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The impact of federal incentives on the adoption of hybrid electric vehicles in the United States

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ABSTRACT

Starting in 2004, the federal government in the United States offered several nationwide incentives to consumers to increase the adoption of hybrid electric vehicles. This study assesses the effectiveness of the Energy Policy Act of 2005 in this regard using econometric methods and data between 2000 and 2010. Our model accounts for network externalities by using lagged sales as an independent variable. This approach helps to capture the exponential initial growth associated with the diffusion of new technologies and avoids overestimating the effect of the policy incentives. Our results show that the Energy Policy Act of 2005 increased the sales of hybrids from 3% to 20% depending on the vehicle model considered. In addition, we find that this incentive is only effective when the amount provided is sufficiently large.

1. Introduction

Efforts to promote the adoption of hybrid electric vehicles in the United States have been steadily increasing over the last decade in response to concerns over environmental impacts from fossil fuel combustion and to reduce consumption of foreign oil. Currently, hybrid electric vehicles (HEVs) represent the majority of available alternatives to traditional internal combustion engine (ICE) vehicles for personal transportation.

HEVs combine an internal combustion engine with an electric propulsion system that is powered by a large battery unit. The battery provides a higher fuel efficiency by using regenerative braking and preventing idling loses (by shutting off the engine), thus allowing most HEVs to at least raise their city-driving fuel efficiency to highway-driving fuel efficiency levels. The proposed benefits of higher fuel efficiency include less pollution and emissions as well as gasoline savings without sacrificing the service provided, though typically at higher prices. These benefits are the primary reasons prompting the government to incentivize their use through tax credits and rebates. However, there is large uncertainty on whether these incentives have been able to induce adoption.

The Honda Insight and Toyota Prius were the first HEVs introduced in the market in the year 2000. Both models are offered only as HEVs. This was followed by the introduction of the Honda Civic Hybrid in 2002 as a hybrid variant of an originally ICE model. Since then, the number of make and models offering HEV alternatives has increased substantially. There are currently over 30 HEV models offered in the market. The majority are hybrid versions of ICE vehicles.[1] Fig. 1 shows the number of available HEV models over time, from 1999 through 2010.

Since the introduction of the Honda Insight and Toyota Prius in 2000, the government used several mechanisms to promote the adoption of HEVs. These mechanisms included a variety of incentives, both non-monetary and monetary. The first federal incentive was HR 1308, Section 319 of the Working Families Tax Relief Act of 2004 (Law No: 108-311) (Thomas, 2003). This Act established that the Internal Revenue Service (IRS) would provide a $2000 taxable income deduction to an alternative fuel vehicle purchase. This included HEVs. The incentive applied for two years starting on January 1, 2004 with an upper bound expense of approximately $400 million to the US government.[2] In 2005 the Energy Policy Act in 2005 (Law No: 109-58) (Barton, 2005),

Abbreviations: HEV, hybrid electric vehicle; ICE, internal combustion engine; GHG, greenhouse gas; C4C, Cash for Clunkers; LDV, lagged dependent variable.

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[1] Hybridcars.com: Hybrid Market Dashboard.
[2] Assuming 35% income tax bracket and that all consumers capture the incentive.

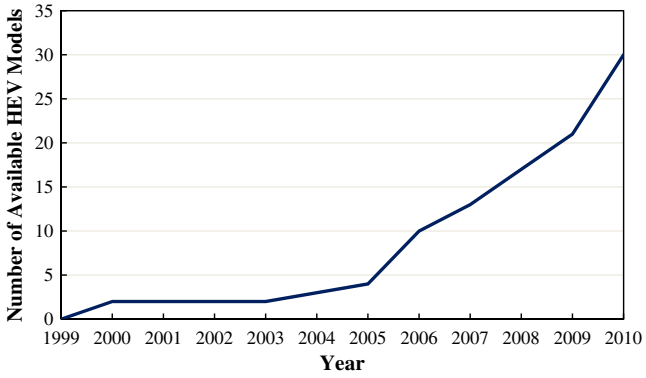

Fig. 1. Number of HEV models commercially available over time. Compiled by the authors using data from: www.autonews.com.

established a new set of incentives via a direct tax credit to consumers for the purchase of an HEV. This incentive was partially scaled to the fuel economy rating of the vehicle, so a greater efficiency would typically result in a higher incentive. In addition, a "phasing out" period was applied to the incentives: if any manufacturer sold 60,000 HEVs within one quarter, the incentives applied to their vehicles would halve twice over the course of the year before being phased out completely. This act was specifically aimed at reducing benefits for foreign vehicle manufacturing companies who had a larger command of alternative fuel vehicles at the time.[3] The Energy Policy Act of 2005 was successful in this regard as Toyota's incentives were phased out on September 30, 2007 and Honda's incentives were phased out on December 31, 2008. A full list of incentive amounts can be found in Table A1 included in the Supplemental Information. The policy ended on December 31, 2010 at an approximate total expense of $1.4 billion to the US government.[4]

The most recent incentive provided by the government was the Car Allowance Rebate System (also known as Cash for Clunkers), which gave a tax credit (either $3500 or $4500) for the trade-in of less fuel-efficient vehicle for a vehicle of higher fuel-efficiency (several hybrid models were offered). The program was in effect between July 1, 2009 and August 25, 2009. Yet, over 700,000 relatively more fuel-efficient vehicles were sold.[5]

This paper characterizes the impact that these federal incentives had in promoting the adoption of HEVs and shows how this effect looks like when accounting for the natural pace of adoption of new technologies.

The literature has studied how different factors shape the preferences of consumers when purchasing HEVs. A first paper by Sallee (2006) performs an in-depth study of the Toyota Prius market. Sallee measures the incidence of tax credits, or consumer's reaction not only to the tax incentive but also to other people's reactions. Specifically, Sallee uses the change in tax incentive from 2005 to 2006 when the Energy Policy Act of 2005 is implemented to investigate strategic shifting of Prius purchases during the fourth quarter of 2005, and concludes that consumers capture all the benefits of the tax incentives. A second paper by Kahn (2006) investigates environmentalism as a characteristic that affects purchasing behavior. Using the number of Green Party voters in an area as a measure of environmentalism from a variety of census data between 1999 and 2005 as well as from the 2001 National Household Transportation Survey data set, Kahn runs a series of regression models to look at differences in consumption and finds that an increase in the share of Green Party voters of 1% decreases the probability that a household owns an SUV (lower fuel economy vehicle) by nearly 20%. Similarly, Sexton and Sexton (2011) investigate the willingness to pay of Prius owners' to appear environmentally friendly. In this paper, the authors suggest that individuals who are predisposed to favor environmental goods receive disproportionately greater utility from environmental products—even more so in the case of Priuses, whose unique design garners additional benefit from signaling environmental responsibility. This effect is termed "conspicuous consumption" and is found to be a statistically significant effect among Priuses' owners.

Three papers use econometric analysis to assess the influence of incentives on hybrid sales. Gallagher and Muehlegger (2011) use aggregate national HEV sales data per capita and fixed effects including as independent variables the presence of High-Occupancy Vehicle (HOV/carpool) lanes, tax credits, sales tax rebates and gas prices while controlling for environmentalism demographics in quarterly periods. Their results indicate that higher tax incentives are associated with more sales, the sales tax incentives having an impact larger than tax credits. HOV lanes, which require either 1 (HOV-1) or 3 (HOV-3) additional passengers besides the driver, exhibit mixed results. The authors find that HOV-1 does not have a significant impact on sales, while HOV-3 is significant in some states. Lastly, they find that a 1% increase in gas prices increases the per capita sales of HEVs between 0.7% and 1%. As one of the first econometric studies of hybrid vehicle incentives, the authors of this paper lay the groundwork for many of the explanatory variables used in follow-up regression models. However, these models do not account for positive network externalities in the adoption and diffusion of the new vehicle models (e.g. accounting for the natural growth of new technology), which is likely to positively bias several of their findings. Our paper is different in this regard. We explicitly allow the growth in the sales of HEVs to follow a S-shaped curve by including the lag of sales as a dependent variable in the regressions.

Another study performed by Chandra et al. (2008) examines the impact of tax rebates on HEV sales in Canada. Their study ranges across all the provinces in Canada, each of which offers different incentives. They generate counterfactual simulations, using a series of models that aggregate rebate values, which they compare to a base case. The latter is measured using existing market data for all HEV models sold in Canada from 2000 through 2006. The authors find that a $1000 increase in the rebate increased the market share of hybrids by approximately 31–38%. Similar to Gallagher and Muehlegger, this paper does not control for the relatively steeper adoption curves one would expect to observe when HEVs are first introduced in the market. Lastly, Diamond (2009) investigates the impact of government incentives for HEVs between 2000 and 2006 by state. He regresses the market share of HEV on vehicle miles traveled per capita, gas, incentives, HOV lane availability, income, and a "green planning capacity" index (a measure of environmentalism) using panel data and both fixed and random effects. This regression is performed on the three most popular hybrid models: Toyota Prius, Honda Civic Hybrid, and Ford Escape Hybrid, which accounted for over 50% of the total share of HEVs during the period of analysis. Diamond's results reveal that monetary incentives are either non-significant or affect negatively the sales of HEV. The author also performs separate regressions separately for each year and obtains drastically different coefficients from the panel regressions.

In sum, previous work in this field fails to account for network externalities in technology diffusion and adoption. Many studies applied to other technologies have established that these externalities lead cumulative adoption curves to take on S-shapes (Bass, 1969; Griliches, 1957), which consist of exponential growth followed by a change in concavity corresponding to a declining rate of adoption as the technology matures and reaches market saturation (Geroski, 2000; Mahajan and Peterson, 1985; Stoneman, 2002). Many studies have shown that the diffusion of new vehicle technologies, such as hybrid electric vehicles, plug-in hybrid electric vehicles and battery electric vehicles, also follows S-shaped curves (Balducci, 2008; Muraleedharakurup et al., 2010: McManus and Senter, 2009). However, econometric studies investigating the effect of policy instruments in automobile markets

[3] Press Release, Senator Carl Levin, "Energy Bill Moves Nation Toward Sounder Energy Policy" July 29, 2005.
[4] Obtained by multiplying the incentive amounts in each month by the respective per vehicle model.
[5] Department of Transportation Press Release August 26, 2009.