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Effectiveness of electric vehicle incentives in the United States

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ABSTRACT

Transportation accounts for 28% of total energy use and 26% of carbon emissions in the US, and battery electric and plug-in hybrid electric vehicles are promising options to decarbonize transportation. Federal and state governments, electric utility operators, and a number of other entities have provided support to accelerate electric vehicle purchases via monetary and non-monetary incentives. In this paper, we evaluate the effect of these incentives on the adoption of electric vehicles. We find that every $1000 offered as a rebate or tax credit increases average sales of electric vehicles by 2.6%. We also find that HOV lane access is a significant contributor to adoption, the effect is a 4.7% increase corresponding to density of HOV lanes (every 100 vehicles per hour). In addition, we introduce a novel variable to capture consumer knowledge of EVs and associated incentives in our model to help explain the state level heterogeneity in response to incentives and find that raising consumer awareness is critical to the success of EV incentive programs.

1. Introduction

The development and adoption of electric vehicles (EVs) has been increasing in sales and model availability over the last decade as a potential mitigation method to reduce greenhouse gas emissions in the transportation sector. Since the introduction of electric vehicles, various entities such as federal governments, state governments, and electric utilities across the United States have offered incentives in an effort to promote their adoption (e.g. IRS 30D, the federal Plug-in Electric Drive Vehicle Credit). These incentives vary in design (monetary credits and rebates, carpool lane access, toll and registration exemptions, etc.), scope (federal, state, and local regions as well as by vehicle type, battery size/range), and magnitude (ranging from hundreds to several thousands of dollars for monetary incentives). We have developed a comprehensive dataset of nearly 200 incentives offered throughout the United States for electric vehicles and the purpose of this work is to understand the effects of the different incentives and what conditions affect their efficacy.

While electric vehicle technology has existed throughout the passenger fleet for many decades, their widespread commercial viability was not realized until the end of 2010 with the release of the Chevrolet Volt (a plug-in hybrid electric vehicle, PHEV) and the Nissan Leaf (a full battery electric vehicle, BEV). The rapid growth of electric vehicle sales (see Fig. 1) corresponds to a swath of incentives for both purchase and usage of EVs. This provides an ideal environment to conduct an econometric analysis of EV sales employing a detailed dataset (described in Section 3). The remainder of the paper is organized as follows: Section 2 provides a comprehensive literature review of incentive efficiency starting from hybrid technologies to more recent electric vehicle incentives, Sections 3 and 4 outlines the data used for modeling and the methods of our empirical analysis, Section 5 details the results of our analysis, and Section 6 concludes the paper with a discussion of the importance of our results.

2. Literature review

The study of vehicle incentives has a rich history for the hybrid electric vehicle (HEV) technology that was first introduced to the US in 2000. One of the earliest studies was conducted by Diamond (2009) who examined sales for the Honda Civic Hybrid, Toyota Prius, and Ford Escape Hybrid at a state level from 2001 through 2006. Diamond employs an econometric approach on a number of control variables, including a “green planning capacity” index: a proxy measure of energy and environmental conservation. Unfortunately, the author consistently finds that the presence of the incentive actually leads to a decrease in the market share of HEVs across all three models. Chandra et al. (2010) is another early look at incentives but in Canadian states and by market share over different vehicle segments. Their results indicate that the presence of a $1000 incentive leads to an increase of the market share of hybrids by more than 30%. In Sallee (2011), the author demonstrates

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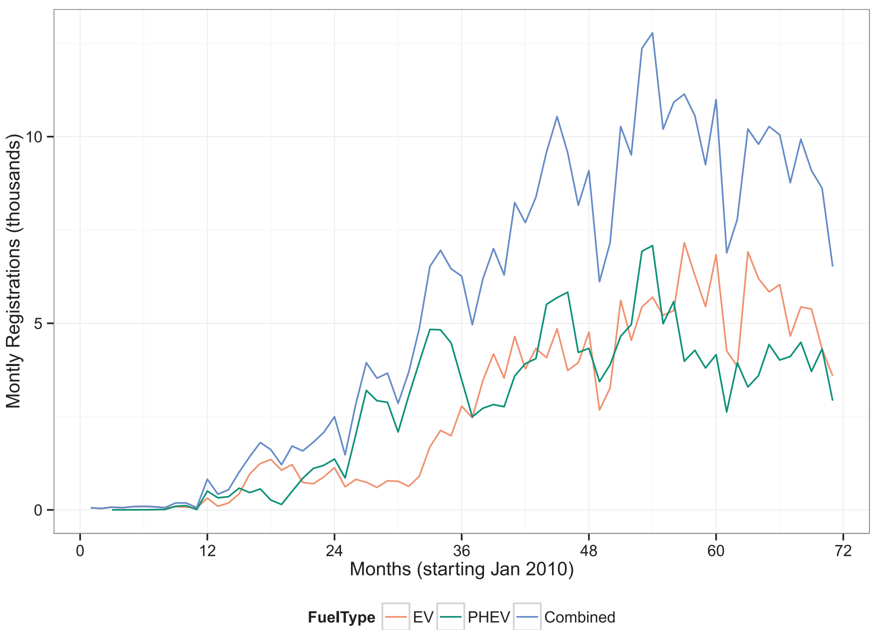

Fig. 1. Monthly sales of electric vehicles in the United States from January 2010 through November 2015. The sales of BEVs (red) are relatively comparable to the sales of PHEVs (green), the sum of the two comprise the combined totals of EVs (blue). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).

that consumers are the ones capturing the majority of benefits from tax subsidies (not manufacturers or dealers). This effect was demonstrated by closely examining the market for Toyota Priuses and associated changes (or non-changes) in price accompanying shifts in HEV incentive amounts. Contrary to Diamond's earlier findings, more recent studies conducted in the US have found a positive impact of incentives on the adoption of HEVs. One such study on the national sales of HEVs demonstrated consistent increases in per-capita sales in response to state level tax incentives. The authors importantly investigated the effect of different types of incentives as well as the effects from how the incentives were obtained (credits versus waivers) and found that waivers tended to be the most effective (Gallagher and Muehlegger, 2011). In Jenn et al. (2013), the authors also take an empirical econometric approach using lagged dependent variables to approximate natural growth of the technology. Their results indicate that literature values tend to overestimate incentive effects but nonetheless the effects are positive and consistent.

More recently there have been a number of studies that have begun to examine the incentives offered for both BEVs and PHEVs. In an effort to identify the largest barriers to the adoption of EVs, Egbue and Long (2012) conducted a survey to identify the primary concerns about the new technology. The largest concerns were that of battery range and cost, the latter being a critical factor that can potentially be alleviated by the presence of monetary incentives. However, Skerlos and Winebrake (2010) argue that the structure of the federal incentives introduced in 2009 would have higher social benefit if the subsidy policies were varied across income. Additionally, Dumortier et al. (2015) examine how the presentation of cost information, specifically regarding total cost of ownership can actually increase the probability that electric vehicles are selected. This can have important implications for providing price information to consumers for monetary incentives as well. An overview of different policy mechanisms is provided by Zhang et al. (2014). While their analysis is primarily qualitative, they supply a thorough summary of different incentives, particularly in the United States. In terms of the effect of incentives, there are a number of studies that estimate the influence of incentives on adoption of electric vehicles via empirical sales data (Sierzchula et al., 2014; Silvia and Krause, 2016; Vergis and Chen, 2015) and via survey-based data (Krause et al., 2013; Helveston et al., 2015; DeShazo et al., 2017; Tal and Nicholas, 2016).

Additionally there are a number of studies concentrated in Scandinavian countries due to EV popularity and relatively successful integration into the auto market. Langbroek et al. (2015) examine the effect of policy incentives but use a stated-choice experiment in Sweden rather than an econometric approach. With this approach, they are able to not only examine monetary incentives but a number of other incentives such as parking discounts, access to bus lanes, and charging discounts. The authors find relatively low price-sensitivity, particularly for individuals who are in an "advanced stage-of-change" (accepting of EVs). Therefore the behavioral component of acceptance of EV use is critical to the success of incentives. Mersky et al. (2016) study the effectiveness of incentives in Norway. The authors argue that the creation or increase of price incentives for EVs are more important than the provision of toll exemptions or bus lane access for increasing adoption. Bjerkan et al. (2016) use a large survey while Aasness and Odeck (2015) use empirical data to elicit the importance of the various incentives for EV owners in Norway. Both studies find that the purchase tax exemption and value added tax exemption are the most important drivers for adoption. However, the high relative success of Norwegian EV adoption has led Holtsmark and Skonhoft (2014) to question the benefits of high adoption rates. The authors argue that from a carbon perspective, the incentives actually motivate households to increase average household vehicle ownership and simultaneously detract from using public transit and cycling. In addition, they point out that the effective carbon price for the monetary policy amounts to around $13,500 per ton of CO_2. Finally, Figenbaum offers a very detailed perspective on the Norwegian EV market based on a technological innovation model and his investigation on various driving factors of adoption. His framework of analysis outlines the dynamics of the policy framework for BEVs (Figenbaum, 2016; Figenbaum et al., 2015).

Beyond the research focused on monetary incentives on the purchase of electric vehicles, a number of studies have been released examining other mechanisms of incentivizing such as high-occupancy vehicle (HOV) lane access, infrastructure subsidies, time-of-use rates, parking benefits, and others. An earlier study by Shewmake and Jarvis (2014) examined the California Clean Air Access Stickers provided for HOV lane access and derived their value by investigating the used car market for hybrids. The authors found the worth of the stickers to be approximately $5800. There are a number of other studies that examine other non-monetary incentives such as the importance of work based charging (Adepetu et al., 2016), parking and charging access (Ajanovic and Haas, 2016; Bakker and Trip, 2013; Hackbarth and Madlener,