2018

Consumer Awareness of Electric Vehicles and Global Purchasing Patterns

John McElgunn
Skidmore College, jmcelgun@skidmore.edu

Consumer Awareness of Electric Vehicles and Global Purchasing Patterns

Student Researcher: Jack McElgunn
Faculty Advisor: Monica Das

This thesis is submitted in partial fulfillment of the requirements for the course Senior Seminar (EC 375), during the Spring Semester of 2018

While writing this thesis, I have not violated any witnessed any wrongdoing, nor have I personally violated any Conditions of the Skidmore College Honor Code.

Name:

Signature:

I. Abstract

The primary purpose of this study is to investigate the relationship of electric vehicle consumer awareness on the subsequent purchasing patterns of consumers across the globe, in conjunction with other macroeconomic variables. For this study EVs have been defined as hybrid electric vehicles (HEVs) or plug-in electric vehicles (PEVs). Data for this study comes from 33 countries in North America, Europe, Asia, and Oceanus over the period from 2011 to 2016. Within the field of research surrounding EV adoption, almost all work has been done at the microeconomic level, this study uses a hybrid macroeconomic approach to bridge the gap in previous literature. In order to gauge consumer awareness at the national level this study utilizes Google Trends data, which tracks the search terms at the country level. The main findings of this study include a significant positive relationship between consumer awareness and purchasing patterns. Consistent with previous literature this study found a significant relationship with household income and EV sales using two different metrics, and found that at the regional level greater policy collaboration creates a more conducive environment for EV adoption.

II. Introduction

As climate change has become an ever more inconvenient truth governments around the world are scrambling to find ways to reverse the damage done to the environment. With many ecofriendly solutions created the issue has become not can we reduce the impact of humans on the Earth, but rather how do we get humans to behave in less harmful ways? In 2010 14% of the worlds greenhouse gas emissions came from the transportation sector, and 95% of the vehicles in the transportation sector ran on petroleum based fuels (EPA); adopting an alternative method of transportation could significantly impact the global ecosystem. Within the public-sector governments have been relying on inefficient economic tools and policy to increase electric vehicle sales.

The main findings within the area of EV research highlight the importance of incentives, public acceptance, microeconomic aspects of the individual consumer, and the awareness of EV vehicle innovations. The work done by Chen et al. (2018) highlights the effects subsidizing EVs has on increasing purchasing behavior in China finding a significant positive impact on EV sales. Similarly, Chandra et al. (2010) found that during the period of their study 26% of EVs sold were due to rebate programs from that region. Both of these papers highlight that consumers' purchase EVs in greater numbers when presented with incentives. For some consumers the incentive of increased fuel efficiency and lower fuel costs is all it takes. The work done by Sallee et al. (2016) found a significant sales response to fuel economy during periods of fuel price volatility. Consumers are extremely responsive to incentives whether they are presented in the form of rebates and subsidies, or market factors like increasing fuel costs.

The purpose of this paper is to investigate the relationship of electric vehicle consumer awareness on the subsequent purchasing patterns of consumers across the globe, in conjunction with other macroeconomic variables. This study uses data from 33 countries in Europe, North America, Asia, and Oceanus over a six-year period ranging from 2011 to 2016. Previous research done by Chandra et al. (2010) and Chen et al. (2018) highlights that the cost benefit ratio of subsidizing EV sales is negative and crowds out the sales of high efficiency light vehicles. The implications of this work could be finding a more cost-effective way to increase EV sales, lower emissions, and increase average fleet fuel economy.

In the field of EV research this study contributes a hybrid approach using macroeconomic and microeconomic variables, and an expansion of consumer awareness metrics over traditional

survey methodologies. This study draws from the work of many other authors all of which have primarily focused on microeconomic relationships. In contrast by taking a macroeconomic approach the results can be generalized at the country and regional level, giving policy makers and manufactures the tools to increase EV sales.

Over the course of research, this study has found a significant positive relationship between consumer awareness and the subsequent purchasing patterns of EVs globally. The significance of these findings can be generalized to the point that by increasing search traffic and the knowledge of EVs, consumers will be aware of the benefits they hold and this will increase sales. The results also suggest that greater cooperation between countries of a region, as seen in Western Europe, can lead to a more conducive environment for EV usage and adoption. Consistent with other findings in this field of research the two gauges used for household income both had a significant positive relationship with EV sales. However, this study failed to find consistent results for some variables that at the microeconomic level previously had been indicative of EV sales.

Moving forward section 3 will give a brief introduction to fuel efficiency and emission policy. Section 4 presents, reviews, and challenges previous literature in this field that this study has been built upon. Section 5 introduces the various data used in the study, while section 6 will dive deeper into how that data was used to create variables and the expectations of the results. Before discussing the methodology and analytical framework in section 8, section 7 discusses the various robustness checks used to verify the results. Section 9 discusses the results from the regression models and section 10 goes into more depth interpreting and analyzing the results. Finally, section 11 draws the final conclusions of this study and discusses future areas of research.

III. Topic Background

In the 1970s greater fuel efficiency for light vehicles, in the United States and other countries, first became an important issue in consequence to the oil embargo by OPEC. In response to this shortage of gasoline the United States government issued the Corporate Average Fuel Efficiency standards (CAFE), which set standards for new manufactured vehicles to be sold in the United States. The CAFE standards focused on fuel economy and CO2 emissions, manufactures who did not meet these standards were fined by the magnitude of fuel efficiency violation per car sold accordingly. Since the 1970s there has been a general global trend towards

high efficiency and renewable energy. Today the largest pressing issues in regards to EVs is global climate change, rising sea levels, and air pollution. These issues have led to environmental mega conferences like the 2015 Paris United Nations Climate Change Conference and many others where global leaders are increasingly more present. For each respective sector, industry leaders are finding ways to increase environmental efficacy, meet new government standards, and meet the new demands of an ever more environmentally conscious consumer base. For the automotive industry their work to lessen the manmade impact on the Earth has resulted in investing in the creation of EVs in their fleet inventory. Agreements have been made by global leaders to meet new emissions and environmental standards. Beyond the collective agreements, individual countries are passing legislation and issuing subsidies to build the infrastructure needed for EVs and to increase sales. Increasing fuel efficiency standards had proven to be an ineffective method to try and create positive market responses as explored in Goldberg (1998) and others. However, gasoline taxes, emissions taxes, and subsidies are all proven methods of government intervention that influence consumers and the automotive market to change.

For this study EVs have been narrowly defined as being a HEV or PEV, before further discussing consumer behavior we must first introduce EVs and what differentiates them from traditional light vehicles. In respect to the differences in motors electric vehicle motors are 3.4 times more efficient than traditional combustion engines (Alternative Fuels Data Center). The benefits of lower energy demand for HEVs and PEVs are highlighted further by the difference in fuel cost and price volatility; looking at Figure 1 you can see the differences in the price of gasoline versus the price of electricity, corrected for engine efficiency. Currently HEVs and PEVs make up 1.1% of vehicles on the roads globally (IEA). Some countries are much further ahead than others in HEV and PEV market share, by 2016 28.8% of the cars in Norway were HEVs or PEVs with the Netherlands being the second leading country at 6.4% market share (IEA). By 2016 to support these vehicles there were over 300,000 public charging stations worldwide (IEA). On a country-by-country basis there has been inconsistent investment in charging stations with some focusing more on fast charge stations and others on slow charging stations. On the global scale there is double the amount of publicly accessible slow charge stations than fast charge. Looking at private charging stations a high percentage are residential and are low voltage slow charge. Charging station access and recharging time are two limiting aspects for these vehicles primarily because of their limited range on a full charge.

In an effort by governments around the world to increase EV adoption there have been different strategies of varying success. To get more EVs to market governments around the world are investing in private research and development, this is to assist companies in the creation of better vehicles. To increase the rate of purchases many countries have been favoring a variety of different types of subsidies and benefits. On a country-by-country basis there are direct government subsidies that lower the cost of purchase, cash rebates at the point of sale, tax refunds, and other methods of refunding consumers. To further the adoption of EVs as a new vehicle fleet type governments and private companies have been investing in creating the necessary infrastructure for EVs to be used for longer journeys. The main focus on building infrastructure for these vehicles is to build high voltage charging stations. Some private manufacturers like Tesla, have taken it upon themselves to create the necessary infrastructure to facilitate the usage of these vehicles.

IV. Literature

a. Consumer Demand for Fuel Economy and Fuel

Before moving to EV specific literature the focus will be on literature having to do with light vehicles, demand for gasoline, and the demand for fuel economy. The purpose of this initial focus is to create a general understanding of how consumer value fuel economy. To be expanded upon is how efficiently consumers value the future costs of for a vehicle in relation to expected future fuel costs. Most of the previous research regarding light vehicles and consumers have focused primarily around fuel consumption demand and fuel economy.

The work done by Goldberg (1998) was done in response to the CAFE standards, which was one of the only corporate fuel efficiency standards for a few decades, making it an isolated study. Similarly to other papers looking at fuel demand and fuel economy, Goldberg (1998) utilized micro consumer expenditure data from 1984-1990. The data used in this study takes descriptive aspects of vehicles purchased and aspects of the individual consumer like age, race, family size, education, type of employment, income, and number of cars within the household; a limitation of this cross-sectional analysis is that it does not account for unobserved consumer and vehicle characteristics. Goldberg (1998) research did find that policies like CAFE that are oriented to shift the composition of car fleets to more efficient cars are promising. Moreover, Goldberg (1998) found that there were damaging effects for this standard on domestic car producers' who

did not make as fuel efficient vehicles; these findings reflect on the market factors pushing car fleet towards higher efficiency, levels of efficiency found in EVs.

Looking further into the American vehicle market from 1978 to 2007, Klier and Linn (2010) took a simplistic yet nuanced approach to analyzing the vehicle market response to changes in gasoline prices. The approach starts by controlling for unobserved vehicle differences and consumer characteristics by using within model year changes in the price of gasoline and vehicle model sales. In this approach Klier and Linn (2010) were able to look at how consumers directly evaluate future costs of maintenance, within their data set they included cars of the same model and year with different millage. The main focus of this paper was to analyze the ability that consumers are able to value fuel economy in current time with volatile gas prices. The results from this study found that over the period from 2002 to 2007 the changes in gasoline price accounted for nearly half of the decline in market share for US manufactures. There is overwhelming evidence from Klier and Linn (2010) and Goldberg (1998) that American consumers are moving towards smaller more fuel-efficient vehicles, similar to EVs. To calculate the magnitude of this effect Klier and Linn (2010) estimated for a $1 increase in the cost of gasoline, the average fuel economy of new vehicles sold increased by 0.8-1.1mgp. The responsiveness to gas prices by consumers fits the classical assumptions for normal goods, with increased price there is lower quantities of consumption, and this is felt by manufactures when consumers choose more fuel-efficient vehicles. By analyzing the findings of Klier and Linn (2010) using classical theories of demand, the argument can be made that consumers will begin to favor more efficient EVs.

The work done by Busse et al. (2016) highlights the stark difference between manufactures in and out of the United States, showing that the global automotive market is demanding higher fuel-efficient vehicles. Though the scope of Klier and Linn (2010) is limited to the United States, depicted consumer response is in accordance with classical economic assumptions which leads us to believe that we can assume that consumers of other countries would behave similarly favoring more fuel-efficient vehicles like EVs.

Similarly, Sallee et al. (2016) investigates the consumer response to energy policy by analyzing how efficiently consumers value fuel economy. In order to access how consumer value fuel economy Sallee et al. (2016) utilized whole sale auction data from July 1993 to June 2008. In their use of microdata they focused on future cost of fuel based on millage, life

expectancy, and fuel economy. By focusing in on these attributes they then estimated the vehicle cost. Using this estimated baseline they were able to then compare their estimates to the sale price, with attention to gas price volatility. The findings of this study suggest that vehicle prices change at a one to one relationship with fuel prices, which means in summary that consumers fully value fuel economy.

Some of the major drawbacks of Sallee et al. (2016) came from how they approached their estimations for fuel-costs, vehicle lifetime, and vehicle value. By focusing on used vehicle auction sales data there is too much emphasis put onto future life of vehicle when estimating the cost of the vehicle, this tends to leave vehicles undervalued by relying primarily on odometer readings. Our study avoids these valuation issues by looking past vehicle prices and focusing on consumer purchases at a larger scale. In conjunction with the issues of valuation there is a second component of valuation that may or may not be passed down to the consumer, because this is auction level data there is the assumption that these distributors will pass on "deals" to consumer to be competitive. By focusing at the whole sale level above the consumer there are strong assumptions being made about the behavior between retailers and consumers, buying a car is one of the few products in modern markets that you are able to negotiate price on. With issue of car price valuation and differences in negotiated prices, our study avoids the issue all together by looking at aggregated behavior at the country level.

The work done by Salle et al. (2016) ultimately found the same findings as Klier and Linn (2010), but there are some very important differences to note. Looking directly at consumers, the work done by Klier and Linn (2010) uses consumer sales data, whereas Salle et al. (2016) utilizes wholesale auction data. Though both papers used similar frameworks the differences in data suggest that Klier and Linn (2010) more accurately estimated the responsiveness consumers have to changes in gas prices, and in turn their subsequent favoring of fuel economy as a response to gas price volatility. In relation to this study both Klier and Linn (2010), and Sallee et al. (2016) reject the data of hybrid vehicles. This rejection of hybrids in their studies was done to more accurately reflect the "average" consumer. However, the connection can still be made that consumer who do purchase EVs are even more motivated by fuel price volatility than consumers who purchase light vehicles. In the case of both Klier and Linn (2010), and Sallee et al. (2016) both studies focus entirely on the United States automobile market but with the work done by

Busse et al. (2016) on manufacturer market share in relation to fuel economy, there will be the assumption that the consumers of other countries behave similarly.

In contrast to the work done by Klier and Linn (2010), Sallee et al. (2016) and Brusse et al. (2016), the work done by Cirillo et al. (2017) takes a much more nuanced approach using survey data that puts consumers in a hypothetical situation where they map out their automotive purchasing behavior into the future. Though this paper looks at the hypothetical there are some very compelling findings that illustrate over time the favoring of EVs.

b. Consumer Motivators in the AFV Market

With the introduction of new products there is always the issue of marketing the product to the public. Some of the rudimental issues of introducing a new product involve communicating the function, benefits of the product, and most importantly that it actually works. New technology adoption typically has varying degrees of exponential growth. With every new technology there are the early adopters, but most consumers are typically more cautious especially with larger purchases like cars. Many of the options presented to consumers on the everyday basis that are sustainable, organic, made under fair trade agreements, or more environmentally friendly products almost always come at a greater cost and need incentivizing.

Governments around the world have made great efforts to increase HEV and PEV purchases, the work done by Chandra et al. (2010) highlights the consumer response to rebate programs. In their study they investigate the cost effectiveness of rebate programs for HEVs as a means to reduce CO2 emissions. Though the main purpose of this paper is not to investigate the responsiveness of consumers, Chandra et al. (2010) does a great job illustrating the how effective the rebate program is to incentivize consumers. Focusing primarily on the British Columbia Province in Canada Chandra et al. (2010) found that over the course of the offered rebate 26% of all HEVs sold were in direct response to the rebate. For this study the authors benefited heavily from using Canadian data for the reason that unlike in the United States in Canada rebates are not dependent on income. In addition to other aspects of Chandra et al. (2010) methodology they were able to make very few assumptions in their analysis of sale and lease data from 1989 to 2006, making their estimations increasingly credible. However, in further analysis the consumers that are attracted to this rebate are consumers who would otherwise be purchasing high performance intermediate passenger cars, intermediate SUVs, and high performance compact

cars. This pull of consumers effectively crowds out vehicles of these classes that have similar vehicle attributes.

The insight from Chandra et al. (2010) is particularly valuable for assessing the effectiveness of rebates for two reasons. The first being that the use of Canadian sales data is unadulterated by other subsidies or government incentives outside of the provincial region, which gives us a unique case to interpret. Secondly, the motivations for this paper were to evaluate if this type of rebate program is a cost effective method to reducing carbon emissions, because of this inherent focus bias can be expunged in an over or underestimation of the effectiveness of rebates to increase HEV purchases.

To provide further insight on the purchasing patterns of consumers in the realm of green economics Lan et al. (2014) provides consumer research data from Taiwan. Lan et al. (2014) focuses on consumer response to different green marketing strategies by brands in Taiwan. The main findings of this study are that the strongest consumer motivator is "cost on purchase, use and maintenance". In conjunction with the insight from Chandra et al. (2010) analysis Canadian consumer response to subsidies, and insight from Lan et al. (2014) we see that the main influencers for consumers in the market for "green" vehicles is cost.

In analysis of German automotive consumers, the work done by Hetterich et al. (2012) provides some insight on how consumers feel towards higher priced vehicles that have ecofriendly components. The study focuses on the use of environmentally friendly materials for car interiors. The study surveyed German automotive customers and found that 66% of consumers would pay a moderate price increase for green car components. Though this finding does not directly correlate to EVs, it does illustrate that consumers are willing to pay more for products that are better for the environment within the automotive sector.

c. Consumer Awareness of EVs

As a relatively new technology that has only begun to become a mainstream product it is important to understand the levels of awareness consumers have towards HEVs and PEVs, and more importantly what aspects effect consumer decisions. With some insight from Lan et al. (2014) in green marketing, this section will pick up with a focus directly towards HEV and PEV awareness.

Taking a microeconomic approach Zhang et al. (2011) analyzed consumer awareness towards EVs and examined the factors that affect consumers' choice in China. The study uses

survey data collected from 299 respondents in the region of Nanjing China. Zhang et al. (2011) utilizes three binary regression models to determine the factors that contribute to the acceptance of EVs, purchase time frame, and purchase price. There are a few major findings in this study, the first being that the number of drivers within a household, vehicles within a household, government policies, and fuel prices significantly influence whether a consumer purchases an EV. Additional factors that influence purchasing and price acceptance are academic degree, age, annual income, the number of family members, maintenance cost, and the opinion of peers. The findings from this study essentially set aside the criteria for consumer in China and what motivates their purchasing behavior of EVs.

Though Zhang et al. (2011) provides great insight into the awareness and motivators of Chinese consumer in Nanjing, this is a small sample pool to be generalizing for the region as well as a country with well over a billion people. Another shortcoming of this study is that this survey data is very limited within itself. Asking a person what they would do often does not align with what people actually do. There is a level of cognitive dissonance with self-report of this kind, especially when examining spending behavior. For a study with the objectives that it had it would have been beneficially for this study to be surveying people within a car dealership not people at a driving school. Even with the critiques of this paper there is still reassuring evidence that is gained. For literature of this topic Zhang et al. (2011) has found consistent results for the type of consumer that purchases EVs. Across countries the prototypical HEV and PEV consumer is a person of higher academic success, higher income, eco-conscious, and values fuel economy.

d. Google Trends as a Gauge of Consumer Awareness and Behavior

Many studies that have the goal of accessing consumer options, levels of awareness, or purchase intent typically rely on survey data as a result of an absence in methodology. However, the work done by Carriere-Swallow and Labbe (2013) and Stephens-Davidowitz (2014) both employ the use of Google Trends search data to remotely access information about consumers. The work done by Stephens-Davidowitz (2014) compares the volume of racial charged searches over the period of the 2008 United States Presidential Election to see if there was a relationship between states where the African-American candidate lost votes and higher level of racial animus. Stephens-Davidowitz (2014) found that this Google Trends methodology was an extremely accurate gauge of the populations voting pattern as a reflection of racist predisposition resulting in votes going the other way. Though this study is extremely, the methodology of using

search behavior as a gauge of racially charged voting behavior can be generalized to purchasing behavior.

The work done by Carriere-Swallow and Labbe (2013) supports the claims that search behavior correlates with purchasing behavior. The study involves using Google Trends search data to identify turning point in sales data for the emerging automotive market in Chile. In comparison to the work done by Stephens-Davidowitz (2014), Chile has a much lower rate of internet usage, but nonetheless Carriere-Swallow and Labbe (2013) models that did contain their Google Trends Automotive Index out preformed all of their other models in identifying turning point is sales data. The major conclusion of Carriere-Swallow and Labbe (2013) is that observing internet browsing habits are an accurate gauge of aggregate consumer behavior in an emerging market.

Looking at the collection of papers there are conclusions that we can draw about the global market for HEVs and PEVs. With consistency across countries it is very apparent that consumers fully value fuel economy, and are extremely sensitive to future expected fuel prices when purchasing vehicles. Consumers across countries follow the classical assumptions of demand, and internet browsing behavior is an accurate gauge of how consumers will act outside of cyberspace. We can also generalize from reports out of many different regions across cultures that income, education, incentives, and employment are all important indicators of how likely one is to be interested in purchasing an EV.

V. Data

The data for this study came from a variety of sources, by far the largest hurdle to jump was data collection. Data used for this study is paneled from 33 countries in Europe, North America, Asia, and Oceanus with separate sources for each region, and in many cases individual countries. Panel data collected for this study is from the time period of 2011 to 2016, with few exceptions that will be noted in the section bellow.

In order to gauge consumer awareness data was collected from Google Trends, which has a detailed record of search histories by country. Similarly, work done by Swallow and Labbe (2013) uses Google Trends data as a gauge of consumer behavior to predict turning points in Chilean vehicle sales data. Google is present in almost every country around the world as one of the largest search engines in every market giving this study a basis for consistency. Data collected from Google Trends search history was compiled for the search topic "Hybrid Vehicle

Topic". By collecting data under a topic field Google Trends compiles all search terms within the given topic of Hybrid vehicles in all languages, within a given region. However, there are some important variations to note on the country by country level. Though Google Trends is an extremely consistent vehicle to collect data for some countries there is only data available for certain regions and cities within the country. It should be noted that for data collected in China it is only coming from 8 regions, Beijing, Shanghai, Anhui, Jiangsu, Zhejiang, Guangdong, Hainan, and Henan. For Greece data was only collected for Athens, and Thessaloniki. Data collected for Iceland and Luxembourg only comes from the Capital region, Ireland only recorded search terms for the cities of Dublin and Cork. In addition the data for New Zealand comes from only 9 of its regions, Portugal's data is collected from only 11 regions, Slovenia only reported data from 2 cities, Switzerland's data comes from only 17 regions, and Turkey's data only comes from 77 of its regions. Of the 33 countries in this study 23 of them have been fully represented in the collection of their search history. The data collected from Google Trends is reported monthly, which was then converted to annual data by averaging. This data is reported as an index on a scale of 0 to 100, the index is a relative comparison to all other search behavior within the contributing regions of a country. The more popular a search term or topic is within a specific time period relative to other searches correlates to a greater valued index closer to 100, with 100 being the most searched topic or term in the specified time period.

The scope of this study is at the global level, to incorporate macroeconomic variables into the study the World Bank Databank has been a useful tool. Data collected from the World Bank includes GDP in current U.S. dollars and GDP per capita in current U.S. dollars collected by both the World Bank national accounts data, and OECD National Accounts data files. Total population data was accessed through the World Bank but collected by the United Nations, Census reports and other statistical publications from national statistical offices, Eurostat: Demographic Statistics, U.S. Census Bureau: International Database, and Secretariat of the Pacific Community: Statistics and Demography Program.

In order to measure the air quality of each individual country air pollution data was accessed through the World Bank. Air pollution in this study has been recorded as the mean annual exposure to suspended particles in the air measuring less than 2.5 microns in aerodynamic diameter; this is a population weighted average of both rural and urban areas. The air pollution data is originally sourced from Brauer, M. et al. 2016, for the Global Burden of Disease Study

2015. The scope of the collected data does not match perfectly with the period of this studies research, to overcome this lack in data the pollution data has been lagged by one year; 2010 recorded data is listed for 2011 and so on. Including air pollution within this study an important gauge of the environmental impact on the populations' health. To measure the human impact on the environment and how that impact may effect policy makers this study has included CO2 emissions per capita, measured as metric tons per capita. Data on CO2 emissions was accessed through the World Bank but originally comes from the Carbon Dioxide Information Analysis Center. Similarly to the air pollution data, CO2 data was only available from 2009-2014 and will be used in lag as well but at a two year lag opposed to a one year lag.

Unemployment data was also accessed from the World Bank defined as a percentage of total labor force. This unemployment data was originally sourced from International Labor Organization statistical database. In addition data for the usage of internet, expressed as percentage of total population has also been acquired through the World Bank. Internet usage data is originally sourced from the International Telecommunications Union. Both groups of data are from 2011-2016 and neither have been reported as a lag variable.

As a measure of education level across countries this study utilizes Barrow and Lee's human capital data. Human capital or educational attainment for this study is measured in percentage of population with completed or incomplete tertiary education. This data is collected on a 5 year basis and did not overlap with any dates in the study. Given the slow moving nature of human capital growth the data is expressed as a constant over the 2011 to 2016 period. This data is also used as a reference for the educational rank of countries within this study. In an effort to aid the collection process this data was accessed via the World Bank.

For this study it was very important to acquire accurate data on the new registration of electric vehicles, for this study EVs consist of plug-in electric vehicles and hybrid electric vehicles. For Canada, China, France, Germany, India, Japan, Korea, the Netherlands, Norway, Sweden, the United Kingdom, and the United States data was accessed directly from the 2017 Global EV Outlook sponsored by the International Energy Agency. To access data on the reaming European countries and Turkey data was accessed through Knoema, but is originally sourced from the IEA as well. The data accessed from Knoema is the most updated, it was accessed through a secondary source due to free public access. New EV registration for New Zealand comes directly from the New Zealand Ministry of Transport. The Ministry of Transport

reports these registration on a monthly basis which was then converted to annual data. Similarly, data for new EV registrations in Australia was accessed through the Australian Bureau of Statistics. Just as with New Zealand this data is reported monthly and was converted to annual data.

Certain dummy variables have been included in this study to incorporate the individual incentive plans governments use to increase consumer purchases. Grouping policies by similarity the dummy variables focus on point of sale rebate, central government subsidies, and tax break incentives. For this particular grouping of information there is only reported dummies for 12 of the 33 countries. These dummy's currently do not do justice to the magnitude of each individual incentive package. Governments around the world have complex reimbursement packages that take different forms, are classified on individual terms, and separate qualifications based on income bracket. Many of these government plans are offered only at the individual region level, which often excludes the vast majority of a country. The reported dummies have been expressed stagnantly over the 2011-2016 time period and reflect the most current changes to policy, this reporting of subsidies is flawed but has been included. Further research would benefit from a more detailed subsidy analysis.

Incorporated into this study is the sales of light vehicles this sales data comes from the International Organization of Motor Vehicle Manufacturers or OICA. This comprehensive data set includes the sales data for all countries in this study. In this study light vehicles are defined as passenger vehicles not used for commercial use. In addition to sales data the OICA was also used to gather production statistics by country, for which only 9 of the 33 countries do not have reported data. This data set does not come from a government source but rather a collective organization of auto manufacturers around the world. This was the most accurate and current data set for both of these statistics. One important issue to note for the production statistics is that some of the vehicles are double counted, this double counting for almost all countries is corrected in later years but not for the 2011-2013 data. This data was included in the study given that it was only for a few countries, more serious issues of data reporting have been omitted such as the partial counting of manufactures within a country. Partial counting of data has occurred for some countries in 2011 and for that reason that individual year has been omitted for some countries.

VI. Variables

This section provides a detailed description of the individual variables used within the study. The dependent variable for every model within this study is *lnHEV*, which is the natural log of the sum of PEVs and HEVs by country controlled for population. This variable is expressed as a log to measure the percentage change in relative EV numbers. It was also very important to control for the population of a country, countries like China who have more than triple the population as the United States need to be held to relative terms when analyzing. The approach to take the log of sales comes from Klier and Linn (2010). The research question of their study differs fundamentally than this study but they used the log light vehicle sales to observe how the independent variables influenced relative changes is vehicle sales. Their study was controlling for gas prices and vehicle characteristics, where this study is focusing on changing environmental and social perceptions of vehicles which is a similar influencing factor that determines vehicle sales. Like in Klier and Linn (2010), Sallee et al. (2016), and Goldberg (1998), we expect the upward pressure of input costs and government policy to increase the sales of more fuel efficient vehicles. Unlike these studies this study introduces a new substitute for fuel efficiency. A drawback of this change in product is the lack of a proven track record for EVs, lack of social acceptance, and difference in vehicle attributes. Klier and Linn (2010) do use a corrective variable to observe for unmeasured differences in vehicle attributes. Correcting for differences in vehicle attributes is something that this study and Goldberg (1998) both lack.

To measure the consumer awareness of EVs by country this study utilizes Google Trend data for the search topic grouping "Hybrid Vehicle". This variable is used primarily to gauge the level of knowledge consumers have of EVs pertaining to fuel economy, price, government incentives, environmental benefits, and dealerships. At the micro level Zhang et al. (2011), and Bailey et al. (2015) these studies were able to use survey data to compile information about consumer awareness. To incorporate consumer awareness on the macro country level this study utilized the same theoretical framework Stephens-Davidowitz (2014) used by utilizing Google Trends information. Stephens-Davidowitz (2014) was measuring the level of racial animus during the 2008 and 2012 elections by state using Google Trends data, similarly this study is using Google Trends data to determine consumer awareness. The variable included in this study is defined as *lnGoogle* within models, which is the natural log of the Google Trends data. This

variable has been logged to measure the elasticity of consumer awareness in an economically significant manner because this data is reported as a scale.

Most studies on EV purchasing patterns has been done primarily at the microeconomic level, studies done by Bailey et al. (2015) and Zhang et al. (2011), have found that household income is a significant factor in purchasing behaviors of EVs. To incorporate these microeconomic findings, which have been found using surveys, this study uses GDP per capita data as the closest representation. Household income in this model is expressed as *lnGDPperCap*, where GDP per capita is expressed as a natural log. This variable has been logged to both scale a large value, and to control for differences in GDP per capita across countries to measure the elasticity of household income on the purchasing patterns of EVs.

Some of the motivations for the development of EVs, amongst many others, includes the negative impact of light vehicles on the environment and air quality. To incorporate the presence of poor air quality within countries this study includes the variable *lnPollution*, which is the natural log of the mean pollution exposure by population of air particles measuring less than 2.5 microns. This measure of pollution in relation to the populations' exposure is expressed as a log to measure the relative change, and for this particular purpose the units of exposure are not what is of importance. The expectation of this variable is unclear, we could interpret the variable in two ways the first being that the air quality is poor because of the lack of EVs, or poor air quality increases the consumer incentives to purchase them.

Similarly to *lnPollution, lnCO2* was included to measure the overall impact of the population within a region on air quality and overall environmental health within a region. This variable is expressed as the natural log of the CO2 emission per capita, and just like with air pollution the units of CO2 emissions are not of focus. CO2 emissions have been included in this study based off of the analysis of government policy which has been discussed in Chandra et al. (2010), Lanet al. (2014), Sallee et al. (2016), Klier and Linn (2010), and Zhang et al. (2011). Many government policies incentivizing EV purchases has been done in an effort to lower CO2 emissions. Pervious work has always discussed the impact of CO2 emissions on the environment and public health but none have incorporated this key insight into their models. The inclusion of both *lnPollution* and *lnCO2* is an area where this study is expanding the breadth of research in this field. The expectation for this variable is that an increase in CO2 per capita is correlated with an increase in EV sales.

In the analysis of the "typical" EV consumer based off of microeconomic surveys, at the micro level people within the higher brackets of educational attainment are much more likely to purchase EVs. This has been stated in Zhang et al. (2011), and Bailey et al. (2015) as an important indicator of EV purchasing patterns. This study has incorporated the variable *RankEducation* to show the relative differences between countries and their relative levels of higher education. Each country has been ranked from 1 to 33, 1 being the highest percentage of population to complete or incomplete tertiary education. For this variable we expect that when the education rank increases, closer to 33, there will be fewer EV purchases.

Not included in previous literature is the usage of internet by population. With a new product such as EVs, it is important to view the relative level of "new" technology usage within a country as it might be indicative of how a population is to accept a new technology like EVs. This variable is denoted simple as *Internet,* and is the percentage of population that uses the internet. Higher rates of internet usage would be expected of countries that have higher EV stock.

Included at the microeconomic level of analysis Bailey et al. (2015) analyzed the employment status of individuals and how that influenced the purchasing patterns of consumers in British Columbia. Finding a significant correlation between employment and EV purchasing this study also includes the variable at the macroeconomic level. Expressed as *Unemployment,* the variable is a measure of the unemployment rate of a population. Higher levels of unemployment are expected to be correlated with fewer EV purchases. Cars are a large investment and it can be assumed that the individual consumer would be making fewer large investments while unemployed in comparison to when they are employed.

As mentioned earlier in the discussion of pollution and CO2 emissions government incentives are an extremely important part of the EV conversation. To incentivize consumers governments across the world have used different tactics to influence consumer purchases. Of the many different incentive packages includes point of sale rebates and tax incentives. In an effort to include these variables this study uses the dummy variables *TaxRebate* and *PointofSaleRebate* to depict the presence of these incentives in a given country. Unfortunately, these variables to not do justice to the differences in magnitude of each incentive. The work done by Bailey et al. (2015) analyzes the regional incentives put forth by British Columbia in Canada

at the dollar level, for the purposes of this study that level of accuracy is unattainable and is a considerable flaw.

To discern the differences in region and regional similarities this study has included dummy variables for each region, excluding Oceanus. There are four dummy variables simply listed as *WesternEurope, EasternEurope, Asia,* and *North America.* These variables add an additional level of analysis by region. Some of these regions have voluntary emissions standards, like the EU's, that may influence EV purchasing patterns at the regional level.

Before moving onto the methodology this will serve as a short discussion of the expected signs of all variables which is summarized in Table 6. Based off of the work from Carriere-Swallow and Labbe (2013) and Stephens-Davidowitz (2014), we should expect to see a positive relationship between *lnGoogle* and *lnHEV*. Both of those papers found that internet browsing behavior had a positive correlation with associated behavior i.e. buying EVs. Outlined in Chandra et al. (2010) countries with undesired level of pollution create incentives for consumers, so we expect to see a positive relationship for *lnPollution* and *lnCO2* on *lnHEV*. For the *lnGDPperCap* variable we expect a positive relationship with overwhelming evidence that as household income increase EV sales do as well supported from Bailey et al. (2015), Zhang et al. (2011), and Lan et al. (2014). The *RankEducation* variable is expected to be negative, this ranking is from 1 to 33 with 1 being the highest level of education so as the variable increases education level lowers, which we expect to negatively influence EV sales. Education level as an indication of interest in EVs is cited in Bailey et al. (2015) and Zhang et al. (2011). The presence of higher levels of internet usage with the *Internet* variable is an indication of higher income, similarly to GDP per capita this variable is expected to behave similarly. In respect to the regional dummies there is no expressed expectations based on literature, but these are expected to be positive and interpreted by relative magnitude. A countries level of employment expressed by *Unemployment* is expected to have a negative relationship. In Bailey et al. (2015) higher levels of employment were associated with higher levels of vehicle sales within the provinces of Canada, inversely an increase in unemployment should be correlated with a decrease in EV sales. For the variables *PointofSale* and *TaxRebate*, we expect both variables to have a positive relationship drawing from the findings of Chen et al. (2018) and Chandra et al. (2010), who found a significant sales response to incentives by consumers.

VII. Methods

This portion of the paper will discuss the different models included in the study. In the presentation of models there is a gradual progression of ideas, simultaneously they all highlight individual aspects of that are determinates for the demand of EVs with a focus on consumer awareness. Model (1) is a univariate linear regression mode, this model in included to highlight the baseline relationship between consumer awareness and EV purchasing patterns. The inclusion of model (1) is meant to provide a level of simplicity, which is continuously built upon in the progression of models.

$$lnHEV_{it} = \beta_0 + \beta_1 lnGoogle_{it} + \in_{it} \quad (1)$$

Building off of model (1), model (2) builds off of the previous model to introduce a few macroeconomic variables that are particularly relevant to the puchase of EVs. As defined in the microeconomic study by Bailey et al. (2015), those that purchased EVs in British Columbia, Canada had greater household income than the general population and achived bachelors degrees at a rate of double that of the Canadian population. The inclusion of *lnPollution* comes in response to the Government action associated with climate change and the promotion of EVs as a result, this is highlighted in the 2017 Global EV Outlook by the IEA (2017). Moving from model (2) to model (3) there is the replacement of *GDPperCapita* with *Internet*. Access to internet is highly correlated with a countries household income and for this reason both were not included due to multicolinearity. The presence of access to internet also highlights on the country by country basis the general level of technological adoption.

$$lnHEV_{it} = \beta_0 + \beta_1 lnGoogle_{it} + \beta_2 lnGDPperCap_{it} + \beta_3 lnPollution_{it} + \beta_4 EducationRank_{it} + \in_{it} \quad (2)$$

$$lnHEV_{it} = \beta_0 + \beta_1 lnGoogle_{it} + \beta_2 Internet_{it} + \beta_3 lnPollution_{it} + \beta_4 EducationRank_{it} + \in_{it} \quad (3)$$

In an effort to further develop the macroeconomic analysis of EV purchasing paterns model (4) build off of model (2) with the inclusion of regional dummies. In regions like Western Europe there is substantial amount of shared infrastucture, and intercountry travel. To include a dummy variable of this kind is also to recognize the regional differeneces. Model (4) and model (5) are extremely similar, model (5) replaced education level with unemployment rate. Bailey at al. (2015) had found that those who purchased EVs had higher rates of employment in British Columbia, Canada; it is included here to investigate this from country to country.

$$lnHEV_{it} = \beta_0 + \beta_1 lnGoogle_{it} + \beta_2 lnGDPperCap_{it} + \beta_3 lnPollution_{it} + \beta_4 EducationRank_{it} + \beta_5 WesternEurope_{it} + \beta_7 Asia_{it} + \beta_8 NorthAme\square ica_{it} + \beta_9 EasternEurope_{it} + \in_{it} \quad (4)$$

$$lnHEV_{it} = \beta_0 + \beta_1 lnGoogle_{it} + \beta_2 lnGDPperCap_{it} + \beta_3 lnPollution_{it} + \beta_4 Unemployment_{it} + \beta_5 TaxRebate_{it} + \beta_7 PointofSaleRebate_{it} + \in_{it} \quad (5)$$

Model (6) is similar to model (2) with the importnt difference of the inclusion of subsidy dummy variables representing different incentives consumers are presented with. The inclusion of these variables are an effect of the findings of Chandra et al (2010), which highlight consumer responsiveness to tax rebates. These variables are representative of government intervention at either the central or regional level.

$$lnHEV_{it} = \beta_0 + \beta_1 lnGoogle_{it} + \beta_2 lnGDPperCap_{it} + \beta_3 lnPollution_{it} + \beta_4 EducationRank_{it} + \beta_5 TaxRebate_{it} + \beta_7 PointofSaleRebate_{it} + + \in_{it} \quad (6)$$

Replacing *EducationRank* was revmoved in model (7) and (8) and in model (8) *lnPollution* was replaced by *lnCO2*. The purpose of these two condensed models is to compare the effect that air pollution has on the population versus how the pollution effecting the enviorment influences EV sales. This comparison is to see what produces stronger sales response if any.

$$lnHEV_{it} = \beta_0 + \beta_1 lnGoogle_{it} + \beta_2 lnPollution_{it} + \beta_3 TaxRebate_{it} + \beta_4 PointofSaleRebate_{it} + \in_{it} \quad (7)$$

$$lnHEV_{it} = \beta_0 + \beta_1 lnGoogle_{it} + \beta_2 \square nCO2_{it} + \beta_3 TaxRebate_{it} + \beta_4 PointofSaleRebate_{it} + \in_{it} \quad (8)$$

VIII. Robustness Checks

This study meets at the crossroads of macroeconomics and microeconomics, with the inclusion of variables from both subsets of economics it was extremely important to do the necissary robustness checks. All of the eight models have been tested for multicolinearity, within the course of this study and the inclusion of many variables multicoliniarity was an issue early on in the process, but was quickly corrected for. All eight models recorded a mean VIF value of less than or equal to 4, nonetheless there are still some important critiques to bring up, the VIFs can be observed on Table 5. Focusing on model (4) and model (5), both including regional dummies, the *Western Europe* and *Eastern Europe* variable recorded a VIF of over 5 in both models. With

a the highest recorded VIF being 6.62, it was still within reason to include the variables rather than drop. This higher VIF in comparison to the other regional dummies may be a result of the data set, just over 75% of the countries included in this study come from Europe. With such a high percentage of countries in the study coming from either Western or Eastern Europe it would make sense that this may create bias within the data set, that bias is what can attribute to the higher than expected VIF.

In comparison of model (2) and model (3) it is important to note the curcial difference of the replacement of *lnGDPperCap* in model (3) with *Internet*. This variation comes as a result of high multicolliniarity, between the two vriables. There is an inherenant relationship across countries with the level of household income and access to internet. This relationship will be discussed further in the discussion section.

The VIF testing for model (6) reported that both *lnPollution* and *lnGDPperCap* reported VIFs of over 5. Either variable could have been ommited to correct for this, but accrosse all other models within this study there was no presence of multicolinearity. In this particular model the higher than expected VIF can be attributed to the smaller grouping of observations. Model (6) is a grouping of only 14 countries, these countries are grouped based on the various consumer incentives provided for the purchase of EV of HEV. This grouping is over high income contries who have all been highlighted in the International Energy Agency's Global EV Outlook, these countries are also incentivising the uptake of EVs and HEVs in the possible response to high levels of pollution. In comparison to the other models this grouping has developed this inherant bias, which is important to note but does not take away from the results.

For all models except model (1), the Hausman test has been run to determine whether to use a fixed effect model or random effect model. For all models the null hypothesis of fixed effects equaling random effects was rejected, signalling that the fixed effect model should be used. However, this study chose to highlight the random effects model instead for several reasons. The fixed effects model ommits all dummy variables on the basis of autocorrelation, these dummy variables are reported on a 0 or 1 basis and are held ocnstant over the 6 year period. To preserve the inclusion of these time-invariant variables that highlighting regional differences, and consumer incentive packages this study chose to highlight the random effects model. Inaddition to the inclusion of variables this study chose the random effects model because there lacked a substantial difference between reported coeficiant significance. Although the

magnitude of the reported coefficeints may have varied slightly between the fixed effects and random effects model, there was no difference in expected signs or significance of the variables. It is under this reasoning that this study reports the random effects model, finding that it provides more meaningful substance to the interpretation of models.

IX. Results

Looking at Table 1 we have our first three models. Model 1 is the univariate model that found a significant reltionship between consumer awareness and EV sales. This simplistic model found that a 1% change in *lnGoogle*, or google trends searches correlates with a 1.3% increase in EV sales. As given by the adjusted R-squared this model only accounts for 6.2% of the change in EV sales.

With attention still on Table 1, Model 2 and Model 3 use random effects models. Model 2 accounts for 35.5% of the change in EV sales, while Model 3 accounts for 41.7%. These two models are extremely similar with the one important difference of GDP per capita being replaced by access to internet in model 3. Both models found a significant relationship between consumer awareness and EV sales at the 1% level, Model 2 had a magnitude of a 1% increase in consumer awareness leading to a 2.1% increase in EV sales, while Model 3 had a magnitude of a 1.68% increase in EV sales per 1% increase in consumer awareness. In addition the two indicators of household income in each respective model, GDP per capita and internet access, were also significant at the 1% level. However, we did not find significance in either model for mean polluiton exposure by population or education rank. For all models within Table 1, all 33 countries within the study are present, these models due to varibales included, are by far the most reaching in terms of generability of findings.

Moving to Table 2 we have Models (4) and (5), these two models include dummy variables for four of the five regions that are covered within this study as well as the inclusion of the macroeconomic variable of unemployment rate. Model 4 registered significant results at the 1% level for both consumer awareness and Western Europe as a region, GDP per capita in the model register significance at the 10% as well. The magnitude of consumer awarenss was a 2.16% change in EV sales per 1% change awareness, GDP per capita had an influencing magnitude of .88% increase in EV sales per 1% icrease in hosehold income, and for the countries in Western Europe the regional effect increased sales by 2.35% relative to others. This model accounted for 43.9% of the change in EV sales.

Model 5 is extremely similar to Model 4, but has the presence of unemployment rate over education rank. This model found consumer awareness significant at the 1% level and a magnitude increase of 1.63% on EV sales. Unemployment rate had a negative significant relationship decreasing EV sales by -0.17% for each increase in unemployment percent, and the regional influence of Western Europe to be positively significant at the 1% level with a magnitude of 3.12% on EV sales. Significant at the 5% level was pollution, North America, and Asia. This model was able to account for 50% of the change in EV sales, unemployment rate was defently a varibale to highlight as it is an indicator if consumers are in a financial position in the future to invest in these vehicles. The magnitude of the Western Europe dummy also is a reflection of the regional importance of compating climate change, support through infrastructure, and cultural factors. This was the first model show where the sample size decreased to 178 observations opposed to 185, but still containing observations from all 33 countries within the study.

Changing focus to Table 3, the three models presented all have a similar theme of analyzing the effect of governemtn action, at both the central and regional level, on EV sales. All of the models shown on this table have olny 79 observations, which only included data from 14 countries. Model 6 found positive significance for consumer awareness at the 1% level having a magnitude of 1.77% increase on EV sales per 1% change in awareness. This model also found significance for GDP per capita, opr household income at the 1% level having a psoitive magnitude of 2.13% on EV sales. This model didn't find significance for tax rebates or point of sale rebates. However, even though there was so reported significance both varibales expressed the expected signs. The limitations of these variables will be discussed further in the discussion section. Overall this model accounted for 29.7% of the changes in EV sales.

Models 7 and 8 both had the goal of analyzing government policy, with a focus on emission effects on humans (model 7) and the effects pollution has on the enviorment (model 8). These two model found no significance of the variables of interest investigating those relationships. However, as in all of the other models both found consumer awareness to be significant at the 1% level.

X. Disscussion

For this study the most important finding is that of the relationship found between *lnGoogle* amd *lnHEV*. Across all models this Google Trends variable was found to be significant

at the 1% level. In interpretation, the Google Trends variable tell us that the behavior of consumers on the internet can be aggregated to accurately depict consumer purchasing behavior. These findings of consumer behavior on the internet accurately reflecting their purchasing, or voting behavior are consistent with the findings of both Carriere-Swallow and Labbe (2013) and Stephens-Davidowitz (2014). The implications of these findings mean that by increasing search behavior of EVs in a region by 1% can increase sales by over 2%. Though the magnitude is small the implication is huge to manufacturers and governments looking to increase EV fleet size.

Looking at the regional differences, the most consistent significant region with the greatest magnitude was Western Europe. These results can be interpreted on a basis relative to the other regions. What the interpretation of this variable on EV sales means is that Western Europe as a region is a more conducive environment for the adoption of EV sales. Western Europe in comparison to other regions has made the greatest efforts to increase sustainable and ecofriendly practices. These environmentally friendly agendas have been pushed primarily by the EU, as well as other organizations, but across the list of organizations Western European countries are by far the best represented. Other contributing factors to why residing in Western Europe would have a positive effect on EV sales could be as a result of greater shared infrastructure, cultural differences, higher regional income than the rest of the world, and high levels of education. Surprisingly the two countries leading in EV sales, The United States and China, do not belong to this region. Another possible reason for higher rates of adoption among Western European countries could stem from higher levels of population density, special effects has been linked to increased social acceptance and subsequent higher purchasing density by the work done by Liu et al. (2017). Social acceptance among consumers is something that this paper had failed to address, papers like Liu et al. (2017) and Zhang et al. (2011) use different methods of quantifying social acceptance but both studies had found an important linkage.

Household income is one of the most unanimously accepted influencing factors in the field of research for EV vehicle adoption. However, this study failed to replicate that importance in totality. This study did find a significant positive relationship between our two household income indicators of *lnGDPperCap* and *Internet*, but this significance was not found in all models. Using internet access as a gauge for household income is something that has not been explored enough within this field of research. In comparison of the two indicators from Model 2

to Model 3 we see that they are both equally significant but GDP per capita as an indicator representing household income does not have as great of a magnitude. Looking at the research done by both Bailey et al. (2015) and Zhang et al. (2011), as household income increases so does likelihood of EV purchase. With internet access being something attainable at a lower household income it is not as telling for EV sales as overall household income, which is a very logical conclusion to why internet access does not have the same level of magnitude.

In the investigation of effects subsidies have on purchasing behavior we were unable to replicate the significance that other studies have but this study was able to replicate the expected signs. From the work done by Chandra et al. (2010), Zhang et al. (2011), and Chen et al. (2018) the presence of subsidies in any form has shown to be a very influential incentive for consumers. Looking at the Global EV Outlook published by the IEA (2017), Sweden has the highest percentage of EVs per fleet which is non-coincidental with their extensive government incentive packages for consumers. This study can attribute the lack of significance for the variables *TaxRebate* and *PointofSale* to their time-invariant properties, limited representation, and biased inclusion by organization. These two variables meant to highlight the presence of subsidies were used as time-invariant dummy variables that did not change as the policies that controlled them changed. Within the time frame of the study some of these incentives increased or decreased in magnitude of benefit to consumers. The price elasticity of consumer demand in the automotive market was depicted very clearly in the work done by Sallee et al. (2016) and Klier and Linn (2010), and a change in price would change consumer behavior. In addition to the short comings of reporting subsidies, data was only included for 14 countries all of whom are members of the International Energy Agency. The presence of subsidy policies from only IEA countries presents a bias of like-minded countries. The short comings of variables representing consumer incentives from governments are likely causes for the lack of significance registered.

Most of the research done within the field of EVs has been done at the microeconomic level, this study takes a macroeconomic approach and when analyzing at the macroeconomic level not all of the microeconomic relationships transfer. At the micro level work done by Zhang et al. (2011) and Bailey et al. (2015) found a significant relationship between tertiary education and EV purchasing patterns. However, this study was unable to replicate the relationship between education level and EV sales. Countries included within this study were ranked on the percentage of population with incomplete or completed tertiary education. At the country level

before regressing there were interesting trends to point out where countries with the higher GDP per capita and EV sales did not necessarily have the expected correlation of higher levels of tertiary education. The differences in cultural norms within countries can help explain why at the country level populations do not achieve higher levels of education. In conjunction at the country level the importance of lowering transportation emissions is not constant either and both could help explain why on macroeconomic level we do not see the relationships we expect to see at the microeconomic level.

Though limited usage in comparison to other variables, unemployment rate was a variable that showed high levels of significance. This relationship was consistent with microeconomic level survey studies by Bailey et al. (2015) and Zhang et al. (2011). Out of the other macroeconomic variables it was a surprise that this variable was highly significant because of the differences in the natural rate of unemployment by country. On a country by county basis cultural and economic factors lead to different levels of natural unemployment. In interpretation of this variable the low magnitude of the coefficient makes is misleading to note this being an actually significant result in application.

In economics it is still under debate how much of an effect environmental issues, without government action, are responsible for changes in consumer behavior. Outlined in work done by Goldberg (1998) and Chen (2018) government action in response to pollution increases fuel economy and lowers greenhouse gas emissions from transportation. In this study the two variables included to gauge pollution levels were insignificant in almost all models, and expressed unexpected signs. In interpretation of the sign of these variables the unexpected sign may be as a result of endogeneity. Within countries that have high rates of pollution this study expected they would have high EV sales in an effort to combat this issue, but it is also possible that countries with high levels of pollution have high levels of pollution because they do not have high EV sales. In reflection of other works it is less important of how bad the issue of pollution is and more important if government action is being taken.

XI. Conclusion

The implications of the main findings in this study cross private and public boundaries for application of influence. Consumer behavior on the internet can be used as a tool to aggregate the purchasing behavior of EVs. More generally, these findings can be applied to markets outside

of the automotive market. In particular the application of consumer behavior as an identification of consumer awareness or knowledge of new technology.

Focusing on the market for EVs, the findings of this study suggest that a method to increase the purchases of EVs would be to increase consumer awareness. This could be done through advertising done by public or private entities. By using the insight from this study governments could better exploit policies with the goal of lowering emissions, increase fleet fuel economy, and overall EV fleet size.

This study like so many other studies within this field fails to incorporate infrastructure into models. For future research it would be beneficial to do research on a country or regional basis focusing not only on EVs but alternative fuel vehicles as a whole. It would be interesting to interpret the spatial effects of resource availability in a country like the United States whose resources vary by state. Looking at Figure 2 from the Alternative Fuels Data Center, it maps the locations of all AFV fueling stations by fuel type and you can see an unequal distribution of fueling stations by type of fuel and location. In regions like the American Midwest there is a higher density of ethanol fueling station, this most likely relates to the abundance of corn and other grains in the region that supply the main inputs for ethanol fuel. Within researching the infrastructure of fueling stations the application of variables found in this study could still be applied. In addition subsidies for EVs in the United States are primarily come from the State level, which would allow for a cross state analysis. This new approach could help fill in the disparities of previous research.

XII. References

Alternative fueling station locator. Retrieved from https://www.afdc.energy.gov/stations/#/find/nearest

Bailey, J., Miele, A., & Axsen, J. (2015). Is awareness of public charging associated with consumer interest in plug-in electric vehicles?

Busse, M. R., Knittel, C. R., Silva-Risso, J., & Zettelmeyer, F. (2016). Who is exposed to gas prices? how gasoline prices affect automobile manufacturers and dealerships. Quantitative Marketing and Economics, 14(1), 41-95.

Carriere-Swallow, Y., & Labbe, F. (2013). Nowcasting with google trends in an emerging market. Journal of Forecasting, 32(4), 289-298.

Chandra, A., Gulati, S., & Kandlikar, M. (2010). Green drivers or free riders? an analysis of tax rebates for hybrid vehicles. Journal of Environmental Economics and Management, 60(2), 78-93.

Chen, C., Hu, W., & Knittel, C. R. (2017). Subsidizing fuel efficient cars: Evidence from china's automobile industry. Unpublished manuscript. Retrieved from

Cirillo, C., Liu, Y., & Maness, M. (2017). A time-dependent stated preference approach to measuring vehicle type preferences and market elasticity of conventional and green vehicles. Transportation Research: Part A: Policy and Practice, 100, 294-310.

Energy Information Administration. (2017). Retail gasoline prices10.6068/DP15F2596CFD00 Retrieved from https://doi.org/10.6068/DP15F2596CFD00

EPA. (2017). Global green house gas emissions data. Retrieved from https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

Hetterich, J., Bonnemeier, S., Pritzke, M., & Georgiadis, A. (2012). Ecological sustainability--A customer requirement? evidence from the automotive industry. Journal of Environmental Planning and Management, 55(9), 1111-1133.

Klier, T., & Linn, J. (2010). The price of gasoline and new vehicle fuel economy: Evidence from monthly sales data. American Economic Journal: Economic Policy, 2(3), 134-153.

Lan, S., Sheng, T., & Zhang, K. (2014). Marketing factors of green economic effect on consumers' purchase intention for the market of family-sedan in taiwan. Research in World Economy, 5(2), 176-188.

Liu, X., Roberts, M. C., & Sioshansi, R. (2017). Spatial effects on hybrid electric vehicle adoption. Transportation Research: Part D: Transport and Environment, 52, 85-97.

Naceur, K. B., & Gagné, J. (2017). Global EV outlook 2017. ().

Sallee, J. M., West, S. E., & Fan, W. (2016). Do consumers recognize the value of fuel economy? evidence from used car prices and gasoline price fluctuations. Journal of Public Economics, 135, 61-73.

Stephens-Davidowitz, S. (2014). The cost of racial animus on a black candidate: Evidence using google search data. Journal of Public Economics, 118, 26-40.
Zhang, Y., Yu, Y., & Zou, B. (2011). Analyzing public awareness and acceptance of alternative fuel vehicles in china: The case of EV

XIII. Appendixies

Table 1

VARIABLES	(1) OLS	(2) Random Effects	(3) Random Effects
lnGoogle	1.299***	2.104***	1.678***
	(0.372)	(0.310)	(0.284)
lnGDPperCap	-	1.597***	-
		(0.406)	
Internet	-	-	0.120***
			(0.0159)
lnPollution	-	0.655	0.788
		(0.571)	(0.514)
RankEducation	-	-0.0171	0.0111
		(0.0319)	(0.0328)
Constant	-14.88***	-35.97***	-27.99***
	(1.418)	(5.509)	(2.187)
Observations	185	185	185
R-squared	0.062	0.355	0.417
Number of country1	33	33	33
Country FE	n.a.	NO	NO

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2

VARIABLES	(4) Random Effects	(5) Random Effects
lnGoogle	2.158***	1.630***
	(0.308)	(0.304)
lnGDPperCap	0.882*	0.383
	(0.496)	(0.394)
lnPollution	0.189	-1.110**
	(0.685)	(0.527)
RankEducation	-0.0359	-
	(0.0380)	
Unemployment	-	-0.174***
		(0.0364)
WesternEurope	2.351**	3.123***
	(1.071)	(0.813)
EasternEurope	0.505	1.570*
	(1.194)	(0.944)
NorthAmerica	1.726	2.452**
	(1.289)	(0.959)
Asia	1.753	2.324**
	(1.481)	(1.125)
Constant	-28.95***	-18.33***
	(6.140)	(5.168)
Observations	185	178
R-squared	0.439	0.508
Number of country1	33	33
Country FE	NO	NO

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3

VARIABLES	(6) Random Effects	(7) Random Effects	(8) Random Effects
lnGoogle	1.772***	1.958***	2.040***
	(0.376)	(0.390)	(0.386)
lnGDPperCap	2.125***	-	-
	(0.575)		
lnPollution	1.584*	-1.060	-
	(0.916)	(0.726)	
RankEducation	0.0169	-	-
	(0.0380)		
lnCO2	-	-	1.038
			(0.722)
TaxRebate	0.960	1.500	1.871
	(0.877)	(1.303)	(1.309)
PointofSalerebate	1.092	0.831	1.385
	(0.719)	(1.133)	(0.963)
Constant	-43.85***	-15.55***	-21.41***
	(8.403)	(3.286)	(2.575)
Observations	79	79	79
R-squared	0.297	0.276	.270
Number of country1	14	14	14
Country FE	NO	NO	NO

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Country	198	17	9.546	1	33
Year	198	2,014	1.712	2,011	2,016
TaxRebate	79	0.848	0.361	0	1
PointofSalerebate	79	0.456	0.501	0	1
EVHEVNewRegistrations	196	10,081	33,874	0	336,000
LightVehicleSales	198	1.516e+06	3.472e+06	5,038	2.438e+07
GDPperCap	198	40,197	24,329	1,447	119,225
MeanPollution	198	16.58	13.51	5.165	74.33
Population	198	1.141e+08	3.136e+08	319,014	1.379e+09
GoogleTrends2	198	47.12	17.69	9.167	87
Education %	198	26.97	11.29	3.580	57.28
RankEducation	198	17	9.546	1	33
Internet	198	77.54	16.78	10.07	98.24
WesternEurope	198	0.515	0.501	0	1
EasternEurope	198	0.212	0.410	0	1
NorthAmerica	198	0.0606	0.239	0	1
Asia	198	0.152	0.359	0	1
Unemployment	191	8.353	4.891	2.700	27.50
CO2perCap	198	8.570	4.093	1.397	21.64
lnCO2	198	2.036	0.494	0.334	3.074
lnhevPOP	185	-9.963	2.204	-17.45	-4.759
lnGDPperCap	198	10.36	0.823	7.277	11.69
lnPollution	198	2.601	0.596	1.642	4.309
lnGoogle	198	3.770	0.431	2.216	4.466
fleetEV	196	0.00955	0.0297	0	0.290

Table 5

Variable	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
lnGoogle	1.12	1.13	1.17	1.10	1.38	1.36	1.20
lnPollution	2.48	2.15	3.76	2.74	7.36	1.91	-
lnGDPperCap	2.45	-	4.18	3.19	6.35	-	-
Rank Education	1.80	1.81	2.93	-	2.20	-	-
Internet	-	2.10	-	-	-	-	-
Western Europe	-	-	6.62	6.38	-	-	-
Eastern Europe	-	-	5.05	5.68	-	-	-
Asia	-	-	6.24	4.78	-	-	-
North America	-	-	2.20	2.15	-	-	-
Unemployment	-	-	-	1.45	-	-	-
Point of Sale	-	-	-	-	2.03	1.96	1.44
Tax Rebate	-	-	-	-	1.65	1.38	1.36
lnCO2	-	-	-	-	-	-	1.29

Table 6

Variable	Expected Sign
lnGoogle	+
lnPollution	+
lnGDPperCap	+
Rank Education	-
Internet	+
Western Europe	+/-
Eastern Europe	+/-
Asia	+/-
North America	+/-
Unemployment	-
Point of Sale	+
Tax Rebate	+
lnCO2	+

Figure 1

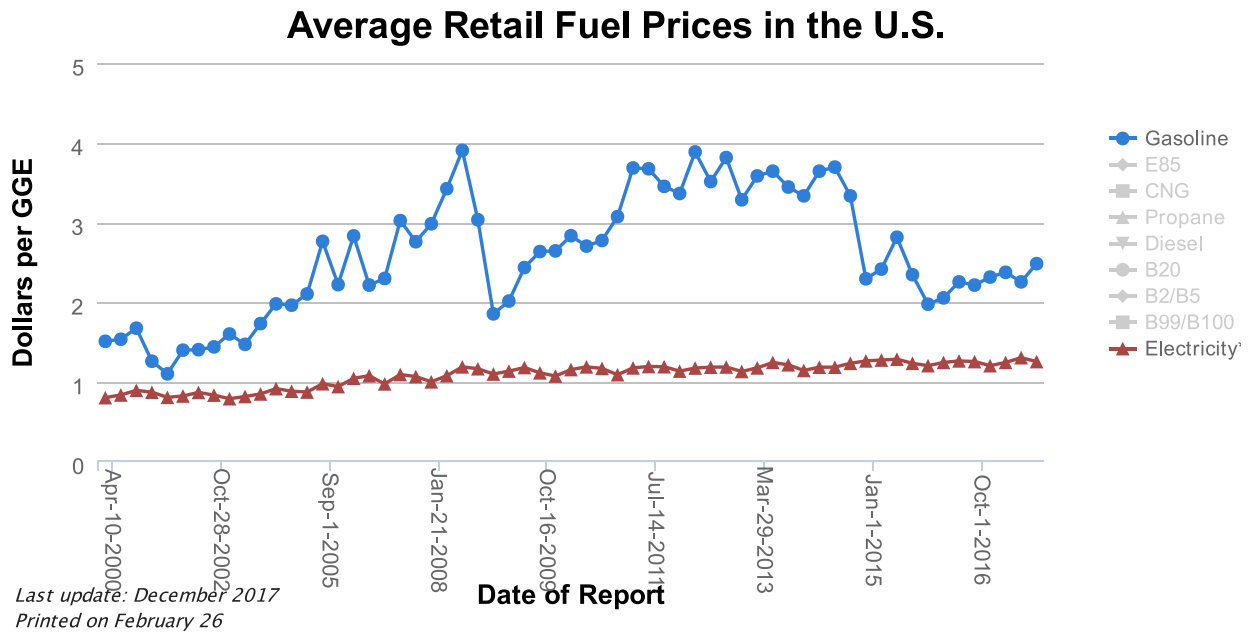

Figure 2