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ABSTRACT

In the absence of a national carbon tax, household driving and electricity consumption impose social costs. Suburbanites drive more and consume more electricity than center city residents. If more suburbanites purchase electric vehicles (EV) and install solar panels, then their greenhouse gas emissions would sharply decrease. Using several data sets from California, we study the demand for electric vehicles and solar panels. We focus on the Tesla given its status as the highest quality EV. We investigate the joint distribution of the stock returns of Tesla and leading solar panel sellers to test for whether investors anticipate a complementarity in sales between these products. Finally, we use current and past vehicle quality and price data to explore trends in EV quality improvements due to industry competition between brands.

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Introduction

All over the world, more households are living at low density in the suburbs of metropolitan areas. Improvements in road networks, rising incomes and the demand for newer, larger homes have fueled this trend (Margo 1992, Glaeser and Kahn 2004,Baum-Snow 2008, Baum-Snow et. al. 2014). Such suburbanization offers private benefits but imposes social costs. In the absence of a national carbon tax, decentralized living can significantly contribute to greenhouse gas emissions through a reliance on gasoline fired cars and ample use of electricity for large suburban homes with the electricity generated by fossil fuels (Jones and Kammen 2014, Graff-Zivin et. al. 2014).

If more suburban households chose to install solar panels and buy an electric vehicle that charges at home, then these households would sharply reduce their carbon emissions from household and transportation activities. If high quality batteries can be developed, such emissions could fall to zero (Gibson and Kelly 2010). The decoupling of suburban living from greenhouse gas production could play a major role in mitigating climate change risk both through the direct effect of reducing suburbanite emissions and also through a political channel. Suburban households would be more likely to support carbon mitigation policies if they faced a lower tax burden from enacting such policies (Cragg et. al. 2013, Holian and Kahn 2014).

Given that center cities tend to attract environmentalists while suburban residents are more likely to be Republicans, what are the possible pathways for such households to embrace the "green lifestyle" of both owning an EV and installing solar panels? One strategy for accelerating the adoption of solar panels and EVs is for their price to decline. International competition in both the solar panel market and the EV market has reduced the price of these products.

A second way for encouraging green choices is to improve the objective quality of the green products. Purchasers of such products are likely to value the intrinsic quality of these products independent of their environmental social benefits. We posit that the Tesla is a prime example of a product that is purchased by "accidental environmentalists." When asked about reasons for purchasing such a car, Tesla owners cite its performance, cargo space, esthetics, safety records rather than its carbon footprint.[1] Many of such buyers do not intend to supply environmental public goods. This group will be more likely to purchase the new generation of green products if they offer a higher level of performance and/or lower operating costs than conventional products.

We use several different data sets to study the correlates of electric vehicle demand and solar panel data in California. California is the epi-center of green product demand. California is the home for 12% of the nation's population and 50% of Tesla sales. We find that areas that are purchasing solar panels are also purchasing electric vehicles and hybrid vehicles. We use micro data on electric vehicle sales in California to explore how personal demographics affect the propensity to purchase different electric vehicles. The Tesla's consumers stand out for their income, education as they refuse to answer several demographic questions in EV buyer surveys.

Given that electric vehicles and solar panels are emergent technologies, the stock market price for key publicly traded companies provides additional information concerning market investor's expectations of the profits for these companies. We study how Tesla's stock price returns correlates with the returns for solar companies and document a positive correlation in their daily abnormal returns.

In the final section of the paper, we explore the supply side of the electric vehicle market. Using EV publications, we have collected detailed make specific information on the attributes bundled into these vehicles. We provide evidence that the price of EVs has been falling over time while the quality of these vehicles is improving. We discuss how competition in this industry, both in terms of vehicle attributes and in vehicle financing options, is likely to lead to higher quality cheaper new EVs. The net effect of these supply side trends is increased quality and price competitiveness of the next generation of EVs and solar panels.

Our paper contributes to an active literature in environmental economics studying how individuals' private purchases of good and services affects the supply of public goods (see Kotchen (2006), Kotchen and Moore (2006) and Kahn 2007). Unlike previous papers, we are especially interested in the role of product quality and producer competition and the introduction

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[1] The Tesla Forum (see http://www.teslamotors.com/forums) reports many quotes from Tesla owners that echo this remark. "The Tesla S class is more efficient than a Prius, quicker than a Porsche 911, and has more cargo space than many SUVs."

of new makes and financing terms for such durables as key determinants of attracting the marginal consumer to make the environmentally friendly product choice.

Consumer Demand for Electric Vehicles and Solar Panels

Differentiated consumer products such as cars represent bundles of packaged attributes. In the hedonic pricing equilibrium, heterogeneous consumers will select their favorite bundle as they face the non-linear attribute pricing function (Rosen 1974). Such consumers are unlikely to recognize that differentiated products differ with respect to their social externality consequences. For example, a household seeking a safe vehicle may choose a large mini-van and will recognize that such a vehicle consumes more gallons of gasoline (a private cost) while ignoring the social costs associated with such fuel consumption (i.e while ignoring the fact that this vehicle will create more greenhouse gas emissions) (Anderson and Auffhammer 2014, Petrin 2002).

To simplify our discussion, we consider a population of suburban single family home owners who can choose to purchase only an EV, only solar panels, solar panels and an EV, or purchase neither solar panels nor an EV. If the household does not install solar panels, it purchases electricity from the local electric utility.[2]

In Tables 1 and 2, we write out the private costs to the household and the resulting carbon emissions. We recognize that a current technological limitation is the absence of good battery storage technology. A home owner cannot currently supersize his panels and generate and store power during the sunny hours and then recharge the EV at night using this power surplus. Our discussion assumes that batteries exist so that a household who buys solar panels and an EV does not buy any electricity from the local electric utility.

The four scenarios described above are summarized in Table 1. If households make these discrete choices solely based on operating expenses, then the set of people purchasing an EV and

[2] People who live in the center city are more likely to live in multi-family housing. In such housing, issues arise concerning who makes the decision over installing solar panels and investing in the garage's recharging stations. Such split-incentives problems hinder the joint adoption of solar panels and EVs. In single family owner occupied housing, such incentive problems do not arise. For more on the split-incentives issue see Gillingham, Harding and Rapson (2012).

solar panels will rise if the price of gasoline goes up, the price of electric cars falls, the price of electricity goes up, or the price of solar panels falls.[3]

Each of these four choices has different implications for annual household greenhouse gas production. Table 2 presents emissions per year in each of the four cases. This table highlights a point predicted by the monocentric model from urban economics. In metropolitan areas where the jobs and culture are concentrated in the center city, land prices will decline with respect to distance from the city center. This means that the largest greenhouse gas reductions from the joint adoption of an EV and solar panels will occur for households who live the furthest from the city center as they will be driving more miles and living in a larger home that uses more electricity. The growth of the low density suburbs means that there are many households in this category. Based on U.S census tract data from 2000, 19% of the nation's metropolitan area residents lived twenty or more miles away from their metro area's City Center while 50% of such residents lived more than ten miles from the city center.

Introducing Preferences over Product Quality

In considering whether to purchase a specific brand of an electric vehicle, a utility maximizing buyer will tradeoff its expected performance, its price, operating cost and the status it delivers for the owner. If electric vehicles are increasingly likely to be perfect substitutes for conventional vehicles or superior in quality to such vehicles, then the marginal purchaser is more likely to be an "accidental environmentalist" who buys the EV due to its quality rather than due to its environmental performance.

Among electric vehicles, the Tesla stands out for its quality. With the introduction of the Tesla Roadster in 2008, Tesla became the first manufacturer to produce an all-electric vehicle that was available for sale in the United States. The Tesla Roadster's all-electric range of over 200 miles is only bested by the current Tesla Model S that was introduced in 2012. The Model S was the first luxury all-electric vehicle to be introduced in the United States and proved that an all-electric vehicle can compete with the most popular luxury car brands. The Model S can achieve an all-electric range of up to 275 miles on a single charge and can accelerate from 0-60

[3] While not shown in Table 1, buyers of electric vehicles also save time by not having to fill up their vehicles with gasoline and through the reduced level of maintenance required for electric vehicles.

MPH is under four seconds. This impressive acceleration time is faster than the Ford Mustang GT and Chevrolet Camaro SS – two iconic American muscle cars. With respect to the all-electric range, the closest competitor to the Model S is the much smaller and less luxurious all-electric Nissan Leaf with a range of 84 miles. The Model S is also the largest car in its class, the performance benefits do not come at the expense of comfort. The most-equipped Model S is priced at roughly $95,000. Below, we will discuss how the introducing of leasing and innovative financing opens the possibility for more people to choose to drive this vehicle.

Data

We investigate the demand for EVs and solar panels using both micro and aggregated datasets that are described in Table 3. Since we do not have a micro dataset that indicates a household's purchase decision for these two products, we must explore this joint demand using different datasets. The first micro dataset we use contains household level data on EV purchases and was collected from California's Clean Vehicle Rebate Project (CVRP). This dataset contains the manufacturer of the vehicle that was purchased, the primary decision factors that influenced the purchase decision, and demographic information for each of the 10,877 households that applied for a rebate through this program. We also use household level data from a sample of 35,491 customer accounts from a large utility company that cover the time periods of January 2, 2008 through December 31, 2011. This dataset indicates whether or not each household has installed solar panels, their level of education, and the census block in which they live.[4]

In addition to the two household level datasets, we also use aggregated data to investigate the joint demand for EVs and solar panels. First, we use vehicle registration data from R.L. Polk & Company that contains the total number of vehicles, the number of all electric vehicles, the number of electric and gas hybrid vehicles, and the number of Tesla vehicles that are registered in each zip code in California for October 2013. Next, we use data from California's Center for Sustainable Energy that allows us to estimate the number of solar panels in each zip code in California. This dataset provides information on the universe of households that applied for a rebate through the California Solar Initiative program. We control for the political ideology of each geographic area using voter registration data from the University of California Berkeley's

[4] This large utility company serves three climatologically distinct areas in the West. The data represents a random sample of customers within each of these climate areas. The data set includes 35,491 unique customer-premise pairs.

Statewide Database. This database contains the number of registered voters in each political party in 2010 for each census block in California. We control for neighborhood demographics using census tract level data from the 2012 American Community Survey's 5-year estimates. Summary statistics for the variables used are shown in Tables 4 and 5. A description of how the datasets were merged using different geographies is included in the appendix.

New Evidence on Electric Vehicle Demand

In this section, we use household and census tract level data from California to study the demographics of the buyers of electric and electric-gas hybrid vehicles. Our study adopts a cross-sectional approach; at any point in time the price of the products, electricity, and gasoline is fixed. Facing these price incentives, we are interested in exploring the demand for Teslas and other electric vehicles as well as the demand for residential solar panels.

First, we investigate the stated motivations for why Tesla buyers purchase this car. The sample consists of 10,877 households that applied for a rebate through California's Clean Vehicle Rebate Project. Results from this survey are presented in Table 6. Tesla owners cite a concern for the environment slightly more often than the average respondent, but they are much less concerned about fuel savings and HOV lane access. Households that purchased a Tesla are more motivated by energy independence, having the newest technology, and vehicle performance rather than by the vehicle's environmental performance.

We now turn to using the Clean Vehicle Rebate micro-data to study the relationship between buyer demographics and electric vehicle choice for the universe of California buyers who purchased an electric vehicle between September 2012 and September 2014 and applied for a rebate. This relationship is estimated using the following multinomial logit model:

$$P(Y_i = j) = e^{\beta_j' x_i} / \sum_{k=0}^{J} e^{\beta_k' x_i} \qquad (1)$$

$P(Y_i = j)$ is the probability that household i chooses a vehicle from manufacturer j when presented with the set of manufacturers J. x_i is a vector of attributes describing the decision maker that contains demographic and geographic characteristics and a time trend.

Results from the multinomial logit model are presented in Table 7. All manufactures of plug in electric hybrid vehicles that were eligible for a rebate other than Chevrolet, Ford, Nissan, Tesla, and Toyota are in the base category. For ease of interpretation, the coefficients are presented as relative risk ratios. Households that live in the Bay Area and are more educated are significantly more likely to choose a Nissan, Toyota, or Tesla. The largest effect is for Tesla buyers. For example, households in the Bay Area are 43% more likely to choose a Tesla over a manufacturer in the omitted category compared to households not living in the Bay area. Households with a college degree or a graduate degree are 28% and 34% more likely to choose a Tesla over the omitted category compared to households with less than a college degree. The probability of choosing a Tesla is increasing monotonically in the level of income, a result unique to Tesla buyers. While there are high end luxury plug in electric vehicles in the base category, the market share of those vehicles is too small to significantly affect the results.

Tesla owners are also unlike the rest based on their non-responses in the survey data. While the effect of age is similar across manufacturers, not answering the survey questions about age and income is a significant and positive predictor of purchasing a Tesla. It is also important to note the difference between "no answer" and "refuse to answer". "No answer" indicates that a question was left blank while "refuse to answer" is assigned to responses indicating the applicant did not want to provide this information.

Next, we study the determinants of the count of electric and hybrid vehicles purchased by households in each California census tract using the follow specification:

$$Y_i = \beta Greens_i + \gamma Solar_i + \lambda X_i + \epsilon_i \qquad (2)$$

where Y_i is the number of all electric, hybrid, or Tesla vehicles in census tract i. $Greens_i$ is the percentage of "green" voters, and $Solar_i$ is the percentage of households that applied for a rebate through the California Solar Initiative program. X_i is a vector of control variables that include census tract demographics, the total number of registered vehicles, and county fixed effects. ϵ_i is the error term.

The results from this specification are presented in Table 8. It is important to note that the number of Teslas is included in the count of all electric vehicles in columns 1 and 4, as well as in the separate Teslas regressions in columns 3 and 6. In each specification, there is a positive association between the number of Teslas in a census tract and the share of the population with a bachelor's degree or higher and income levels. There is a positive association between the census tract's population density and the Tesla count, but the Tesla count is also higher in census tracts further from the city center. All else equal, the number of all-electric, hybrid, and Teslas is higher in areas with more liberal registered voters.[5]

Starting in column (4), we include the census tract's share of homes that have solar panels. Across all three specifications, we find a positive association between the share of homes with solar panels installed and the number of electric vehicles. It is important to note that we are controlling for measures of tract average ideology and income. This positive correlation is suggestive evidence of the complementarity between these durable demand choices. However, these reduced form estimates do not provide information on what would be the correlation between these choices if gas prices were higher or if the price of Tesla vehicles were lower.

Solar Panel Demand

First, we use micro-data from the Clean Vehicle Rebate Project to investigate whether or not buyers of all electric vehicles are more likely to purchase solar panels compared to buyers of plug-in hybrids. Since buyers of an all-electric vehicle can offset some of the additional electricity that is used to charge their vehicle by installing solar panels, holding all else constant, these buyers should be more likely to bundle their vehicle purchase with solar panels. The results are summarized in Table 9. Of the 6,169 rebate applicants that purchased an all-electric vehicle, 45% stated they either have solar panels installed or plan to have them installed within one year. Of the 4,708 buyers of a plug-in hybrid, only 36% stated they have installed or plan to install solar panels within one year. This result provides some evidence that buyers with the most to gain from bundling an EV purchase with solar panels are more likely to do so compared to buyers that will receive lower benefits from this joint purchase.[6]

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[5] As a robustness check, all of the regressions the follow were estimated using the percentage of the census tract that voted no on Proposition 23 in place of the percentage of Democrat, Green, or Peace and Freedom party members in each census tract. A yes vote on Proposition 23 would have suspended AB 32 so a "No" vote was the pro-environmental vote. All of the results using this measure were similar to those using the party registration variable.

[6] Since plug-in hybrids also use gasoline as an energy source, buyers of these vehicles will not receive as large of a benefit from a solar system that could offset most of the electricity used by the vehicle.

Next, we use micro-data from a large utility company to explore the correlates of household level solar panel adoption by estimating the following equation:

$$Y_{ij} = \beta Vehicles_j + \alpha Greens_j + \lambda X_{ij} + \epsilon_{ij} \qquad (3)$$

where Y_{ij} a dummy variable equal to one if household i in census tract j has solar panels installed. $Vehicles_j$ and $Greens_j$ are the same variables as described as above. X_{ij} is a vector of control variables that includes census tract demographics, education of the utility account holder, distance from each account holder's census block group to the nearest central business district, and county fixed effects. ϵ_{ij} is the error term. Robust standard errors are achieved by clustering at the census tract. The results are presented in Table 10. Households with a bachelor's degree or higher are 0.4% more likely to have solar panels installed, and households in areas with larger homes and more owner occupied homes are more likely to have installed solar panels on their home, while neighborhood income is not statistically significant after controlling for these variables.[7] Households in areas with more liberal voters and in areas further from the nearest city are also not significant predictors of a household's decision to install solar panels. While the percentage of all-electric vehicles in a household's census tract is not significant at conventional levels (P-value equal to .12), there is a positive and significant correlation between the share of hybrid electric vehicles in a census tract and a household's decision to install solar panels. A one percentage point increase in the number of hybrid vehicles in the census tract leads to a 0.15% increase in the probability a homeowner has solar panels installed. This result provides more evidence that households view these two durable goods as being complements.[8]

Lastly, we investigate the determinates of solar panel adoption at the census tract level by estimating the following equation:

$$Y_i = \beta Greens_i + \lambda X_i + \epsilon_i \qquad (4)$$

where Y_i is the number of solar panels in census tract i divided by the number of housing units in the tract. $Greens_i$ is the percentage of "green" voters, X_i is a vector of control variables that

[7] Bollinger and Gillingham (2012) present evidence of peer effects influencing the diffusion of solar panels such that when one neighborhood adopts them that this has a causal effect on raising the likelihood that spatial neighbors adopt.
[8] All-electric vehicles make up only 0.14% of all vehicles in a typical census tract in California. Even though the coefficient for all-electric vehicles is larger than the coefficient on electric-gas hybrid vehicles, there is not enough variation across census tracts to precisely estimate this correlation.

include census tract demographics, and public utility or county fixed effects. ϵ_i is the error term. The results are presented in Table 11. A one percentage point increase in the number of residents in the census tract with a bachelor's degree or higher leads to a 0.0026 percentage point in the share of homes with solar panels installed, while a $1,000 dollar increase in the median census tract income leads to an increase of 0.0032. The results also show that areas with lower percentage of liberal voters and a higher share of black and Hispanic residents have more solar panels with solar panels installed. A one percentage point increase in the number of registered Democrat, Green, or Peace and Freedom members decrease the percentage of homes with solar panels installed by 0.037. We also find that there is a significant suburban effect for solar panels. The share of homes with solar panels installed is significantly higher in areas with larger homes that are further from a city center. The percentage of homes with solar panels installed in a census tract increases by 0.165 for a one-room increase in the median house size. With the average census tract having only 0.9% of homes with solar panels installed, this is equivalent to an 18% increase. The absence of a liberal voter effect and the presence of this suburban effect is consistent with the hypothesis that "accidental environmentalists" in the utility service area are adopting solar as a household financial investment in reducing the household's operating costs.

Since solar panel adoption could be affected by policies set by the electric utility companies, Column 2 includes fixed effects for five major electric utilities in California. The results are robust to the inclusion of these fixed effects and differences are found in the share of solar panels for census tracts served by different electric utilities.

Stock Market Evidence on Expectations of the Joint Returns to Investing in Electric Vehicle and Solar Companies

Stock market share prices embody all current information concerning future earnings of a specific company. The efficient markets hypothesis suggests that it is interesting to consider the covariance in the rate of return for Tesla's shares relative to publicly traded shares of solar companies. We estimate the correlation between these companies using stock data from Tesla, Solar City, First Solar, and the Dow Jones Industrial Average. Since Tesla, Solar City, and First Solar went public at different times, we use data from the overlapping dates. It is important to note that Elon Musk helped found Solar City and also serves as chairman, and thus a common management component exists for these two companies.[9] We used these data to estimate the following equation:

$$\%\Delta\ Tesla\ Stock\ Price_t = \beta_0 + \beta_1 \%\Delta\ DJIA_t + \beta_2 \%\Delta\ Solar\ Stock\ Price_t + \epsilon_t \quad (5)$$

If $\beta_2 > 0$, this suggests that investors view Tesla Motors and solar companies as complements. The results are presented in Table 12.[10] We find that Tesla's stock price is positively and statistically significantly correlated with both solar companies' stock price. Since Elon Musk is involved in the management decisions at Tesla and Solar City, it is not surprising that there is a stronger correlation between the stock prices of these two companies. A one percent increase in the price of Solar City stock leads to a .28% percent increase in the Tesla stock price. Using all data from the overlapping dates for Tesla and First Solar, a one percent increase in the price of First Solar stock leads to a .10 percent increase in the Tesla stock price.

One possibility is that there are common public policies that act as an omitted variable as they drive the stock price dynamics for both Tesla and the solar companies. On November 2, 2010, California voted against adopting Proposition 23 which would have postponed the implementation of AB 32 (the California Global Warming Solutions Act of 2006). Meng (2013) presents evidence studying the relationship between company stock prices and prediction market information about the likelihood of Federal carbon legislation. To address this potential concern, we estimate the correlation between the Tesla and First Solar daily abnormal returns after November 2, 2010. While the correlation is slightly stronger post Proposition 23, the estimates in Columns 2 and 3 are not statistically different (P=0.29).

Emerging Trends for Electric Vehicles and Solar Panels

Several promising trends suggest that the price of solar panels and electric vehicles will decline and that their quality will improve over time. In this section, we provide some evidence

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[9] The overlapping time period for the Tesla and Solar City stock returns is December 14, 2012 through September 23, 2014. The overlapping time period for the Tesla and First Solar stock returns is June 30, 2010 through September 23, 2014. These dates do not overlap with the national American Clean Energy and Security vote of 2009 (the Waxman-Markey Bill).

[10] In results available on request, we have included the percent change in daily gas prices (interpolated from weekly gas price data) as an extra control variable. We find that our main results are robust to including this variable.

that the price of adopting these two technologies is falling at the same that time quality is improving.

Declining Prices for Electric Vehicles and Solar Panels

First, we look at some recent trends in the pricing and quality of electric and electric-gas hybrid vehicles. Using data from several print and online resources, we compare the manufacturer's suggest retail price and miles per gallon equivalency of four major electric and hybrid vehicles over time.[11] The results are shown in Table 13. For each of the four vehicles that are highlighted in Table 13, the prices are falling while their efficiency is improving or remaining constant. These suggestive results highlight the fact that the cost of ownership of electric vehicles in the United States is falling. For the four vehicles that are highlighted below, there has been a decrease in price of 7-17% in the past three to four years.

Even more dramatic is the declining cost of installing solar panels. According to Clean Technica, the average cost of solar panels has fallen from $76.67 per watt in 1977 to only $0.613 in 2014.[12] This technology continues to be more expensive than conventional energy sources but learning by doing and international trade and specialization offers the possibility of future further price declines (see Borenstein 2012, Sawhney and Kahn 2012, Van Benthem 2008)

New Financing Options

Dating back at least to Hausman (1979) economists have noted that consumers reveal a distaste for making large upfront investments in more energy efficient durables even if these durables offer large future reductions in expected operating costs. Allcott and Wozny (2012) estimate that car buyers reveal an indifference between achieving a $1 reduction in the present value of energy savings versus not paying 76 cents more in purchasing the vehicle. Such a high implied discount rate suggests that any financing options that reduce the upfront out of pocket costs could lead to many marginal durables buyers to change their behavior. When state and

[11] Historical data was not available for all makes and models. Since the interior and exterior features do not significantly change over time, quality is measured by vehicle efficiency with respect to the miles per gallon equivalency.
[12] http://cleantechnica.com/2014/09/04/solar-panel-cost-trends-10-charts/

federal tax incentives are considered, it is now possible for consumers to invest in these technologies with little to no upfront costs.[13]

Sellers of solar panels and EVs have increased the menu of financing options for paying for these products. One of the more innovative financing arrangements comes through Tesla's Resale Value Guarantee. This allows consumers who buy a Tesla and finance their purchase through Tesla's official financing program to know exactly what Tesla is willing to pay for the vehicle after three years of ownership. Currently, this price is equal to 50% of the base price of the 60 kWh version plus 43% of the price of all options including the upgrade to the 85 kWh battery pack. A back-of-the-envelope calculation shows that this buy back value is sufficient to pay off the remaining loan balance if the buyer no longer wants to continue making the payments to Tesla after three years. While the monthly payments under the lease option are $195 per month cheaper than the monthly payment to purchase, this option allows consumers to own their Tesla and have the option to terminate their monthly payments at the same time as they would under the lease agreement.

Consumers who are considering installing solar panels on their home also have a variety of financing options from which they can choose. For households with low incomes that simply want to take advantage of "green electricity" there are solar power purchase agreements that allow them to do this with no out-of-pocket costs. The solar company owns and maintains the equipment and the household simply pays the solar company for the electricity that is generated. While the electricity rates under this arrangement will be less than those charged by most utility companies, this option does not give the ability to lock into a long term low electricity rate that is available if the solar system is leased or purchased.

For households with higher incomes and a qualifying credit score, it is now possible to lease or purchase solar panels with $0 upfront cost. Since the solar companies install the system and take responsibility for all of the maintenance at no cost to the homeowner, the decision to lease or purchase depends on the financial characteristics and goals of the household. Before the option to purchase a solar system for $0 money down, many homeowners made the decision to

[13] State and federal tax incentives now allow consumers to purchase or lease these vehicles for $0 down. Since the tax credit can be claimed by the manufacture and applied to the down payment, consumers do not have to make this expenditure out of pocket and wait until they file their taxes to be reimbursed. Since this does not apply to non-plug in vehicles, these incentives can lead the marginal consumer to make the switch to a plug-in hybrid or EV. Since the rebates are also available to consumers who lease a plug-in hybrid or EV, it is possible for a skeptical consumer to experience this type of vehicle with a low monthly payment and without being locked in to a more expensive long-term loan payment.

lease a system to reduce their out of pocket costs. This new option allows consumers to own their system from day one and allows them to receive the federal tax credit that is equal to 30% of the cost of the solar system. For households choose to lease their solar system, the 30% federal tax credit goes to the solar company to offset the upfront cost of the system.[14]

Solar City has introduced a new financing arrangement that allows qualified consumers to purchase their solar system with monthly payments determined by the amount of energy produced by the solar panels. This option allows a household to 1) own their system from day one with $0 upfront costs, 2) receive all of the state and federal tax benefits, 3) have no responsibilities for the solar system's maintenance, and 4) not be locked in to a monthly payment in the event the system does not produce enough electricity. Lastly, in the event that the homeowners decide to sell their home, the solar system is now considered an asset (compared to a liability with the lease agreement) that will make the home more attractive to potential buyers.

These new financing terms for solar panels and EV will lead to marginal households adopting these new technologies. In Table 1, we discussed how a household's expenditures would change if they made investments in an EV and solar panels. We now discuss how much a household could save each month under these new $0 down EV and solar financing options. The results are presented in Table 14.[15] Regardless of the decision to purchase an EV or a conventional vehicle, there are many households that can benefit by choosing to have solar panels installed under the current financing terms. In this scenario, a households with a solar system sized to offset the electricity used by household activities and their EV will have an estimated monthly expenditure of $89 compared to a monthly expenditure of $255 for a household that drives a conventional vehicle and does not have solar panels installed. As expected, a significant amount of savings can be realized if a household chooses to purchase or lease an EV with a solar system sized to completely offset the electricity used by their home and EV. However households, that drive only a few miles per month, have higher than average

[14] If the household's tax liability is less than 30% of the cost of the system, or if the household has $0 tax liability, they will have to pay these upfront costs out of pocket.

[15] Expenditures for solar were based on estimates from http://www.costofsolar.com. We assume that the home is between 1501 and 2500 square feet, has little shading, a composite roof, and uses 573 kWh per month at a price of 18.12 cents/kWh. The monthly payment for solar was based on having a 30 year loan with zero money down and an interest rate of 4.5%. Vehicle costs are based on a household driving 1,000 miles per month. The cost of operating an EV is based on the Tesla which uses .291 kWh per mile, and the cost of operating a conventional vehicle was based on an average of 22 MPG and a price of gasoline of $3.05 per gallon (http://energyalmanac.ca.gov/gasoline/). For simplicity, we also assume that the consumer has sufficient credit to purchase the conventional vehicle for $0 down.

electricity costs, or are in areas with lower gas prices, it may not be in their best interest to purchase these durable goods.[16] For households that are described in Table 14, the lower costs for these durable goods will lead to marginal households adopting these green technologies for purely non-environmental reasons leading to a new wave of "accidental environmentalists."

Conclusion

A typical suburban Californian household who drives 15,000 miles per year and whose daily consumption of electricity is 25 kWh has an annual carbon footprint of 8.2 tons from transportation and household electricity consumption..[17] If the social cost of a ton of carbon dioxide is $35, this translates into a suburban household social cost of $288 per year. Such households are both contributing to the challenge of climate change and are more likely to oppose carbon pricing (because they would pay more) than center city residents with a smaller carbon footprint.

This study has investigated a nascent promising trend that suburban households will be increasingly likely to purchase both solar panels and electric vehicles. Improvements in their quality and price reductions lead to a new marginal buyer of green products those who we have labelled "accidental environmentalists". If a sufficient number of suburbanites made this "green choice", then the suburban carbon curve would bend such that the differential in carbon production between center city residents and suburban residents would shrink. In fact, a new trend has begun such that suburban homebuilders are including solar systems as a standard feature of their homes leading to low carbon homes being the default option in these areas.[18]

While we have focused on electric vehicles and solar panels, ongoing research has examined other 'green products' that also bundle high quality and private gains independent of their environmental impact. For example Magnusson, et al. (2001) found that the most important purchase criteria for organic products were related to private benefit such as higher quality and

[16] The effect of quality improvements on the adoption of solar panels and EVs is even more important given the recent decline in gasoline prices. Holding quality constant, as the cost of operating a conventional gasoline powered vehicle drops relative to that of an EV, marginal households will be less likely to choose the more environmentally friendly EV. Based on the data used to generate Table 14, the price of gasoline would have to fall to $1.15 per gallon for the cost per mile driven to be equal for traditional and electric vehicles. This is equivalent to a 62% decrease based on current gasoline prices,

[17] We are assuming that the vehicle achieves 27.5 MPG and that the power plant's emissions factor is the same as California's (source http://www.epa.gov/cleanenergy/documents/egridzips/eGRID_9th_edition_V1-0_year_2010_Summary_Tables.pdf).

[18] http://online.wsj.com/articles/home-builders-tap-the-sun-1417481331. Accessed December 5, 2014.

better taste rather than the environmental attribute. Similarly, highly energy efficient LED lighting has many advantages over traditional light sources. According to the US Department of Energy, these advantages include, to name a few, compact size, increased lifetime (longer even than compact fluorescent bulbs), and greater dimming and control capability.[19] Another private benefit commonly associated with green products is their health attributes. Many consumers presume not only that organic foods taste better, but that they also provide greater health benefits than their conventionally grown counterparts (Huang, 1996; Didier & Lucie, 2008). Cows that produce milk certified by the USDA as organic, for example, are not exposed to the carcinogenic hormones, antibiotics and pesticides of conventional dairy practices.[20] Several other studies showed that health concerns were a major reason why people choose organic food products (Annett et al., 2008; Maguire et al., 2004).

[19] http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led_advantage.pdf
[20] http://www.organicfacts.net/organic-animal-products/organic-milk/health-benefits-of-organic-milk.html

Appendix: Data Methods

To merge the zip code level datasets with the census tract demographics, we used data from the United States Department of Housing and Urban Development's USPS to Zip Code crosswalk files. For each USPS zip code in the United States, this dataset indicates the 2010 census tracts that are within its boundary, and the proportion of the zip codes population that falls within each census tract. For example, 41% of zip code 91377 is in census tract 7403, 43% is in census tract 7405, and 16% is in census tract 7406. For the vehicle registration and solar datasets, the number of vehicles and solar panels in each census tract was calculated using these weights. For example, there were 11,594 vehicles in zip code 91377. We assigned 4,754 of these to census tract 7403, 4,985 to census tract 7405, and 1,855 to census tract 7406.

Public utilities were assigned to a census tract in a similar way. If a census tract was assigned to more than one public utility based on the zip code level data from the California Energy Commission, the zip code that made up the largest share was identified. The public utility that served this zip code was assigned to the census tract. If the largest zip code in a census tract could not be identified due to it being split equally by more than one zip code, we randomly chose one of the public utilities present in the census tract.

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Table 1: Household Expenditures as a Function of Durables Choice

	Purchase EV	Purchase Conventional
Purchase Solar	• Pay for EV and for solar panels • Pay $0 to the electric utility • Pay $0 for gasoline	• Pay for conventional vehicle • Pay for solar panels • Pay $0 to the electric utility • Pay for gasoline
Not Purchase Solar	• Pay for EV • No payments for solar panels • Pay electricity bill • Pay $0 for gasoline	• Pay for conventional vehicle • No payments for solar panels • Pay electricity bill • Pay for gasoline

Table 2: Household Greenhouse Gas Production as a Function of Durables Choice

	Purchase EV	Purchase Conventional
Purchase Solar	0	(Miles/MPG)*20
Not Purchase Solar	Household KWH for home and car*utility emissions factor	Household KWH*utility emissions factor + (Miles/MPG)*20

Table 3: Description of Datasets

Data	Description	Source	Unit
Micro Datasets			
Vehicle Rebate	• Household data for residents who applied for a rebate through the California Clean Vehicle Rebate Project • Demographics and motivations for purchasing by vehicle manufacturer • No geographic identifier	California Center for Sustainable Energy	Household
Solar	• Account data for 35,496 electricity accounts • Presence of solar panels • Education level • Census block group	Large utility company	Household
Aggregated Datasets			
Vehicle Registration	• Number of registered vehicles in 2013	R.L. Polk & Co.	Zip Code
Solar	• All households that have applied for a solar rebate	California Center for Sustainable Energy	Zip Code
Political	• Number of registered voters by political party in 2012	Statewide Database- University of California, Berkeley	Census Block
Demographics	• Census tract characteristics	2012 ACS	Census Tract

Table 4: Summary Statistics for Census Tract Variables

Variable	Mean	S.D.	Min	Max
Total Vehicles	3430.21	1713.39	1.38	23035.9
Total Electric Vehicles	4.94	7.56	0	129.18
Total Hybrid Vehicles	85.36	76.79	0.02	1294.04
Total Tesla Vehicles	0.97	2.84	0	59.85
Percent of Households With Solar	0.9	1.06	0	12.64
% Democrat, Green, or Peace and Freedom	46.13	12.93	16.44	84.75
% No on Prop 23	62.57	11.86	0	100
Percent Bachelor's Degree or Higher	29.68	20.17	0	100
Median Household Income (1000s)	66.21	31.38	2.5	250
Percent Black	6.07	9.7	0	92.65
Percent Hispanic or Latino	36.42	26.52	0	100
Median Number of Rooms	5.13	1.11	1.3	9
Percent Single Family	59.46	27.67	0	100
Percent Owner Occupied	55.8	24.16	0	100
People Per Square Mile	8406.87	9325.21	0.35	164629.5
Miles to Central Business District	17.12	17.13	0.04	162.57

Table 5: Summary Statistics for the Electric Utility Micro Data

Variable	Mean	S.D.	Min	Max	N
College or Higher	0.34	0.47	0.00	1.00	35,491
Distance to CBD	18.40	19.65	0.06	100.26	35,491
Has Net Energy Metering System	0.01	0.09	0.00	1.00	35,491

Table 6: The Most Important Factor in the Electric Vehicle Purchase Decision

	Tesla	Total
No Answer	0.76	0.66
Saving on Fuel	12.31	37.27
Reducing Environmental Impacts	22.99	21.20
HOV Lane Access	7.22	15.05
Increased Energy Independence	9.10	6.66
A Desire For the Newest Technology	15.46	5.48
Vehicle Performance	20.19	5.19
Supporting the Diffusion of EV Technology	7.78	5.11
Other	4.17	3.37

Values in the table are the percentage of respondents who indicated each category as the most important decision factor. Of the 10,877 respondents, 1,966 purchased a Tesla.

Table 7: Multinomial Logit Regression Results for EV Choice

Variables	(1) Chevrolet	(2) Ford	(3) Nissan	(4) Tesla	(5) Toyota
Time Trend	0.870***	0.928***	0.898***	0.856***	0.899***
	(0.00563)	(0.00684)	(0.00608)	(0.00608)	(0.00693)
Bay Area	0.996	0.872	1.254**	1.434***	1.395***
	(0.110)	(0.105)	(0.137)	(0.177)	(0.176)
Southern CA	1.288**	0.869	0.814**	1.182	1.720***
	(0.131)	(0.0974)	(0.0845)	(0.139)	(0.202)
Male	1.390***	1.060	1.137	1.589***	1.065
	(0.114)	(0.0973)	(0.0938)	(0.146)	(0.0946)
Age	1.006*	1.010***	0.988***	1.030***	1.001
	(0.00333)	(0.00386)	(0.00328)	(0.00403)	(0.00361)
No Age	1.520	1.567	0.570*	5.233***	1.335
	(0.439)	(0.510)	(0.168)	(1.640)	(0.406)
No Answer (Education)	1.095	0.748	1.806	1.412	1.561
	(0.390)	(0.314)	(0.676)	(0.543)	(0.578)
Refuse to Answer (Education)	0.865	1.052	1.526	1.192	1.615
	(0.306)	(0.411)	(0.545)	(0.448)	(0.593)
College	0.891	0.878	1.287**	1.282*	1.253*
	(0.101)	(0.114)	(0.158)	(0.180)	(0.166)
Graduate Degree	0.874	0.887	1.599***	1.342**	1.392**
	(0.101)	(0.116)	(0.198)	(0.188)	(0.186)
No Answer (Income)	1.387	2.751***	0.709	7.551***	1.028
	(0.321)	(0.810)	(0.167)	(2.781)	(0.251)
Refuse to Answer (Income)	1.340	2.588***	0.806	10.30***	0.912
	(0.290)	(0.730)	(0.173)	(3.677)	(0.208)
$50,000 to $99,999	1.233	1.858**	0.860	1.268	0.748
	(0.245)	(0.494)	(0.168)	(0.462)	(0.157)
$100,000 to $199,999	1.391*	2.576***	0.895	3.103***	0.855
	(0.266)	(0.665)	(0.167)	(1.073)	(0.171)
$200,000 to $299,999	1.442*	2.670***	0.704*	6.565***	0.762
	(0.298)	(0.728)	(0.144)	(2.323)	(0.167)
$300,000 to $399,999	1.242	1.977**	0.522***	8.687***	0.650*
	(0.296)	(0.611)	(0.126)	(3.225)	(0.168)
$400,000 to $499,999	1.172	1.858	0.419**	17.91***	0.331***
	(0.383)	(0.747)	(0.145)	(7.510)	(0.137)
More Than $500,000	1.109	1.396	0.391***	39.21***	0.783
	(0.319)	(0.532)	(0.122)	(15.24)	(0.240)
Constant	6.647***	0.989	12.50***	0.220***	3.335***
	(1.955)	(0.354)	(3.635)	(0.0936)	(1.040)
Observations	10,877	10,877	10,877	10,877	10,877

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Regression Results for the Count of Electric and Hybrid Vehicles in a Census Tract

Variables	(1) # Electric	(2) # Hybrid	(3) # Tesla	(4) # Electric	(5) # Hybrid	(6) # Tesla
Percent Bachelor's Degree or Higher	0.196***	1.921***	0.0589***	0.198***	1.935***	0.0594***
	(0.0127)	(0.0674)	(0.00413)	(0.0127)	(0.0672)	(0.00416)
Median Household Income (1000s)	-0.00145	-0.0834**	0.0175***	-0.00983	-0.160***	0.0142***
	(0.00673)	(0.0324)	(0.00307)	(0.00678)	(0.0333)	(0.00297)
Percent Black	0.00113	-0.725***	0.00340	-0.0113	-0.839***	-0.00152
	(0.00974)	(0.0731)	(0.00368)	(0.00975)	(0.0731)	(0.00346)
Percent Hispanic or Latino	0.0208***	-0.446***	0.0112***	0.0185***	-0.467***	0.0104***
	(0.00696)	(0.0467)	(0.00276)	(0.00686)	(0.0462)	(0.00267)
People Per Square Mile	-3.78e-06	0.000149**	1.17e-05***	8.33e-07	0.000191***	1.35e-05***
	(9.35e-06)	(7.03e-05)	(3.05e-06)	(9.33e-06)	(7.06e-05)	(3.15e-06)
Miles to Central Business District	0.0301***	0.0764**	0.0150***	0.0271***	0.0487	0.0138***
	(0.00564)	(0.0372)	(0.00169)	(0.00572)	(0.0373)	(0.00165)
Total Vehicles	0.00135***	0.0229***	0.000236***	0.00131***	0.0225***	0.000219***
	(0.000115)	(0.000779)	(2.75e-05)	(0.000115)	(0.000786)	(2.65e-05)
% Democrat, Green, or Peace and Freedom	0.0130	0.551***	0.0184***	0.0487***	0.878***	0.0326***
	(0.0128)	(0.0962)	(0.00482)	(0.0136)	(0.103)	(0.00518)
Percent of Households With Solar				0.952***	8.715***	0.377***
				(0.139)	(0.909)	(0.0764)
Constant	-7.304***	-48.00***	-5.182***	-9.293***	-66.19***	-5.970***
	(1.061)	(7.213)	(0.430)	(1.116)	(7.340)	(0.505)
Observations	7,945	7,945	7,945	7,945	7,945	7,945
R-squared	0.405	0.699	0.318	0.415	0.707	0.329
Model	OLS	OLS	OLS	OLS	OLS	OLS
County FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: EV Owners Stated Plans for Installing Solar Panels

Do you Have/Plan to Install a PV System?	BEV	Plug-in Hybrid
Currently Installed	24.49	17.91
Plan to Install Within One Year	20.68	18.35
No and Have No Plans	53.82	62.68
No Answer	1.01	1.06
Number of Responses	6,169	4,708

Values indicate the share of households that answered yes to each question.

Table 10: Micro Regression Results for the Probability of Having Solar Installed

Variables	(1) Has Solar Installed
College or Higher	0.00366***
	(0.00112)
Median Number of Rooms	0.00260**
	(0.00108)
Median Household Income (1000s)	-4.17e-05
	(4.34e-05)
Percent Owner Occupied	8.96e-05*
	(5.02e-05)
Distance to CBD	8.67e-05
	(8.35e-05)
% Democrat, Green, or Peace and Freedom	6.82e-05
	(7.91e-05)
Percent Electric in Tract	0.00775
	(0.00493)
Percent Hybrid in Tract	0.00149***
	(0.000561)
Constant	-0.0232***
	(0.00663)
Observations	35,491
R-squared	0.008
Model	OLS
County Fixed Effects	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11: Census Tract Regressions for the Share of Households with Solar Panels

VARIABLES	(1) % Solar
Percent Bachelor's Degree or Higher	0.00265**
	(0.00130)
Median Household Income (1000s)	0.00321***
	(0.000875)
Percent Black	0.0122***
	(0.00117)
Percent Hispanic or Latino	0.00297***
	(0.000790)
People Per Square Mile	-1.27e-06
	(1.37e-06)
Miles to Central Business District	0.00278***
	(0.000988)
Median Number of Rooms	0.165***
	(0.0184)
% Democrat, Green, or Peace and Freedom	-0.0374***
	(0.00195)
Constant	1.611***
	(0.150)
Observations	7,945
Sample	Full
R-squared	0.432
Model	OLS
County FE	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 12: Regression Results for Explaining the Daily Tesla Stock Returns

VARIABLES	(1) % Change Tesla Price	(2) % Change Tesla Price	(3) % Change Tesla Price	(4) % Change Tesla Price
% Change DJIA	0.678***	1.070***	1.062***	0.661***
	(0.241)	(0.119)	(0.123)	(0.247)
% Change Solar City Price	0.276***			0.272***
	(0.0577)			(0.0597)
% Change First Solar Price		0.100***	0.106***	0.0171
		(0.0347)	(0.0359)	(0.0576)
Constant	0.241	0.198*	0.217**	0.241
	(0.162)	(0.106)	(0.110)	(0.162)
Observations	429	1,028	941	429
R-squared	0.163	0.106	0.110	0.163
Post Prop 23	Yes	No	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 13: Trends in Electric Vehicle Pricing and Quality

Vehicle	Type	Year	Price	MPGe
Chevrolet Volt	Plug-In Hybrid	2014	$34,185	98
	Plug-In Hybrid	2013	$39,145	98
	Plug-In Hybrid	2012	$39,145	94
	Plug-In Hybrid	2011	$41,000	93
Toyota Prius Plug-In	Plug-In Hybrid	2014	$29,900	95
	Plug-In Hybrid	2013	$32,000	95
	Plug-In Hybrid	2012	$32,000	95
Ford Focus Electric	Battery Electric	2014	$35,170	105
	Battery Electric	2013	$39,200	105
	Battery Electric	2012	$39,200	105
Nissan Leaf	Battery Electric	2014	$28,980	114
	Battery Electric	2013	$28,800	115
	Battery Electric	2012	$35,200	99
	Battery Electric	2011	$32,780	99

Table 14: Monthly Expenditures for EV and Solar

	Buy EV	Buy Conventional
Purchase Solar	$89	$198
Do Not Purchase Solar	$157	$242