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Do electric vehicle incentives matter? Evidence from the 50 U.S. states

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ABSTRACT

We estimate the effectiveness of policy incentives for adoption of electric vehicles (EVs) in the 50 U.S. states. We employ a rich dataset of semi-annual state-level new EV vehicle registrations by make and model from 2010 to 2015 and state-level policy instruments that could affect new EV model registrations. We construct two measures of policy, one which aggregates policy instruments that can be assigned a value and a second that aggregates those without explicit values. Using a within model difference-in-difference estimator with high-dimensional fixed effects, we find that a $1000 increase in the value of a state's model-specific EV policies increases registrations of that model within the state by 5–11%.

1. Introduction

A new generation of electric vehicles (EVs) was introduced to the commercial market in 2010 with the arrival of the Nissan Leaf and Chevrolet Volt.[1] Since then, every major car manufacturer has brought an EV to market. This revival was motivated by energy security and environmental concerns, coupled with rising fuel costs and fuel efficiency standards (Energy.gov, 2014). The performance of new EV models has improved tremendously, a trend perhaps best embodied by the development of luxury sports cars by Tesla Motors (Energy.gov, 2014). Battery electric vehicles (BEVs), that operate solely on electricity, and plug-in hybrid electric vehicles (PHEVs), that run on both gasoline and electricity, can potentially reduce greenhouse gas (GHG) emissions and local air pollutants as well as provide grid support by acting as an energy storage device (Richardson, 2013; Galus et al., 2010; Lund and Kempton, 2008).

In recognition of the potential social benefits of EVs, the U.S. government offers consumers a tax credit that is scaled according to battery capacity and capped at $7500 (IRS, 2015). Nearly half of U.S. states also offer some type of purchase-related financial incentive. With the relative infancy of new EVs to market, the question remains how well the federal and state governments' broad policy objective, to stimulate sales of new EVs, is facilitated by the various policy instruments implemented by these governments.[2] This study is the first to address this question by applying advanced econometric techniques to panel data for the 50 U.S. states to estimate the effectiveness of financial incentives and other policy instruments on new EV registrations from 2010 to 2015. The U.S. EV market provides an ideal case study due to variation in the type and timing of policy instruments implemented between states and the integration of EVs into the national automobile market since 2010. We employ a rich dataset of semi-annual state-level new EV registrations by make and model from 2010 to 2015 and state-level policy instruments affecting new registrations of EV models. We construct two measures of policy: one that aggregates policy instruments with money values and a second that aggregates those without explicit estimates of their value. Using a within model difference-in-difference estimator with high-dimensional fixed effects, we find that a $1000 increase in the value of model-specific state EV policy instruments results in an additional 5–11% increase in state registrations of that model. Our results are robust to a variety of different specifications, time periods, and measures of policy instruments.

2. Prior studies on policy instruments and EV sales

Few studies have empirically explored the relationships between policy instruments supporting EV use and adoption. Since the introduction of EVs to the mainstream auto market is relatively new, we review similar empirical studies on the effectiveness of policy

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[1] The Tesla Roadster, the earliest entrant to the new generation of EVs, was released in 2008.
[2] Borrás and Edquist (2013) and del Río and Howlett (2013) point out the importance of distinguishing between policy objectives and policy instruments used to achieve the objectives.

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incentives on the adoption of hybrid electric vehicles (HEVs). To summarize, the existing literature suggests that financial incentives for vehicle purchase matter and that some non-financial incentives like access to high occupancy vehicle (HOV) lanes and charging infrastructure also matter. For a more complete review of literature on factors that affect EV adoption, see Coffman et al. (2017).

There are four studies that look at the U.S. EV market that closely relate to our work. Jin et al. (2014) compare 2013 EV market shares with state-level incentives and finds that direct subsidies are the biggest determinant of EV sales followed by access to HOV lanes. Lutsey et al. (2015) investigate city-and utility-level policy instruments as well as charging infrastructure in the 25 most-populous U.S. metropolitan areas using 2014 EV market shares. They find that cities with higher EV sales tend to have more diverse incentives, greater charging infrastructure per capita, greater model availability, and more promotional activities. Building upon prior work, Lutsey et al. (2016) and Slowik and Lutsey (2017) examine the 2015 and 2016 EV market in the top 50 metropolitan areas, respectively. While these studies provide a glimpse into the effectiveness of state and municipal-level incentives for EVs, their results are drawn from single-year samples.

Charging infrastructure appears to be a strong contributor to EV adoption.[3] In a regional and municipal analysis of EV incentives in Norway, Mersky et al. (2016) find that the number of charging stations is the greatest predictor of EV sales while access to bus lanes and road toll waivers are not statistically significant predictors. Sierzchula et al. (2014) draw a similar conclusion with respect to the number of charging stations per capita at the national level. Results on the impact of charging infrastructure should be interpreted with caution, however, since investment in charging infrastructure is likely endogenous, both responding to and affecting the base of purchased EVs (Mersky et al., 2016).

Several regional analyses support the findings that HOV lane access, regardless of actual passenger count, is important to EV sales. Looking at the 2010–2013 time period, Sheldon and DeShazo (2016) attribute a quarter of California's EV registrations to its HOV lane access policy. Prior studies on HEVs similarly find that consumers are willing to pay a premium for HOV lane access. Bento et al. (2014) estimate that HEV owners in Southern California gain $473 annually from purchasing a sticker to access HOV lanes, regardless of vehicle passenger count. Similarly, Shewmake and Jarvis (2014) find that in 2005 HOV lane access could have been sold to Californians for $5800 per sticker, instead of being freely allocated to HEV owners. In a study of Virginia, Diamond (2008) finds that the impact of HOV lane access is highly dependent on the local provision of HOV lanes.

The broader HEV literature suggests upfront vehicle purchase incentives, larger incentive amounts, and higher gas prices have the greatest effect on HEV sales. Based on a study of 22 metropolitan areas, Beresteanu and Li (2011) find that HEV sales in 2006 would have been 37% lower if gasoline prices had remained at their 1999 level and that the federal tax credit accounted for 20% of HEV adoptions in 2006. Counter to Sierzchula et al. (2014)'s findings for EVs, Diamond (2009) finds in a U.S. state-level analysis that gasoline prices had the strongest effect on the HEV share of state automobile markets. The divergence in findings could be because EVs can be run on both electricity and gasoline, depending on the model and Sierzchula et al. (2014) did not distinguish between BEVs and PHEVs. Similar to Jin et al. (2014), Diamond (2009) also finds that vehicle purchase incentives and carpool lane access positively impact HEV adoption, though weakly. Within types of vehicle purchase incentives, sales or excise tax waivers have a slightly larger effect on HEV sales than rebates received with a lag. Although the estimated coefficient for carpool lane access is positive and statistically significant, this result is driven by Virginia, which was the only state to offer HOV lane access to HEVs between 2001 and 2004. Consistent with Diamond (2009), Gallagher and Muehlegger (2011) find mixed evidence regarding effects of HOV lane access, that increased HEV sales track higher gas prices, and that the type of tax incentive is as important as the amount of the incentive. Lastly, Jenn et al. (2013) examine the impact of the Energy Policy Act of 2005 on HEV sales in the United States and find that the Act's tax credit for EV purchases increased sales on average by 4.6% per $1000 of tax credit. This result is only statistically significant for HEVs that qualify for more than $1000 in tax credits. Jenn et al. (2013) also find that higher gas prices were associated with additional HEV sales.

3. Consumer-oriented state EV policy instruments

We identify four main categories of consumer-oriented policy instruments affecting EVs: Capital Financial Incentives, Operating Financial Incentives, Preferred Access Incentives, and Disincentives. Though we focus primarily on state-level policy instruments, we also use county, city, metropolitan area, or utility-specific policy instruments when they are well documented and apply to the majority of the population or residential customers in the state (U.S. EIA, 2011–2016). Capital financial incentives consist of vehicle purchase incentives and home charger incentives. Vehicle purchase incentives are those directly related to the purchase of EVs, and include rebates, excise tax credits, income tax credits and sales tax exemptions. Home charger incentives refer to subsidies to purchase and install home charging systems. Operating financial incentives include reduced vehicle license tax (VLT) or registration fees, time-of-use (TOU) electricity rates specifically for EV charging, and an exemption from emissions inspection for EVs in states where inspections are otherwise mandatory. Preferred access incentives entail the use of HOV lanes without occupancy restrictions, and parking privileges such as designated or free parking. Lastly, a number of states have implemented a disincentive, an annual EV fee intended to make up for lost gasoline tax revenues.

To create our database, we start with the U.S. Department of Energy's Alternative Fuel Database Center (AFDC). The AFDC documents existing and expired U.S. state laws and incentives related to EVs (AFDC, 2016a). Whenever the AFDC website lacks information on date of implementation or other details, Wee (2016) supplements the AFDC database with information taken from more than 300 government (state, city, and county) and utility websites, including the use of the WayBackMachine (Internet Archive, 2018). Additional information is obtained via phone interviews and email correspondences with various state departments and agencies as well as Clean Cities coalitions (state and city-level organizations supported by a U.S. Department of Energy program).[4] This collection of data provides the timing of implementation of identified EV policy instruments within states and, where possible, their money value.

Table 1 provides a summary of the BEV and PHEV policy instruments affecting consumers between 2010 and 2015 by U.S. state. The dataset is documented in detail in Wee et al. (in press).

Rogge and Reichardt (2016) emphasize the importance of understanding the dynamics of the mix of policy instruments, in terms of their collective efficacy. There are 19 and 16 states that have offered a vehicle purchase incentive for BEVs and PHEVs, respectively. We note that all PHEV policy instruments also apply to BEVs, but some BEV policy instruments do not apply to PHEVs. Six states ended their BEV purchase subsidies by 2015, while four others—Louisiana, Maryland, Pennsylvania and Utah—adjusted the size of their incentive. Hawaii, for

[3] Bleda and del Río (2013) argue that supply-side factors like public charging infrastructure are important and subject to "deep coordination failures" that may lead to suboptimal investment.

[4] AFDC and government websites generally provide information on current incentives, but frequently do not list program start dates for both current and expired programs. The semi-annual dates reported in this study reflect dates of policy implementation except when the actual implementation date could not be determined; in these cases, the policy enactment date is used instead.