An Analysis of Green Purchasing Behavior: Hybrid-Electric Vehicle Adoption at the State Level

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Abstract: In an attempt to identify and better understand the relationship between green social/political behavior and consumer purchases, this study will model the purchase of Hybrid-Electric Vehicles at the state level controlling for incomes, energy prices, energy taxation and tax incentives for HEV adoption while additionally specifying the role of social/political behavior, climate, and commuter travel times to work. Green social/political behavior is shown to have a considerable impact on the decision to purchase a Hybrid-Electric Vehicle, although this impact is smaller in magnitude when considering the broad economic factors of incomes and energy prices.

Introduction

You can't see it, but it's what you don't see that matters in the green story.[1]
Michael Rehwinkel, President, Georgia-Pacific Wood Products

The green movement is sweeping America. As of 2007, some 35 million Americans claimed to regularly purchase earth-friendly products.[2] A recent survey finds that no less than 9 out of 10 Americans claim that the U.S. must become a "global leader in hybrid technology to reduce dependence on foreign oil, create jobs and curb carbon dioxide emissions."[3]

Former Vice-President Al Gore gave a voice to climate change and great impetus to the green movement overall with his 2006 documentary *An Inconvenient Truth*, reigniting the ongoing public debate surrounding "responsible consumerism," and "carbon footprints." (Gore's film has become the 5th largest grossing documentary in the world to date).[4] The term

"carbon footprint," while not coined by Gore, has become the source and summit of the green movement in the United States. A cursory search on Lexis-Nexis Academic reveals more articles containing the phrase since the film's release date of May 24th, 2006 (996 articles) than all combined prior (181 articles).[5]

What exactly is it that business leaders like Michael Rehwinkel find so difficult to grasp about this movement? Perhaps it is the fact that there seems to be, as Rehwinkel summarized, more than meets the eye when considering the complex relationship between green social/political behavior and consumer purchasing behavior.

This study seeks to circumvent the difficulty of establishing this relationship, documented in the literature review, by focusing on a narrow but contextually important purchase – the consumer's choice of vehicle. The purchase of an HEV, the green movement's self-proclaimed[6] showcase product, reflects the strongest of green consumer convictions, and therefore should be interpreted as a conservative insight into the adoption of the entire, more economically accessible green product spectrum. By modeling the impact and interplay of economic and political motivations on HEV adoption it will be possible to better identify and understand the magnitude of impact the green movement has on consumer purchases in the broader, real economic space of consumer choice.

Therefore this study will build upon current research in seeking to model the purchase of HEV's at the state level controlling for incomes, energy prices, state-level energy taxation and state-level tax incentives for HEV adoption while additionally specifying the role of politics, climate, and commuter travel times to work.

Literature Review

D'Souza (2004) defines the green consumer as "…those consumers that are highly environmentally concerned…characterized as buying green products whenever they see an opportunity to do so."[7] Connolly and Prothero (2008) state that "green consumption must be understood in terms of a process that has led to individuals feeling both responsible for and empowered in dealing with risks to both themselves and to the wider environment."[8] These definitions seem to endure throughout; however some take exception to broad definitions of green consumers at all, arguing that these consumers adopt more selective and sometimes even seemingly random behavior. From Moisander (2007):

> Few ecologically minded consumers decide to do everything right, or in an environmentally responsible manner. More probably, the majority of green consumers do only what they perceive as their fair share of the things that they know and come to think of as environment-friendly behaviors that can be done. Nonetheless, although people do not regularly engage in some or manner the ecologically relevant behaviors they know of, they may still consider themselves "ecologically responsible" green consumers.[9]

Moisander provides an outline of the breadth of green consumers, which complements later difficulties we will examine in their segmentation. She defines those "radical" green consumers as "drastically reducing the number of purchases of everything," while the more

mainstream green consumer lives by "carefully choosing products and services that are the least destructive to the environment…without significantly compromising one's way of life."[10]

Alternatively, Peattie (2001) argues for a "return to rationality" in defining and understanding the motivations of the green consumer,[11] sentiments confirmed in Lee (2008) which found that pure social influence, not environmental concern, was the top predictor of adolescent green purchasing behavior. Lee finds that green purchases are "more easily activated by emotional involvement than by rational assessment (as reflected by the finding that environmental attitude ranked only as the second-to-last predictor)."[12]

As a result, no clear, consistent relationships between the political green movement and green purchasing behavior are found, see Pickett-Baker & Ozaki (2008),[13] de Paco & Raposo (2009),[14] Mildebrath (2009);[15] or alternatively finds broad economic factors to hold more robust explanatory power, see Hicks (2006),[16] Lee (2008), de Paco & Raposo (2009). In the particular case of HEV's, a recent study by online polling company Harris Interactive found that 80% of consumers cite costs and insufficient fuel savings as the main reason for not purchasing a hybrid vehicle,[17] while other, similar analyses show clear economic advantages only when driving in metropolitan areas or above-average distances regularly.[18]

Perhaps the most convincing, Hicks (2006) was able to explain the state-level use of Alternative-Fueled Vehicles with great statistical confidence and significance using only broad economic factors including incomes, energy prices, state-level taxation and incentives. Mildebrath (2009) and de Paco & Raposo (2009) both find price as the leading factor in the decision to purchase a green product, while additionally Pickett-Baker & Ozaki (2008) and McDonald, et al (2009)[19] highlight the complexity of the consumer experience when considering a green purchase in any sector[20,21,22,23.] "It seems therefore mistaken to frame and target consumers solely as goal-oriented individuals and powerful market actors who use their purchasing power to bring about social change."[24]

Still others argue that green consumerism can be seen as a political movement in the marketplace unto itself, akin to boycotting or the post-9/11 American "freedom fries" movement.[25] Stolle, Hooghe & Micheletti (2005)[26] contend that green consumer activism is on the rise in Europe and elsewhere, citing the European Social Survey of 2002.[27] Ironically, this bi-annual survey has since omitted that particular line of questions making it difficult to validate these findings over time. Even as Stolle, Hooghe & Micheletti acknowledge the gaining political force of the green ideology, they still generally warn against drawing the immediate parallel to a widespread adoption of green products in the marketplace on basis of ideology alone.[28]

For these researchers, the thought of widespread green consumer purchases may be in effect opposed to the meaning of the ideology itself. In her book *Political Virtue and Shopping*, Micheletti argues that the political nature of consumerism can actually do harm to the underlying ideological movement. "[Consumerism] detached from other concerns can potentially disenable an ideological driven environmental association."[29] Her work exhaustively documents the difficulty of sustaining the true nature of the original, underlying ideology once it is adopted in the wider consumer mindset. In other words, her argument is the existence of a kind of political-economic paradox, "the marriage of profit and principle is an uneasy one."[30] This seems to echo the findings of Moisander and others that the underlying ideology may perhaps only serve as the conception of purchasing behavior, with broader economic factors soon after assuming the primary compelling force.

Finally, as might be expected, segmentation efforts have shown that the marketplace is highly complex, with consumers displaying a wide spectrum of motives and characteristics;[31] see Pickett-Baker & Ozaki (2008) for the best synopsis of this. Most literature agrees that income and education seem to be strongly linked to green consumerism, see Lee (2008), Mildebrath (2009) and de Paco & Raposo (2009). Women in particular seem to identify more with green consumerism, see Pickett-Baker & Ozaki (2008) and Lee (2009).[32]

De Paco & Raposo (2009) segment the green market into three main categories: (1) "the uncommitted" (36%), younger, more educated with "negative positions in relation to some environmental aspects," (2) "the green activists," (35%) gen X'ers and Baby Boomers who enjoy more income and favorable positions towards all environmental aspects, and (3) "the undefined," (29%) who are either older or less educated than the other segments and consider their actions as unrelated to the greater environment.

In summary, current literature seems to give a consistent witness to basic, purely economic factors playing an insufferable trump card to the self-proclaimed green ideals of the consuming public. The research additionally shows that green consumers are not segmented with ease. Save for income and education, they occupy various areas of social and demographic life. Finally, the green belief system contains a wide spectrum of behavior from granola green to glamour green, each side blaming the other for the inescapable niche status of this elusive movement. These elements combined have created much difficulty for researchers to establish a clear, consistent link between green social and political behavior to green purchases.

Model Discussion

The model constructed attempts to address the lack of strong empirical evidence of political/social behavior's influence on green consumer purchases. Therefore the unique data elements introduced in addition to current research are chiefly political in nature. The Federal election green party and democrat party voting percentages used capture broader political sentiment, while Sierra club membership seeks to capture more refined "conservation green" social/political behavior that can span the traditional political spectrum or bypass it altogether.

Among the more economic factors, including incomes, energy prices and incentives, data used largely represents current research methods. Additions to these methods include the use of real-dollar tax incentives and mean travel times to work. The use of real dollar tax incentives versus the current use of dummy variables seeks to obtain an estimator with more relevance to marketing and policy discussion, while the specification of travel times to work seeks to further refine the microeconomics of time and personal budgeting on the green purchasing decision, although there are limitations with the available data discussed later. Finally, the introduction of climate data attempts to capture any impact milder, more agreeable climates have on green purchases, specifically relevant in the current discussion of vehicle choice. However, as outlined later, this particular data element is limited as it varies over the panel and not over time.

For statistical analysis and estimation purposes, current research methods were strongly considered and adopted throughout. The use of a panel regression with spatial effects lines up directly with Hicks' study on alternative-fueled vehicles and attempts to mirror the study's empirical strength. The addition of a random-effects model accomplishes two goals: one, to

verify the estimators arrived at using the spatial model, and secondly, to help understand any specific explanatory or empirical advantages gained by using the spatial specification.

Data

In further refining the specification of Hicks (2006) this model uses many of the same explanatory variables. A main difference is the use of left-side HEV's at the state level as opposed to Alternative-Fueled Vehicles. HEV's are considered a subset of AFV's, therefore many of the same variables are expected to apply.

Hybrid-Electric Vehicle purchases were measured by vehicle registration data on lease from the R.L. Polk marketing research firm.[33] HEV registration data is observed in registrations per thousand people and hereafter performs as a proxy for vehicle purchases. Metropolitan incomes were gathered from the U.S. Department of Commerce, Bureau of Economic Analysis Regional Economic Information System (REIS) and measured at the levels, in millions of US Dollars. All-grade retail unleaded gasoline prices were obtained from the Energy Information Administration,[34] measured in the average weekly price in real cents per gallon. State gasoline tax levy data were obtained from the Tax Foundation,[35] measured in cents of tax levy per gallon. Sierra Club membership data were obtained directly from the source,[36] measured in members per thousand people. Voting data were obtained from the U.S. House of Representatives Office of the Clerk and the Federal Election Commission,[37] measured as the party's percent of votes cast in the most recent federal election. Population data and commuting times were obtained from the U.S. Census Bureau,[38] with commuting times measured in mean minutes traveled to work. Snowfall data were obtained from the National Climatic Data Center[39] measured in average annual metropolitan area snowfall in inches.

State tax incentives data were obtained from individual state sources, cross-checked with the compilation available on the HybridCars.com research forum, measured by the average vehicle real dollar incentives available, or, where applicable, fixed real dollar incentives.

Data were organized in a 5 year panel, 2004-2008 for the 48 lower United States and the District of Columbia. Summary statistics are provided below in Exhibit 1.

Exhibit 1:
Summary Statistics and Variables
2004-2008 48 Lower State Panel and the District of Columbia

Variable	Mean	Std. Dev.	Min	Max	Measure
HEV Vehicle Registrations	1.74	1.55	0.08	8.60	Registrations per thousand pop.
Average Weekly Retail Gasoline Prices	267.1	47.1	198.4	337.2	Real cents per gallon
State Gasoline Tax Levy	0.22	0.06	0.04	0.46	Real cents per gallon
Metropolitan Incomes	195.0	253.0	5.6	1,540.0	Real USD $ (Millions)
Sierra Club Membership	2.32	1.78	0.04	15.37	Members per thousand pop.
State Tax Incentives	245	634	0	3,426	Real USD $
Green Party Voting	0.002	0.004	-	0.025	Green percent of votes cast
Democratic Party Voting	0.493	0.116	0.007	0.925	Democrat percent of votes cast
Mean Travel Time to Work	23.3	3.5	16.0	31.2	Minutes
Average Metropolitan Area Snowfall	30.5	23.5	0.0	91.3	Average annual snowfall, inches
Spatial Dependent Variable	0.09	0.28	-	1.00	Spatial dependent variable

Specification for Aggregate Hybrid Vehicle Purchases

The primary specification is a panel regression with spatial effects, where state-level registrations of HEV's in state *i* in Year *t* are dependent on state-level fixed-effects (α), average weekly gas prices, the state-level gasoline tax levy, states' real metropolitan incomes, membership in the Sierra club, the average real dollar tax incentive per vehicle (or fixed real dollar incentive in applicable states), green party and democratic party percent of votes cast, respectively, the state-level mean travel time to work, state-level snowfall, the dependent variable weighted by the spatial matrix $\delta\omega$, which is the first-order contiguity matrix of the lower 48 states and the District of Columbia, and the normally distributed error term. As in Hicks, the spatial element $\delta\omega$ introduced in this model seeks to control the effect of spatial autocorrelation on the error term and identify any impact of border-state HEV adoption on observed states' adoption rates. As an alternative, a random-effects panel regression is also presented, whose validity was confirmed with a Hausman test on FE and RE estimators found in Appendix A.

Exhibit 2
Primary Model Specification

$$(HEV\ \mathrm{Re}gistrations)_{i,t} =$$
$$\alpha + \beta_1(Gasoline\,\mathrm{Pr}ices)_{i,t} + \beta_2(GasolineTaxes)_{i,t} + \beta_3(Metropoli\,\mathrm{tan}\,Incomes)_{i,t} +$$
$$\beta_4(SierraMembers)_{i,t} + \beta_5(StateTaxIncentives)_{i,t} + \beta_6(GreenVoting)_{i,t} + \beta_7(DemocratVoting)_{i,t} +$$
$$\beta_8(CommuteTime)_{i,t} + \beta_9(Snowfall)_{i,t} + \delta\varpi(HEV\,\mathrm{Re}gistrations)_{i,t} + \varepsilon_{i,t}$$

All variables exhibit satisfactory levels of stationarity using an Augmented Dickey-Fuller test for the individual panels with a time trend, therefore all data are estimated at the levels. These tests should be interpreted with caution given the relatively small time series observed.

Results

Initially the economic estimators appear largely in accord with previous findings, with differing magnitudes. As in Hicks, metropolitan incomes and gasoline prices exhibit impact at high levels of significance. An increase of one standard deviation in metropolitan incomes increases HEV adoption by 0.21 registrations per thousand people. Additionally, the strongest estimator can be found in gasoline prices, a one standard deviation increase (~47 cents per gallon) increases adoption by 1 registration per thousand people, one tenth of one percent.

The political variables introduced into this specification exhibit relatively strong and significant coefficients. In the better performing spatial model, an increase of one standard deviation in Sierra club membership per thousand people increases HEV adoption by 0.46 registrations per thousand people. Similarly, an increase of one standard deviation in democratic and green party voting percentages increases HEV adoption by 0.25 and 0.1 registrations per thousand, respectively, although the green party estimator falls just outside of

10% statistical significance. Finally, the spatial variable's small coefficient of 0.006 shows that HEV adoption rates in a given state are impacted in a small order of magnitude by neighboring states. This is less spatial impact than that found in Hicks, which is what might be expected given the additional social/political specifications made here.

Exhibit 3
OLS Estimates of HEV Registrations per Thousand rates, 2004-2008, Impact Analysis

	Spatial Model				**Random-effects**
Variable	HEV Registrations	Increase$_1$	Result$_2$		HEV Registrations
Intercept	-5.560444***				-5.692796***
Average Weekly Retail Gasoline Prices	0.0205749***	$ 0.47	1.00		0.0206***
State Gasoline Tax Levy	0.5032896				1.758763
Metropolitan Incomes	8.40E-10***	$253M	0.21		9.56E-10**
Sierra Club Membership	0.2580379***	1.78	0.46		0.125836***
State Tax Incentives	0.0000666				0.000106
Green Party Voting	25.97756	0.4%	0.11		10.15814
Democratic Party Voting	2.13444***	11.6%	0.25		1.42681**
Mean Travel Time to Work	-0.016079				0.0112882
Average Metropolitan Area Snowfall	-0.001692				0.002036
Spatial Dependent Variable	0.0068369*$^{\Delta}$				
R-Squared	0.671				0.638
*** Sigificant at the 1% level	** Sigificant at the 5% level				
* Significant at the 10% level	$^{\Delta}$ 95% Confidance interval crosses zero				
1: Increase of one standard deviation in independent variable					
2: Resultant increase in dependent variable					

Among the non-performers can be found snowfall, commuter travel times, state-level gasoline tax levy and state tax incentives. An alternative state tax incentive dummy was inserted into both specifications and was also shown to be without significance. Both snowfall and commuting time data are completely fixed over time and varied only by state, which may explain their ineffectiveness as estimators even in the preferred random-effects specification. The Census Bureau's mean travel time to work data used, measured in mean minutes traveled, has much to be desired in capturing the variation of commuting efforts over the panel and time series. This may have further contributed to the ineffectiveness of that particular variable.

As for the state-level incentives, perhaps the short duration of the time series is unable to capture valid estimators for these variables. Where observed, states' incentives were largely, although not completely, fixed over the observed time series, further hindering their performance.

It should be noted that the specific behavior of the HEV registration data during the observed time period seems to impact the estimators in both models. The 3 year 2004-2006 panel performs far better under both specifications than the 5 year panel, which may demonstrate the impact of the peak 2007 and valley 2008 HEV registration levels on the estimators. A panel observed over a longer time period will likely prove an effective remedy to this inefficiency.

Further caution should be taken given the relatively low overall regression fit, which may exhibit the difficulty of efficient estimation in this specific time series. Postestimation results also indicate the possible danger of omitted variable bias in both models when observing the behavior of the residuals by panel.

Conclusions

Overall, the intent of this research was to address the empirical gaps that exist in current research in discovering the relationship between green political/social behavior and green consumer purchases. While current literature defines and explores well the increases and nuances of green consumer sentiment, it struggles to define clear, empirically sound economic relationships.

To address this problem, this study turned to the hallmark green consumer purchase: the Hybrid-Electric Vehicle (HEV). This particular purchase was thought of as a strong, conservative measure of broader green purchasing behaviors. By modeling the purchase of HEV's at the state-level, introducing political/social variables and controlling for broad economic factors, it was hypothesized that a significant, contributing relationship between social/political behaviors and consumer purchases would be found.

To this end, the findings outlined here seem to contribute to current research in two distinct ways. Firstly, despite the model's inefficiencies and bias, it strongly confirms existing findings on the primary impact and magnitude of energy prices and incomes on HEV purchasing behavior. Gasoline prices and Metropolitan incomes were once again the largest and most significant predictors of HEV purchases. This is an important confirmation of current research and emphasizes the primary importance of broad economic factors on the green purchasing decision.

Secondly, and quite distinctly, the strong performance of the social/political estimators, although secondary in magnitude when considered among the research-consistent energy price and income estimators, may be preliminarily interpreted as supporting the positive impact of green social/political behavior on consumer purchases. This would be a new and significant contribution to the body of research.

However, it must be noted that this interpretation warrants much caution. Further research that models the behavior of more economically-accessible green products over a longer time series is most certainly needed to validate this relationship, which at this juncture remains preliminary at best. Perhaps additional exploration of other factors such as education and gender would also be warranted in future research as well.

Managerial Implications

"The global auto industry will be forever changed in 2009."[40] Today's automakers are struggling now more than ever to adapt to the rapidly changing environment. Global demand for new automobiles is estimated as being lower now in 2009 than any time in the last 20 years.[41]

This research has many implications for automakers seeking to gain footing during this crucial time. Firstly, it highlights the primary importance of economic factors in the decision to purchase a hybrid. Many managerial conclusions might be drawn from this finding alone: as scarcer resources force tougher consumer choices, some consumers may find themselves drawn to familiar, more economically feasible vehicle choices, as demonstrated in recent consumer behavior in purchasing other green products such as compact-fluorescent light bulbs.[42] However, some consumers may alternatively find themselves drawn to newer technologies when certain economic conditions are met, as demonstrated in the recent behavior of consumers in response to the U.S. Government's "cash-for-clunkers" program. The Toyota Prius, the most widely recognized and best-selling hybrid vehicle, is currently the 4th largest vehicle being sold under this new program.[43]

Secondly, these findings seem to lay a framework for a more refined understanding of the political and social underpinnings of green purchases. Among the political estimators, Sierra Club membership was the most significant and consistent performer. From the Sierra club website: "The Club is America's oldest, largest, and most influential grassroots environmental organization. Inspired by nature, we are 1.3 million of your friends and neighbors, working together to protect our communities and the planet."[44]

This would seem to suggest a unique green nature of the HEV purchase decision. The Sierra Club, while representing a wide variety of behaviors, is largely a conservationist green group. This would seem to reflect those green consumers who have strong sentiments of conservation and perhaps frugality, behaviors which until now may not have been considered as strong contributing factors to the HEV purchase decision. These nuances are documented in further detail in Appendix C, which contains HEV use summary tables that are hoped to assist managers in the analysis of current HEV penetration, growth and opportunities by market based on these new considerations. These findings may lead managers to consider new target demographics and characteristics in marketing efforts.

Appendix A
Hausman Specification Test Results

Exhibit 4: Hausman Test for Specification Results

Variable	RE (b)	FE (B)	Diff	sqrt(diag(V_b-V_B))
avgwkgas	0.0206	0.0201509	0.000449	.
stgastax	1.758763	1.443575	0.315188	.
metinc	9.56E-10	5.87E-09	-4.91E-09	.
sierra	0.125836	0.0191019	0.106734	.
sttaxinc	0.000106	-0.0001676	0.000274	.
polgrn	10.15814	-2.931629	13.08976	3.244083
poldem	1.42681	0.1607286	1.266082	.
chi2(6)	=	(b-B)'[(V_b-V_B)^(-1)](b-B)		
=	238.77			
Prob>chi2	=	**0.0000**		

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We reject the null hypothesis at the 99% confidence level, therefore the FE specification is inconsistent. This is most likely due to the FE already present in the snowfall and mean travel time data.

Appendix B
HEV Registrations, Growth by State

State	HEV*	State	HEV
CA	8.60	PA	2.93
OR	7.18	NY	2.90
VT	7.16	WY	2.79
WA	6.18	KS	2.65
VA	6.07	UT	2.48
DC	5.94	OH	2.39
MD	5.50	TX	2.33
MA	5.39	MO	2.30
IA	5.30	IN	2.30
CO	5.19	SD	2.23
NH	5.08	NE	2.18
CT	4.99	GA	2.15
AZ	4.60	AR	2.05
NM	4.28	MI	2.02
RI	4.10	TN	1.88
DE	3.92	WV	1.84
ME	3.60	OK	1.74
NJ	3.52	SC	1.69
NV	3.51	KY	1.66
WI	3.46	AL	1.61
MT	3.31	ND	1.51
MN	3.29	LA	1.34
FL	3.28	ID	1.11
IL	3.28	MS	0.95
NC	3.02		

*2008 HEV Registrations / 1,000 pop.

State	Growth*	State	Growth
OR	393%	NY	85%
MA	374%	WA	84%
MT	330%	TN	83%
IL	295%	FL	82%
IA	250%	NV	82%
NH	224%	OH	79%
VA	224%	OK	76%
AZ	215%	NJ	73%
CA	183%	MO	70%
MN	167%	DE	70%
WY	151%	IN	69%
NE	145%	ME	67%
RI	137%	GA	64%
SD	132%	KY	61%
AR	132%	CO	61%
VT	128%	WI	58%
TX	123%	MI	57%
KS	119%	WV	55%
NM	117%	ND	50%
DC	114%	MS	43%
UT	103%	PA	43%
CT	98%	SC	42%
MD	97%	AL	36%
NC	92%	ID	21%
LA	86%		

*5-Year linear growth rate in HEV / 1,000 pop.

Exhibit 5: 2008 HEV Registrations (Left)

Exhibit 6: 5-Year Linear Growth in HEV Registrations by State, 2004-2008 (Right)

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