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The Impact of Different Incentive Policies on Hybrid Electric Vehicle Demand and Price: An International Comparison

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Abstract: Significant efforts to incentivize the uptake of energy efficient vehicles (EEVs) are evident across the globe. Given EEV markets are dynamic, and consumer demand may fluctuate in response to incentives, this may also lead to other market forces influencing prices. An analysis of EEV incentives, therefore, must account for the possible endogeneity between demand and pricing. Here we estimate the effects of different types of incentives on the demand and price premiums of a specific group of EEVs: plug-in and conventional hybrid electric vehicles (HEVs). For the first time we dis-entangle the endogeneity between HEV demand and price, using error components three-stage least squares (EC3SLS) regression, and establish that increased HEV price premiums lead to reduced demand. In turn, we also establish that increased HEV demand leads to lower price premiums. Additionally, we find that one-off subsidies are associated with higher consumer demand, however, unlike other types of incentives, are also associated with higher HEV price premiums. This finding suggests that HEV manufacturers and/or dealers are absorbing a significant monetary benefit from one-off subsidies, raising a question regarding the appropriateness of HEV subsidies, particularly in non-HEV manufacturing nations. We also find that higher fuel prices are associated with higher HEV demand and price premiums.

Keywords: hybrid electric vehicles; plug-in hybrid electric vehicles; energy efficient vehicles; incentives; endogeneity; error component three stage least squares

1. Introduction

Increasing the share of energy efficient vehicles (EEVs) is a goal shared by many governments around the globe. Many EEV-specific policy initiatives have been initiated with the principal aim to reduce the transport sector's contribution to total greenhouse gas emissions, and in turn, anthropogenic climate change. Some governments also seek to leverage EEV sales to reduce exposure to local air pollution, reduce dependence on foreign oil, and support innovation and jobs within the automobile manufacturing sector. While having the advantage of low or no tailpipe emissions, and in most cases lower operating costs, EEVs are often disadvantaged by higher purchase costs and operational or technological uncertainty.

Different types of EEV policies may affect consumer demand in different ways, with no clear trend in the literature suggesting which types of incentives most significantly increase the uptake of EEVs. Moreover, there is a general dearth of research into the effects of these incentives on the interaction between demand and prices of EEVs using revealed preference data. An overview of the existing literature in this field is included in Section 2.

Considering the number of EEV related policies that have been implemented around the world, and the current interest in EEVs internationally, this particular study focuses a specific group of EEVs, hybrid electric vehicles (HEVs), and aims to:

1. Identify which factors affect the demand and price of HEVs at the regional level
2. Establish that HEV demand and price are endogenous, and understand the implications of this endogenous relationship
3. Estimate the effects of various factors (including government policies) on HEV demand, and
4. Estimate the effects of various factors (including government policies) on HEV price premiums.

In order to achieve these four aims, we have collected panel data from 15 international regions, with a history of HEV purchases and policies, between 2008 and 2012. Using these data, we construct an econometric model system and use error-components three-stage least squares regression (EC3SLS) [1] to simultaneously analyze the impact of market factors on HEV demand and price, while accounting for the possible endogenous relationship between HEV demand and price. The econometric model employed in this study is described further in Section 3.

To address aims 1 and 2, a number of exogenous factors are included in the model, including: socio-demographic characteristics of the consumer population, economic factors, and incentive policy indicator variables. In order to address aims 3 and 4, we aggregate incentive policies into four categories based upon how and when they affect consumers. Details of the different incentive policies active in each region, as well as the categorization of these policies, are discussed in Section 3.4. The results of this study are detailed in Section 4, while the implications and conclusions from these results are outlined in Sections 5 and 6.

2. Background and Literature Review

The term energy efficient vehicle (EEV) has been used to describe many different types of vehicles by different researchers and jurisdictional authorities. In this study we focus on all vehicles recognized as hybrid-electric and plug-in hybrid-electric vehicles, during the period of analysis (2008–2012), by local and national governments, in each of the sampled regions. More broadly speaking, however, one can find EEV or low-emission vehicles, across the literature, referring to a wide range of different types of vehicles—some based on their CO₂ emissions, others based on their main fuel for propulsion, and others being a combination of the two. With such broad definitions of EEVs around the globe, complications arise in deciding which incentives apply across different situations and vehicle types. Additionally, complications also arise in directly comparing the results of different EEV studies, based on the differing types of vehicles analyzed.

For this analysis, we focus solely on privately owned (non-fleet), new hybrid-electric vehicles (HEVs) that were sold on the market between 2008 and 2012. These vehicles include plug-in hybrid-electric vehicles (PHEVs), but exclude battery electric vehicles (BEVs)—mainly due to the low volume of these vehicles sold during the period of analysis. A latter dataset of battery electric vehicle sales will be analyzed are part of a separate study, utilizing a similar model to that adopted here, in order to see whether similar incentive effects are observed for this related, but different group of EEVs.

2.1. Hybrid Electric Vehicle Technology

Hybrid-electric vehicles use both petroleum and an electric battery to operate. The way these two fuel sources drive the vehicle can vary across models. Both sources may operate in parallel to propel the vehicle. Alternatively, the vehicle may be primarily driven by one source, with the other supporting operation. One of the most popular hybrid-electric vehicles on the market globally is the Toyota Prius, known as a series-parallel hybrid. The Prius has both an electric motor and a petroleum-fueled engine, and both can operate simultaneously or independently, with the operation choice tailored to suit what is most energy efficient in each encountered scenario [2]. The current majority of Prius

models do not require plugging in for charging, as the battery is charged internally. This dual motor configuration, however, is considerably more fuel-efficient than a comparable vehicle with only an internal-combustion engine (ICE). More recently, however, plug-in hybrid-electric vehicles (PHEV) have been introduced, particularly amongst existing hybrid-electric models, such as the Toyota Prius. These newer vehicles have the added advantage of being able to run purely on electricity, without petroleum, for shorter distance i.e., less than 100 kilometers. Although the market for battery electric vehicles (BEVs) is expanding, as mentioned previously, such vehicles were not included in this analysis, largely due to a lack of global data available for the specific period of analysis.

2.2. Consumer Preferences towards Energy Efficient Vehicles

In conjunction with a significant increase in consumer demand for EEVs that has occurred globally over the past 15 years, the corresponding literature has also grown. A large proportion of these studies have involved the analysis of consumer preferences through stated preference (SP) surveys, in which a series of hypothetical scenarios are presented to respondents who then make choices about what vehicles they would expect to purchase in the future. These studies have analyzed vehicle purchase preferences in a number of countries, including: Norway [3], Denmark [4], United Kingdom [5], Germany [6,7], U.S. [8–12], Canada [13] and Australia [14].

The reliance on stated preference tasks, in these studies, was largely motivated by a lack of available real-world data, at the time of analysis, due to the relatively short amount of time that such vehicles have been available in markets globally. SP surveys provide the benefit of being able to test preferences towards different vehicle types and/or attributes that may not be available on the market at the time of the survey, or with which the respondent has had no prior experience. This last point, however, is also a weakness of SP tasks as respondents must select among hypothetical choices with attributes or technologies of which they likely to be unfamiliar with. Such uncertainty in decisions may lead researchers to analyze preferences that do not in fact reflect real world market conditions. As EEVs continue to grow in popularity, there is a parallel increase in the availability of revealed preference (RP) data—as is the case in this study—opening the potential to analyze actual EEV owner behavior and choices.

There are a couple of revealed preference (RP) studies that have examined factors influencing EEV demand. One such study, conducted in the State of California, U.S., found that a community's share of Green Party registered voters, acting as a proxy for community "environmentalism", was positively correlated with hybrid-electric vehicle sales, providing strong evidence for a link between environmental awareness and demand for EEVs [15]. Another RP study, by Sexton and Sexton [16], suggested that, through their theory of "conspicuous conservation", individuals seek status by demonstrating austerity in the context of increasing concerns about the environment. They estimated that individuals were willing to pay US\$ 430 to US\$ 4,200 more for a Toyota Prius (depending on the consumer's location) in order to obtain green status from this product.

Despite numerous interesting findings across the existing literature, one notable gap is that the possible endogeneity between EEV demand and price has largely been ignored, along with the possible implications of this relationship. One of the principle contributions of the study detailed here is to establish whether this endogenous relationship exists, and what the implications of this relationship might mean for policy-makers, and consumers alike.

2.3. Effect of Incentive Policies and Fuel Prices on Energy Efficient Vehicle Demand

A number of studies have focused on analyzing the impact of various EEV incentive policies, in several markets around the globe. Musti and Kockelman [11] found that EEV cash rebates, and the doubling of fuel prices, both had negligible impacts on EEV demand, in Texas, U.S. In contrast, they found that a 'fee-bate', where vehicle owners are charged or compensated using a carrot-and-stick approach, depending on the fuel-efficiency of their vehicle, could result in a 10% increase in demand.

Another U.S. study, this time based on revealed preference data, found that direct monetary incentives had little to no effect on consumer demand for EEVs, however, incentives with an indirect monetary value, such as an exemption from High-Occupancy Vehicle (HOV) lane restrictions, resulted in a significant increase in EEV demand [2].

Another RP study revealed that an exemption from a congestion tax in Stockholm for EEVs led to a 10.7% increase EEV sales [17]. It should be noted that, in this particular study, EEVs included flexi-fuel ethanol vehicles in addition to hybrid-electric vehicles.

Martin [18] found that U.S. income tax credits for hybrid vehicles were more effective in encouraging demand for EEVs than a doubling of the fuel tax. Diamond [19] analyzed cross-sectional data and found that EEV sales in the U.S. between 2004 and 2009 increased as a result of upfront monetary incentives. They also observed a statistically significant relationship between EEV demand and fuel prices. Similarly, Beresteanu and Li [20] found that EEV sales in the U.S. would have been 37% lower, in 2006, if petroleum prices had stayed at 1999 levels. They also found that the federal income tax credit incentive accounted for 20% of EEV sales in 2006.

Gallagher and Muehlegger [21] conducted one of the few studies that have attempted to estimate the effects of different incentive policies using RP data. By analyzing quarterly EEV sales data in the U.S., between 2000 and 2006, they found that the type of incentive offered was just as important as the monetary value of the incentive, in terms of the impact on consumer demand. Sales tax waivers were found to have a larger effect on EEV demand compared to income tax credits, conditional on incentive values. They also found that higher fuel prices led to higher rates of EEV adoption. A similar study of sales tax rebates in Canada, by Chandra et al. [22], found that sales tax rebate incentives led to a substantial increase in the share of EEVs, accounting for 26% of their sales.

By employing an ordinary least squares (OLS) regression analysis of EEV national sales data, combined with economic and demographic factors, for 30 countries in 2012, Sierzchula et al. [23] found that financial incentives, combined with local production facilities, were significantly and positively correlated with EEV adoption rates. Unfortunately, incentives were aggregated to a single parameter in the regression, and, as such, did not provide insight into the potential variation across different policy incentives.

As demonstrated by this summary of incentive policy studies, while many incentives have been found to have a significant impact on EEV markets, there are no clear trends with respect to the impacts of specific types of incentive policies. In particular, uncertainty still exists around whether or not monetary incentives, particularly those paid up front, are effective policy levers in increasing EEV demand. Despite this uncertainty, monetary incentives continue to be the most prevalent category of supportive EEV policies available in markets globally. Disentanglement of the effects of different policies on EEV demand remains a significant interest, combined with the potential flow-on effects on EEV pricing. It is crucial to acquire a greater understanding of whether EEV initiatives have made these vehicles more affordable, or instead have exacerbated the price gap between EEVs and their internal combustion engine equivalents.

2.4. Effect of Incentive Policies and Fuel Prices on Energy Efficient Vehicle Prices

The economic motivation for providing incentives is that by increasing the utility of a product, this can result in either (or both) increased demand (consumer response) for the product and/or increased product price offerings (supplier response). The extremes of market response range from 100% of the incentive policy 'value' being subsumed into commodity price (with no demand response) to 100% of incentive policy 'value' being allowed to drive consumer demand through increased consumer surplus.

In one of the only studies focusing on the impact of incentive policies on EEV prices, Sallee [24] assessed the effect of incentives on the price of EEVs using a representative sample of 15% of the Toyota Prius transactional sales in the U.S., between 2002 and 2007. Contrary to expectations, under a standard, competitive tax incidence model, where capacity was constrained, he found that government

subsidies did not affect the prices paid for a Toyota Prius during this period. He explained the lack of price response by suggesting that Toyota purposefully did not absorb the value of the government subsidies in order not to stifle future demand for their vehicles. Although this hypothesis may be true, the discrepancy may also be attributed to the nature of the data. During the period of analysis, the government subsidy was initially worth US\$ 2,000, which later increased to US\$ 3,400 (after 2005). Upon examination of the Toyota Prius factory options during this period, it was revealed that an individual could spend an additional US\$ 6,400 (24% of the base model price) on upgrades. Given that the transactional data only reported paid prices, without details regarding factory options, it would be difficult to disentangle changes in prices arising from factory options versus manufacturer/dealer price increases, particularly given that approximately half of the potential factory upgrade cost was equal to the policy incentive.

Another factor that has been found to affect vehicle pricing is that of fuel prices. This body of literature is particularly relevant to this study given fuel price taxation is often cited as an alternative to government incentives, in order to induce a shift towards more fuel-efficient vehicles.

Analyzing vehicle sales from four major automobile manufacturers in the U.S., between 2003 and 2006, Langer and Miller [25] found that a US\$ 1 increase in petrol price (per liter) would lead to a 10.7% increase in the price gap between the least and most fuel-efficient vehicles. Increased fuel prices were generally associated with lower vehicle prices, except for in the case of highly efficient vehicles, such as the Toyota Prius.

Similarly, Busse et al. [26] analyzed vehicle sales between 1999 and 2008 at 20% of automobile dealerships in the U.S. They found that a \$USD 1 increase in petrol price (per liter) would lead to 9.7% decrease in the price of an average car, but would increase the price of a Toyota Prius by 17.2%.

Beresteanu and Li [20] analyzed vehicles sales from 22 metropolitan statistical areas in the U.S., between 1999 and 2006, and found that if the petrol price had remained at 1999-levels, in 2006, the Toyota Prius would have been 7.0% cheaper. Taking into account this price difference, and converting to fuel price per liters, this translates to a 24.8% increase in the price of a Toyota Prius due to a US\$ 1 increase in petrol price.

All three of these studies provide strong evidence to suggest that fuel price increases lead to an increase in EEV prices, and that these price increases are largely due to a shift towards more fuel-efficient vehicles to reduce exposure to the increased petrol prices. In this paper, we compare the magnitude of the estimated effect of fuel price changes, and different incentive policies, on EEV pricing.

An important gap remains in the literature regarding whether certain government incentive policies are less prone to price responses than others; results of which may yield insight into what policies are more likely to be subsumed into prices offered by suppliers versus those that will be left to influence demand. One of the principle aims of this paper is to address this research gap by analyzing panel data of HEV sales in 15 regions across the globe.

3. Methodology

The following section of this paper details the methodology adopted for this analysis, starting with a conceptual overview.

3.1. Conceptual Overview

The econometric model employed in this study consists of three equations:

Equation (1). Annual HEV Marginal Demand (MD) i.e., annual HEV sales as a proportion of total annual vehicle sales

Equation (2). Annual HEV Aggregate Demand (AD) i.e., proportion of HEVs active in the current vehicle fleet, and

Equation (3). HEV Price Premium i.e., the normalized difference between the dealer-listed price of a new Toyota Prius (HEV) and its internal combustion engine vehicle (ICEV) equivalent, a new Toyota Corolla.

Equation (1) captures the short-term or marginal demand for HEVs; Equation (2) captures the long-term demand for HEVs, and the cumulative effects of HEV market momentum; and Equation (3) captures the price premium attributed to HEVs, relative to comparable ICE vehicles:

$$\text{EEV Price Premium} = \frac{(A-B)}{B}$$

where :

A = Dealer-listed Price of Toyota Prius (non-plug-in hybrid; base)

B = Dealer-listed Price of Toyota Corolla (equivalent specification)

Our motivation for creating the price premium variable is multifold. Firstly, by using this normalized difference in listed prices, the relative cost of an HEV common across all markets analyzed is compared to the cost of a fossil fuel vehicle, which is also common across all markets analyzed. Secondly, the HEV price premium captures, in a single variable, what consumers will pay relative to a well-known and top-selling fossil fuel alternative. Finally, by using listed prices of both the Prius and Corolla to calculate this variable, we avoid the possible bias associated with transactional data, which includes the embedded costs of factory fitted options (e.g., see [24]). This bias is particularly unwanted when trying to assess how, and to what extent different incentive policies affect HEV price premiums.

The potential drawbacks of the HEV price premium calculation, as implemented in this study, include: different dealer markups that might exist (we believe this to be minimal in these low profit margin offerings), and a lack of reflection of other EEV market offerings that may significantly differ from the Toyota Prius.

As shown in Figure 1, we assume that incentive policies (1) designed to promote demand for HEVs have direct effects on the Annual HEV Marginal Demand (2), the current Annual HEV Aggregate Demand (5) and the HEV Price Premium (4). Part of our ambition in constructing the price premium variable has been to reduce the possible Supply-Chain Factors (3) that may affect HEV pricing. Nonetheless, it should be noted that some unobserved supply-chain factors might still explain some differences in price premiums between each region; these are not considered as part of this analysis.

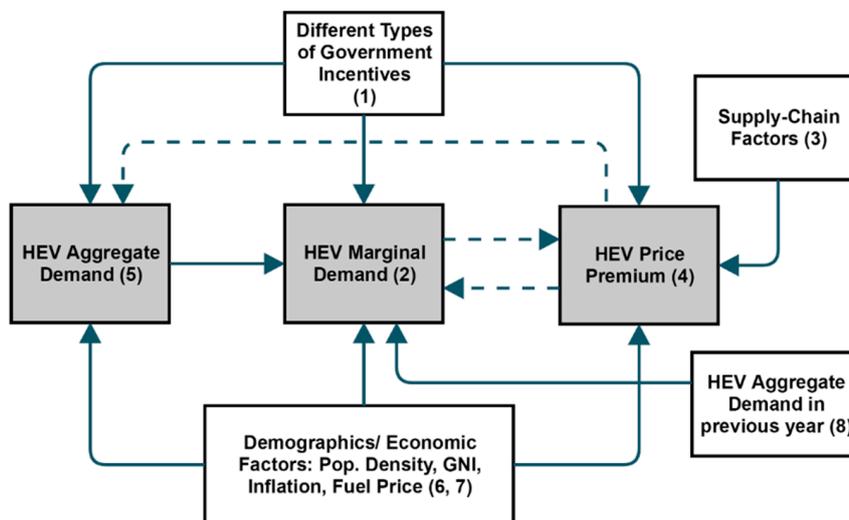


Figure 1. Conceptual Model of Factors Influencing HEV Price Premium, Annual HEV Marginal Demand and Annual HEV Aggregate Demand.

It is assumed that various economic (6) and demographic (7) factors have influenced the price premium of HEVs (4), the Annual HEV Marginal Demand (2) and the current Annual HEV Aggregate Demand (5). Furthermore, we assume that the Annual HEV Aggregate Demand of the year prior (8) would also affect the current year’s HEV marginal demand (5). We assume that such a mechanism took place due to economies-of-scale and/or higher levels of public awareness of HEVs.

The final relationships displayed in Figure 1 show the potential endogenous relationship between HEV price premium (4), and the marginal (2) and aggregate (5) demand for HEVs – see dotted lines in Figure 1. If different incentive policies (1) have affected HEV price premiums (4) while simultaneously affecting demand for HEVs (2 & 5), it could also be true that these three factors interact. Ignoring this potential endogeneity would lead to biased parameter estimates, and therefore, we have aimed to capture these potential interactions through this model.

Based on the relationships depicted in Figure 1, the collected panel data required a system of linear equations modeling approach, with HEV Price Premium (4), Annual HEV Marginal Demand (2) and Annual HEV Aggregate Demand (5) set as dependent variables. To estimate the parameters for this system of equations, we combine three-stage least squares (3SLS) regression with an error-components variant to account for the panel nature of the analyzed dataset, resulting in an error-component three-stage least squares (EC3SLS) regression model [1], as describe further below.

3.2. Model Specification

The estimation of a systems of equations with error components is a specialized topic described in Baltagi [1], denoted as error-component three stage least squares (EC3SLS). To illustrate the procedure, consider the following system of equations:

$$y = Z\delta + u$$

where :

$$y = (y'_1, \dots, y'_M)', u = (u_1, \dots, u'_M)', \delta = (\delta'_1, \dots, \delta'_M)', Z = \text{diag}[Z_j]$$

with $Z_j = [Y_j, X_j]$ of dimension $NT \times (g_j + k_j)$, for $j = 1, \dots, M$.

In this system there are g_j included right-hand side Y_j , and k_j included right-hand side X_j for the system of equations with N observations and T time periods.

Focusing on the j^{th} equation,

$$y_j = Y_j\alpha_j + X_j\beta_j + u_j, j = 1, 2, \dots, M,$$

with additive error components structure given by:

$$u_j = Z_\mu\mu_j + Z_\lambda\lambda_j + v_j, j = 1, \dots, M,$$

and where: $Z_\mu = I_N \otimes e_T$, $Z_\lambda = e_N \otimes I_T$, I_N and I_T are identity matrices of the order N and T , while e_N and e_T are vectors of ones of the order N and T . μ'_j , λ'_j and v'_j are all random vectors representing individual-specific, time-period specific and random error terms, respectively. Baltagi [1] shows that the EC3SLS estimator based on a system of equations with error components of the form above can be expressed as a weighted combination of three 3SLS estimators: within-groups, between-groups, and within-and-between groups:

$$\delta_{EC3SLS} = \hat{a}_1\delta_{3SLS}^{(1)} + \hat{a}_2\delta_{3SLS}^{(2)} + \hat{a}_3\delta_{3SLS}^{(3)}$$

where :

$$\hat{a}_h = \hat{H}^{-1} \left\{ Z^{(h)'} \left[\left(\hat{\Sigma}^{(h)} \right)^{-1} \otimes P_{X^{(h)}} \right] Z^{(h)} \right\} \text{ for } h = 1, 2, 3$$

$$\hat{H} = \sum_{h=1}^3 \left\{ Z^{(h)'} \left[\left(\hat{\Sigma}^{(h)} \right)^{-1} \otimes P_{X^{(h)}} \right] Z^{(h)} \right\}$$

$$\delta_{3SLS}^{(h)} = \left[Z^{(h)'} \left[\left(\hat{\Sigma}^{(h)} \right)^{-1} \otimes P_{X^{(h)}} \right] Z^{(h)} \right]^{-1} \left[Z^{(h)'} \left[\left(\hat{\Sigma}^{(h)} \right)^{-1} \otimes P_{X^{(h)}} \right] y^{(h)} \right] \text{ for } h = 1, 2, 3$$

with $\hat{a}_1, \hat{a}_2, \hat{a}_3$ summing to an identity matrix.

Being a weighted combination of three 3SLS estimators (between groups, between time-periods and within-groups-and-time-periods), the EC3SLS estimator yields efficient parameter estimates of a system of interrelated equations, with cross-correlated error terms, and accounting for serial correlation and heteroscedasticity arising from HEV market trend data within regions observed across multiple years. The model estimations were carried out using the statistical software package STATA. The full derivation of the EC3SLS estimator is described by Baltagi [1].

It should also be noted that, as is the case with all instrumental variable methods, the estimates produced are only reliable if an appropriate set of instruments are specified. Through the iterative process of modeling this system of equations, regular checks were performed to ensure that instruments were independent of the error terms. Effort was also made to check the sensitivity of the model to specification changes, and the difference in estimates obtained through the use of single-equation methods, such as individual error-component regressions for each of the included equations. The next section of this paper provides further details on the dataset analyzed.

3.3. Dataset

A significant barrier to investigating the effect of different incentive policies on EEV consumer demand and market prices is the lack of publically available EEV sales data at the appropriate spatial (regional) level. With the assistance of numerous helpful contacts within local governments, academia, and the non-government organization sector, we were able to obtain non-fleet HEV sales and regional economic data for 15 metropolitan regions around the world, between 2008 and 2012. An additional 9 regions and 2 years were included in the original dataset, but had to be excluded from the final model given the need for a balanced dataset when implementing EC3SLS.

Table 1 provides the sources and units used for each variable included in the dataset analyzed. Significant effort was made to check reported statistics across multiple sources for each region, and to ensure that collection and reporting methods were consistent.

Table 1. List of data variables collected for each region, including units and data source.

Variables	Units	Source/s
Annual HEV Marginal Demand (Number of new HEVs sold/Total annual vehicle sales)	%	National Statistics Offices National Motoring Departments Local NGO/Lobby groups Local Contacts
Annual HEV Aggregate Demand (Number of HEVs active/Total number of vehicles in fleet)	%	National Statistics Offices National Motoring Departments Local NGO/Lobby groups Local Contacts
HEV Price Premium ([average listed local dealer price of a new Toyota Prius – average listed local dealer price of new Toyota Corolla]/[average listed local dealer price of a new Toyota Corolla])	%	Local Toyota Dealership Websites (with the assistance of the Internet Archives’ Wayback Machine)
Gross National Income Per Capita	US\$	National Statistics Offices Organisation for Economic Cooperation and Development World Bank

Table 1. Cont.

Variables	Units	Source/s
Average Disposable Income Per Person	US\$	National Statistics Offices Organisation for Economic Cooperation and Development World Bank
Inflation Rate p.a.	%	World Bank
Average 12-month Petrol Price	US\$/liter	International Energy Agency World Bank
Population Density	Persons/km ²	National Statistics Offices Organisation for Economic Cooperation and Development
Previous Years Annual HEV Aggregate Demand (Previous Years' Number of HEVs active/Total number of vehicles in fleet in previous year)		National Statistics Offices National Motoring Departments Local NGO/Lobby groups Local Contacts
Incentive Policies	Dummy Variables	Local Government websites Local NGO websites Local Contacts

3.4. Overview of Incentive Policy Categories

Table 2 provides an overview of the incentive policies offered to consumers in each region of this particular study—categorized by country. In general, there are a wide range of policies offered across the regions, creating challenges to isolate their individual effects on EEV markets.

Table 2. Overview of incentive policies active in each metropolitan region, noting that many of these policies also apply to battery electric vehicles, which are not analyzed in this study.

Metropolitan Regions by Country	Incentives
Norway (Asker, Trondheim, Bergen, Oslo)	Norway's extensive list of incentive policies may be why it has one of the highest MD rates of EEV vehicles. These incentives include: No value-added tax (VAT) for BEVs (worth approx. 5,000 EUR); Bus lane access; toll road and congestion charging exemptions; no import duty; no annual vehicle tax; free parking in public car parks; free domestic vehicle ferries; and no vehicle registration tax.
Sweden (Stockholm, Gothenburg, Jönköping, Malmo)	Sweden was one of the earliest promoters of EEVs. Major policies include: EEV owners exempt for first 5 years of registration fees, congestion tax exempt (mainly concerning Stockholm owners) and free inner-city parking (Stockholm, Gothenburg, Jönköping). From 2007 to 2009, a green vehicle cash rebate also existed: vehicles emitting less than 120g/km CO ₂ emissions received 10,000 SEK (1,100 EUR). This was later turned into an income tax reduction. Gothenburg also had free inner-city parking until late 2010.
Germany (Dusseldorf, Munich, Stuttgart, Frankfurt)	Germany undertook a different approach to other regions; no direct EEV subsidies were implemented but substantial funding was directed to EEV research. The only incentive policy is a 10-year exemption from the CO ₂ -emissions based circulation tax, worth up to 170 EUR per year.
USA (California)	The US, particularly California, also has had a number of incentives for EEVs include: federal tax offsets worth up to US\$ 3,400 up to 60,000 vehicles per manufacturer (expired 2011); one-time national tax credit, worth up to US\$ 7,500 depending on battery capacity for a PHEV; California also had initiatives to get cash rebates of US\$ 1,500 for a PHEV. Additionally there were numerous free parking schemes for EEVs in several cities, as well High-Occupancy Vehicle (HOV) lane exemptions and insurance discounts.
Hong Kong	In the densely population country of Hong Kong, the main incentive involved a waiving of the first registration fee is waived, which is significant with a value of US\$ 6,000–9,000.
Singapore	The sole incentive in Singapore was a rebate provided to offset the first registration fee, which was equal to 40% of the open market value of the vehicle. Given the high vehicle registration fees in Singapore, this single policy had a high monetary worth.

One of the challenges in analyzing the effects of different incentive policies on EEV markets is the sheer breadth and variation of government schemes, including in regards to the precise types of EEVs eligible for these schemes. In order to ensure that policies across regions were comparable, and to simplify the analysis, the incentives were aggregated into four categories, depending on how and when the incentive affects the consumer:

- One-off subsidies (upfront cash rebates, income tax credits)
- Purchase cost reductions (reduced/exempt from sales tax, import duty, registration tax)
- Running cost reductions (reduced/exempt annual vehicle tax, emissions tax), and
- Usage-based benefits (exempt from tolls; congestion charges; parking fees).

The main motivation behind this grouping was to facilitate a better understanding of how different types of policies affect EEV markets; in this case, specifically HEV markets. Gallagher and Muehlegger [21] suggest that different types of incentives indeed have different market effects. The specific categorization adopted in this study differentiates between one-off and ongoing savings, and operating versus non-operating benefits.

4. Results

In arriving at the final results of this analysis, a substantial number of model specifications were tested and compared on theoretical appeal, plausibility of effects, and overall goodness of fit. The results of the final EC3SLS model estimate are detailed in Table 3.

Table 3. Estimation results from EC3SLS model.

Estimation Results (by Equation)	Parameter Estimate	Standard Error
Equation (1): Annual HEV Marginal Demand (percentage points) =		
Gross National Income per capita (10k USD/person)	+1.02	0.16 ***
Inflation (%)	-0.69	0.12 ***
Population Density (10k persons/km ²)	+0.24	0.09 ***
Average Annual Petrol Price (US\$/liter)	+1.65	0.39 ***
One-off subsidies (Incentive Type A)	+1.03	0.31 ***
Prior Year Annual HEV Aggregate Demand (%)	+1.35	0.21 ***
<u>HEV Price Premium</u>	-0.02	0.01 **
Equation (2): Annual HEV Aggregate Demand (percentage points) =		
Gross National Income per capita (10k USD/person)	+0.26	0.12 **
Inflation (%)	-0.09	0.03 ***
Population Density (10k persons/km ²)	+0.06	0.04 *
Average Annual Petrol Price (US\$/liter)	+0.35	0.15 ***
One-off subsidies (Incentive Type A)	+0.26	0.12 **
Purchase cost reductions (Incentive Type B)	+0.27	0.13 **
<u>HEV Price Premium</u>	-0.01	0.00 ***
Equation (3): HEV Price Premium (percentage points) =		
Average Disposable Income Per Person (10k USD/person)	+0.29	0.42
Inflation (%)	-3.85	0.82 ***
Population Density (10k persons/km ²)	+4.49	0.49 ***
Average Annual Petrol Price (US\$/liter)	+19.66	2.92 ***
One-off subsidies (Incentive Type A)	+11.28	2.67 ***
Purchase cost reductions (Incentive Type B)	-11.88	2.79 ***
Long-term cost reductions (Incentive Type C)	-18.73	1.71 ***
Usage-based benefits (Incentive Type D)	-7.80	1.39 ***
<u>HEV Annual MD (%)</u>	-3.68	0.40 ***

***: significant at $p \leq 0.02$; **: significant at $p \leq 0.05$; *: significant at $p \leq 0.01$. Nb. R^2 has no statistical meaning in the context of instrumental variable (IV) methods, such as EC3SLS, and therefore has not been reported. For IV models, some regressors act as instruments when parameters are estimated, however, the instruments for the endogenous right-hand side variables are not estimated. As a consequence, the residuals are computed based upon regressors that are different from those used to fit the model, and the residual sum of squares (RSS) is no longer constrained to be smaller than the total sum of squares (TSS). Each of the three equations were estimated individually, ignoring endogeneity, with the following R^2 values produced: Equation (1): 0.73, Equation (2): 0.18, Equation (3): 0.65.

Focusing on the first equation in Table 3, Annual HEV Marginal Demand (MD), a positive relationship was found to exist between HEV demand and that of Gross National Income (GNI). The rate of inflation was found to be negatively related with MD, suggesting that a high value of money discourages demand, as expected. Further, as population density increases so does HEV MD. This is likely to capture that HEVs are best suited in more urbanized environments (high congestion, low average trip lengths, high cost of fuel). As found by Martin [18], Beresteanu and Li [20] and Gallagher and Muehlegger [21], a statistically significant positive relationship was observed between petrol prices and HEV MD. Precisely, a US\$ 1 increase in petrol price (per liter) appears to result in a 1.6 percentage point increase in annual market penetration (MD). It is clear from this that high fuel costs incentivize the purchase of HEVs, presumably due to their lower fuel consumption.

The prior years' HEV Aggregate Demand (AD) was also found to be positively-related with HEV MD. This finding suggests that greater consumer awareness, through increased exposure in the market to HEVs, could contribute positively to HEV MD.

Although all policy type variables were tested, the only statistically significant policy type effect observed in Equation (1) was for one-off subsidies (Type A incentives). A positive relationship between this policy type and HEV MD was found to exist; a finding consistent with Martin [18], Diamond [19], Beresteanu and Li [20] and Sierzchula et al. [23], but differing from Musti and Kockelman [11] and Riggieri [2]. This result suggests that demand for HEVs, on average, is approximately 1 percentage point higher when such incentives are on offer to consumers.

Referring to the endogenous parameter in Equation (1), the HEV Price Premium was found to have a negative and statistically significant relationship with HEV MD, with a 1% increase in the HEV Price Premium resulting in a 0.02 percentage point decrease in MD. This finding provides evidence to support the relationship alluded to between (2) and (4) in Figure 2, and suggests that the higher the HEV Price Premium, the lower the HEV MD. This finding is in line with expectations i.e., when HEVs are less price competitive relative to ICE vehicle models – consumer demand is lower.

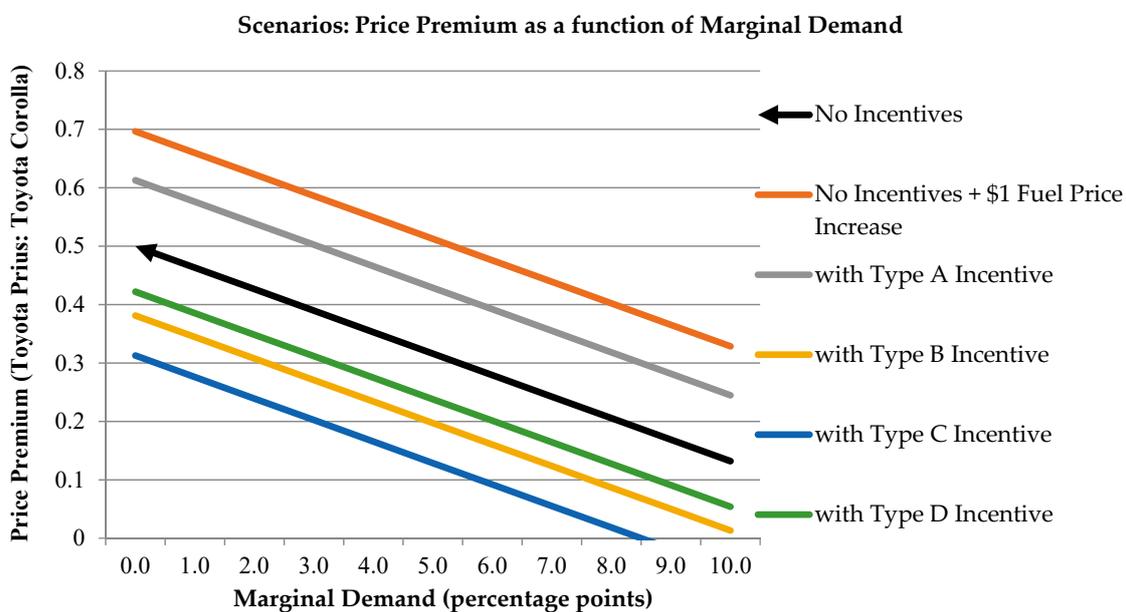


Figure 2. Price Premium as a function of Marginal Demand for various scenarios.

Upon inspection of Equation (2)—HEV Annual Aggregate Demand (AD): as was the case for HEV MD, increasing GNI and decreasing inflation rates were found to be positively associated with HEV AD. Population density was also observed to be positively associated with HEV AD, but with a lesser magnitude effect than in Equation (1). The fuel price was again found to have a positive and significant effect on HEV AD, with a US\$ 1 increase in petrol price (per liter) resulting in a 0.35 percentage point

increase in AD. Because AD is the cumulative demand for HEVs, this is in line with expectations that the effect of fuel price is lower, than the relative impact on HEV MD.

Incentive policies appear to play larger roles influencing aggregate demand compared to marginal demand. Both incentive Types A and B were statistically significant and positively related to HEV AD. In markets where Type A incentives were present, AD was 0.26 percentage points higher on average, whereas for Type B incentives AD was 0.27 percentage points higher on average. This finding for Type B incentives is line with the results of Chandra et al. [22]. HEV Price Premium was also observed to be statistically significant and negative with respect to AD, with a 1% increase in HEV Price Premium resulting in a 0.01 percentage point decrease in AD. Similarly to MD, this finding suggests that the higher the HEV Price premium, the lower the overall Fleet Penetration (AD); noting that the effect of an increase in price premium is about half for AD as it is for MD.

Finally, we turn to Equation (3)—HEV Price Premium. Similar to the effects found by Beresteanu and Li [20], Langer and Miller [25] and Busse et al. [26], here we observe that a US\$ 1 increase in petrol price (per liter) would result in approximately a 20% increase in the HEV price premium. In other words, this increase would widen the gap between HEV and conventional vehicle prices by approximately 20 percentage points.

Average disposable income per capita was included in this regression, as it was found to be significant in the preliminary 3SLS and individual error component estimations, however, although positive, was not statistically significant in the final EC3SLS model. Increasing inflation was found to be associated with lower price premiums (−3.9%), while higher population density was associated with higher price premiums (+4.5%).

All four types of incentives were found to be statistically significant in Equation (3). The estimation results show that when purchase cost reductions (Type B), longer-term reductions (Type C) and usage-based benefit incentives (Type D) have been offered, the HEV price premium is lower by −11.9%, −18.7%, −7.8% respectively. In contrast, the parameter for one-off subsidies (Type A), such as cash rebates, is associated with higher HEV price premiums (+11.3%).

These results suggest that HEV incentive policies that have a monetary value that is easy to equate at the point of sale (e.g., Type A; upfront subsidies) are associated with higher HEV prices, relative to comparable ICE vehicle models. This supports the hypothesis that HEV manufacturers/dealers, on average, appear to be capturing at least part of the incentive's monetary benefit.

The negative association of other types of incentives with HEV price premiums suggests that these types of incentives may have been harder to absorb into vehicle price increases (e.g., sales tax waivers—Type B), or harder to quantify due to their longer term impacts (e.g., annual emission fee waivers—Type C) or because of their differential effect on consumers (e.g., free road tolls—Type D). It is difficult to definitively outline why these incentives were associated with lower price premiums, but given they may have been more difficult to absorb, these policies may have instead spurred additional pricing competition between manufacturers and dealers.

After controlling for the effects of population density, inflation, fuel prices, and incentive policies, regions with lower MD were observed to have higher price premiums i.e., a 1 percentage point decrease in MD results in a 3.7% increase in the HEV Price Premium. There are a couple of possible explanations for this finding. First, where HEV demand is low, due to economies-of-scale, the price of HEVs would be substantially higher than comparable ICE vehicles. That is, the costs associated with delivering and selling HEVs in a low demand market are increased as a result of sales staff training costs, mechanic up-skilling costs, marketing and advertising costs, shipping and delivery costs, etc., all of which have not benefited from economy of scale. Another explanation is that factors outside the market are at play, such as prices set to limit sales, or limits in supply chains, with prices subsequently set high despite low demand. These latter explanations are speculative and based on anecdotal evidence.

Finally, looking at estimates across the demand and price equations, the policy group that leads to an increase in HEV price premiums (Type A) also leads to an increase in demand for HEVs (MD and

AD). This suggests that this type of incentive is attractive to both suppliers and consumers, with the monetary value of this policy partially captured through demand and price.

5. Discussion

EEV markets around the world are dynamic, with vehicle manufacturers setting purchase prices based on numerous factors, many of which are unobserved (e.g., internal incentives, business strategies, etc.). In this analysis, we were particularly interested in quantifying the effects of government incentive policies on demand and pricing of HEVs, as a specific group of EEVs. The different government incentive policies were aggregated into four categories based on how and when they affect consumers.

All four types of incentive policies were found to have statistically significant relationships with HEV price premiums. On average, price premiums were lower in regions where Types B, C and D were implemented, and higher where Type A incentives had been implemented. Specifically, HEV premiums were 11.3% higher on average in markets where one-off purchase price reductions were in place, suggesting that this incentive type is perhaps most easily absorbed into vehicle price by HEV manufacturers and/or dealers. With that being said, these observations are specific to Toyota—based on the construction of the HEV price premium variable (see Equation (1))—and therefore, may not apply to other HEV manufacturers and/or dealers.

Nonetheless, this is an important finding given the prominence of Type A incentives introduced around the world, and is in line with literature finding similar effects in solar photovoltaic [27] and vehicle retirement scheme markets [28]. This finding is, however, in contrast to Sallee [24] who did not find this effect when analyzing transaction data of Toyota Prius sales in the USA between 2002 to 2007. In this prior study, it was suggested that Toyota did not increase HEV prices with the aim of preserving future demand for HEVs. As previously outlined, it is also possible that such an effect could not be detected using transaction data given factory upgrade option costs are confounded with sales prices. The advantage of this current study is that we computed HEV price premiums based upon the normalized difference between dealer listed base prices of a new Toyota Prius (HEV) and its ICE vehicle equivalent, a new Toyota Corolla—thus removing potential effects of factory options (see Equation (1)).

Although upfront subsidies clearly have a positive influence on HEV demand, the association with higher HEV price premiums raises an important question as to whether this type of incentive is an efficient means of driving uptake, particularly in non-HEV manufacturing nations. In nations where HEVs are manufactured, absorption of part (or all) of the subsidy benefit by HEV manufacturers and/or dealers, may simply be rationalized as another form of industry support. In contrast, however, in non-EEV manufacturing countries there may be less justification for directly subsidizing overseas industry, and therefore, it is particularly important to consider whether other incentive types, which cannot be captured as easily by HEV manufacturers/dealers i.e., incentives types B, C and D, might be more appropriate policy levers in these nations.

Utilizing the estimation results from Equation (3), the effects of different policy incentives on price premiums and MD have been illustrated under a range of scenarios (see Figure 2). HEV price premiums are highest under the US\$ 1 increase per liter in fuel price scenario, followed closely by the introduction of a Type A incentive.

An increase in the price premium by the same amount as the Type A incentive would require a 57.4 cent (US\$) increase in average fuel price per liter. In other words, HEV manufacturers and/or dealers, on average, saw an equivalent market opportunity to raise HEV prices through the offering of Type A incentives as a 57.4 cent (US\$) increase in fuel prices. In contrast, incentive Types B, C, and D were associated with lower HEV price premiums, on average. It is possible that these other types of incentives coincided with increased market competition, and/or otherwise contributed to or coincided with economies of scale in these markets.

It is possible that the differences in HEV price premiums that we have identified may be due to other factors. Given the complex relationships existing in the market between supply and demand,

as well as profit margins, market responses by vehicle manufacturers (and/or dealers) are potentially more complicated than what is captured in our model, particularly from endogenous unobserved factors, like internal market strategies. However, given the comprehensive set of controlled exogenous factors in the model; a model specification that allows for endogeneity; the sample size and number of unique regions; and a lack of spurious trends in the price premium data, we are confident that these effects capture the average effects that indicate how policies have influenced these markets.

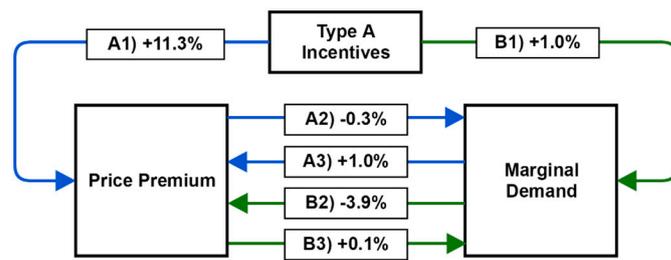
Focusing on the demand side of the model—Equations (1) and (2)—only incentive Type A was found to be statistically significant and positively related to MD, while Types A and B were statistically significant and positively related to AD. This means that HEV markets with Type A incentives had higher HEV price premiums (+11.3 percentage points) on average, but they also had higher Annual HEV sales, with a 1.4 percentage point increase in MD and 0.3 percentage point increase in AD, on average. This finding is in contrast to markets where Type B incentives were present, which had a 0.3 percentage point higher AD and a 11.9 percentage point lower HEV price premiums, on average. Type A incentives appear to be effective in increasing the demand for HEVs, as suggested by Martin [18], Diamond [19] and Sierczula et al. [23]. These same policies also appear to increase HEV price premiums, suggesting that both consumers and suppliers respond to Type A incentives. Further research is required to better understand the mechanisms by which suppliers are responding to government incentives to raise HEV prices.

The effect of Type B incentives is in line with expectations. Given that these policies reduce HEV purchase costs i.e., sales tax waivers, etc., they result in increased AD. These policies may be directly or indirectly paid to dealers and simply passed on to consumers. For example, a sales tax waiver could be in place in a country that does not collect sales tax on HEVs from a dealer or reimburses a dealer for sales tax on the vehicle—thus benefiting the dealer directly. Also, the sales tax rebate may be linked to base prices—and thus increased prices may result in the marginal tax to be paid by the dealer, dis-incentivizing a sales price increase. Again, further research is required to better understand the underlying mechanisms involved.

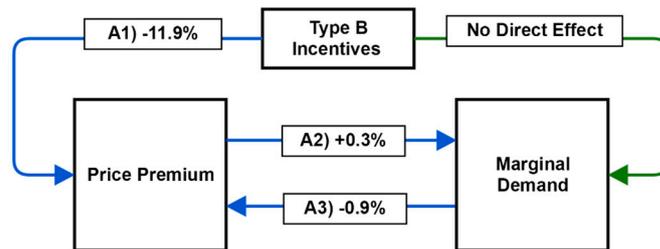
In terms of the endogeneity, higher HEV price premiums were found to be associated with lower HEV MD and AD, while lower annual HEV sales (MD) were found to be associated with higher HEV price premiums. This establishment of endogeneity between these variables has wider repercussions for the indirect effects of policy incentives. As shown in Figure 3, due to the existence of endogeneity between HEV price premium and marginal demand, a policy that affects one of the variables indirectly affects the other.

Take Type A incentives—in Figure 3 we can see the average direct effects of this type of policy on price premium (+11.3%) and marginal demand (+1.0%). The increase in price premium, however, in turn leads to an indirect reduction in marginal demand, which in turn leads to a further increase in MD. Although these indirect effects are somewhat countered by Type A's positive affect on MD, after taking into account the indirect effects, Type A incentives in fact lead to a 8.4% increase in price premium, but only a 0.8% increase in MD.

In contrast to the mechanism at play for incentive Type A, again referring to Figure 3, while incentives Types B, C, D do not directly affect MD, on the basis of the endogenous relationship between MD and price premium, each of these policy types leads to an increase in MD, as well as a decrease in price premium. It should be noted that the increase in MD for each of these policies, however, is less than that of incentive Type A. These are significant findings, particularly in light of the existing literature largely failing to account for the potential endogeneity between HEV demand and price. As a result of not accounting for this relationship, other studies are likely to have under or over-estimated the impact of particular incentive policies. This paper provides evidence to suggest that this relationship is statistically significant, and does have a substantial impact on the overall effect of incentive policies on the HEV market, highlighting the importance of taking this relationship into account in future studies.



Cumulative Type A Incentive Effect:
 Price Premium = $A1 + A3 + B2 = (11.3 + 1.0 - 3.9) = +8.4\%$
 Marginal Demand = $B1 + A2 + B3 = (1.0 - 0.3 + 0.1) = +0.8\%$



Cumulative Type B Incentive Effect:
 Price Premium = $A1 + A3 = (-11.9 - 0.9) = -12.8\%$;
 Marginal Demand = $A2 = (0.3) = +0.3\%$

Similarly:
 Cumulative Type C Effect: Price Premium = -20.4% ; Marginal Demand = $+0.4\%$
 Cumulative Type D Effect: Price Premium = -8.5% ; Marginal Demand = $+0.2\%$

Figure 3. Indirect effects of different government incentives on Price Premium and Marginal Demand due to endogeneity for Type A incentives and Type B incentives.

Referring to Figure 4; Figure 5, a 1% decrease in inflation rates or an additional 10,000 persons/km² was found to have approximately the same positive effect on AD (+0.09%; +0.06% respectively)—relative to the ‘No Incentives’ scenario. A 1% decrease in inflation, however, was found to have almost three times the effect on MD compared to an increase in population density by 10,000 persons/km²—again, relative to the ‘No Incentives’ scenario.

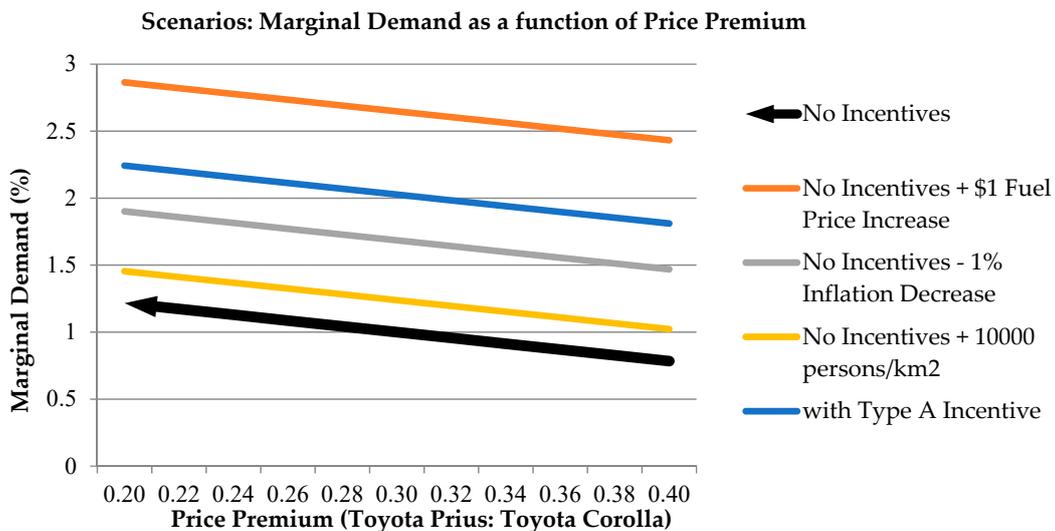


Figure 4. Marginal Demand as a function of Price Premium for various scenarios.

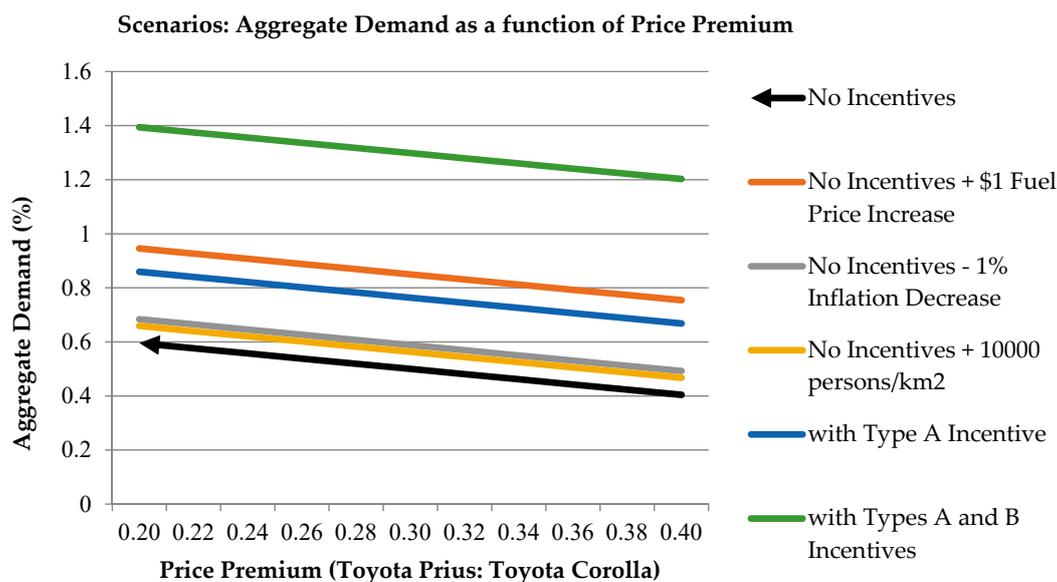


Figure 5. Aggregate Demand as a function of Price Premium for various scenarios.

6. Conclusions

In this study we investigated the effects of a range of incentive policies, introduced by governments to encourage the uptake of HEVs, on both the demand for and price of HEVs, using a set of panel data from 2008 to 2012, across 15 regions. A model, using Error-Component Three-Stage Least Squares (EC3SLS) regression, was implemented to estimate a system of equations that included three dependent variables: Annual HEV Marginal Demand (MD); Annual HEV Aggregate Demand (AD) and HEV Price Premium – a proxy for the price ratio between a HEV and a comparable ICE vehicle. This model system allowed the testing of hypothesized endogeneity between HEV price and demand.

In order to quantify these relationships, we developed a model system capturing relationships between MD, AD and HEV Price Premium, controlling for the effects of socio-economic factors, and accounting for the effects of four different types of government incentives.

One-off subsidies (Type A), such as cash rebates, were found to be associated with higher HEV MD and AD, by 1.4% and 0.3%, on average, respectively. However, Type A policies were also found to be associated with higher HEV price premiums; 11.3% higher, on average. In contrast, purchase cost reduction policies (Type B) were associated with higher HEV AD; by 0.3%, on average, and lower HEV price premiums, by 11.9% on average. Similarly, longer-term cost reduction policies (Type C) and usage-based benefit policies (Type D) also appear to be offered in markets with lower HEV price premiums, by 18.7% and 7.8%, on average, respectively.

The evidence from this study suggests that, while consumers are sensitive to cash rebates, HEV manufacturers and/or dealers have been absorbing, at least partially, the monetary value of one-off subsidies through increased HEV prices, relative to ICE vehicle equivalents. While this may be acceptable in countries that manufacture their own HEVs (and/or other types of EEVs), it raises an important question around whether one-off subsidies are the most efficient means of driving HEV uptake, particularly in non-vehicle manufacturing nations.

We also found that fuel prices would need to increase by 75–88 cents (US\$ per liter) to have the same effect on HEV demand as incentives. Fuel tax increases, paired with targeted government incentives, could lead to substantially increased demand for HEVs, albeit with potential price premium impacts.

As hypothesized, a significant, endogenous relationship between HEV demand and price was established, through our model, with higher HEV price premiums associated with reduced HEV demand (MD: -0.02% , AD: -0.01%), and lower HEV MD associated with higher price premiums ($+3.7\%$). This finding is particularly notable for other researchers analyzing the effects of incentive

policies on HEV, and broader EEV markets, as omission of these effects would lead to econometric inefficiencies and bias.

Market AD or ‘momentum’ appears to play a role in influencing MD. The marketing impact of an increased share of HEVs may assist in improving MD, emphasizing the importance of HEV visibility within the vehicle fleet. For this reason, government or private sector (e.g., taxis) adoption of HEV fleets may serve to increase visibility of HEVs, and MD.

There are numerous other factors that could affect manufacturer and/or dealer responses to government incentives, however, given the strength of the findings of this study, comprised of 15 regions globally, observed across several years, there is substantial evidence demonstrating the significant influence of endogeneity and policy incentives on HEV demand.

Consumers may not be the only beneficiaries of monetary incentives provided to encourage an uptake of HEVs, as HEV markets are complex and suppliers also respond to price signals. Numerous policies appear to be associated with lower price premiums between HEVs and ICE vehicles, thus increasing the competitiveness of HEVs.

It is possible that the categorization of policies in this study has introduced bias in regards to the estimates of the effects of each incentive type upon HEV demand. It is also possible that the policy categorization we applied fails to capture other important underlying common features within each group. We aim to further investigate the impact of policy categorization in a separate study focused on battery electric vehicles.

One might also expect that not every potential factor affecting HEV demand and price was included in our model, despite our attempts to capture the predominant factors. For example, while this study focused on private purchases, it could be the case that the policies implemented in different regions had significantly different effects on fleet-purchases—which generally form a large proportion of overall vehicle sales, and in turn could affect the profit margins of HEV manufacturers and/or dealers, with spillover effects, negative and positive, on private-buyers. Our model also does not capture the effects of marketing campaigns, as well as changes in environmental awareness and behavior, which both could have affected HEV price and demand.

Despite the possible limitations of this study, we have clearly established that different types of HEV incentive policies have varying, significant, and potentially unintended impacts on both HEV demand and pricing. While some incentive policies, such as one-off subsidies, may appear to be a logical approach for supporting the development of HEV, and broader EEV markets, policy-makers must account for the broader impacts of these policies, particularly in terms of vehicle pricing. These effects can only be accurately assessed, and understood, after accounting for the significant and endogenous relationship between demand and price, as was done for the first time in the literature, as part of this study.

Author Contributions: Conceptualization, J.W., S.W. and J.F.; data curation, J.W.; formal analysis, J.W.; investigation, J.W.; methodology, J.W. and S.W.; supervision, S.W. and J.F.; validation, J.W., S.W. and J.F.; visualization, J.W., S.W. and J.F.; writing—original draft preparation, J.W.; writing—review and editing, J.W., S.W. and J.F.

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