | (1.6068) |
| Observations | 125,614 | 125,614 | 125,621 | 125,619 | 72,283 | 72,283 | 72,283 | 72,283 |
| R-squared | 0.1829 | 0.0195 | 0.4769 | -0.0382 | 0.2032 | -0.1095 | 0.4949 | -0.1878 |
| adj.R-squared | 0.1808 | 0.0188 | 0.4202 | -0.0389 | 0.1996 | -0.1109 | 0.4405 | -0.1891 |

Standard errors in parentheses

With demographic.

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

**Log specification**