DETERMINANTS OF PHEV PURCHASE INTENTIONS IN A CANADIAN CITY[1]

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Introduction

Cars consume considerable energy and contribute greatly to global greenhouse gas (GHG) emissions. According to the International Energy Agency, road transport accounts for 90 percent of energy used in transportation, and passenger cars consume 64 percent of this energy (IEA 2015, p. 1). The largest share of Canada's emissions is due to transportation (CAPP 2015). Recently, Reiter and Kockelman (2017) estimated annual health and other indirect costs of an electric vehicle (EV) at $62 on average, compared to $136 for a car fueled by gasoline. While increasing adoption of EVs could reduce fuel consumption and harmful emissions (Skippon et al. 2016), market acceptance is uncertain and adoption continues to fall short of expectations (Liao et al. 2017). Inspired by the potential of electric transportation, this study focuses on determinants of plug-in hybrid electric vehicle (PHEV) purchase intentions in a Canadian city.

PHEVs run on batteries, recharged by plugging into the electric power grid. They are also equipped with an internal combustion engine (ICE), which burns gas or diesel fuel, to recharge the battery and/or replace the electric motor when battery charge is low, extending vehicle range to resemble that of a conventional ICE vehicle. The remainder of this paper is organized as follows. The next section presents a review of the literature and development of hypotheses. The third section describes data collection and analysis procedures. Next, the fourth section presents the results. The fifth section offers conclusions, along with implications for theory and policy.

Literature Review

The review focuses on literature about EV adoption/purchase intentions, with a special focus on PHEVs. Recent, more detailed reviews of this rather voluminous literature are published elsewhere (e.g. Coffman et al. 2017; Liao et al. 2017).

Environmental concern refers to consumers' opinions about improving air and water quality, reducing emissions and protecting the environment (Krause et al. 2016). Since PHEVs imply lower fossil fuel consumption and GHG emissions, environmental concern should impact PHEV purchase intentions. Consumers demonstrate willingness to conserve energy and reduce emissions by adopting EVs (Ozaki and Sevastyanova 2011). According to Carley et al. (2013), environmental concern increases consumers' preference for EVs. Axsen and Kurani (2012) consider concern about the environment to be a factor influencing PHEV perceptions within car buyers' social networks. Drawing on a crowd-sourcing survey of American consumers, Krupa et al. (2014) reported that environmental concern and concern about energy independence inspire buyers to consider PHEVs.

Carley et al. (2013) also found *experience* with and knowledge about EVs to increase purchase likelihood. Experience seems to result in more favorable attitudes toward PHEVs, and higher purchase intentions. A similar result was reported by Larson et al. (2014).

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Many studies have identified *vehicle price* as an important determinant of willingness to consider an EV and purchase intentions (e.g. Krause et al. 2016; Larson et al. 2014). Others focus on operating costs and the *total cost of ownership* (Dumortier et al. 2015; Letmathe and Suares 2017), including purchase price, maintenance, insurance, financing and fuel costs. Higher gasoline prices seem to stimulate EV adoption (Diamond 2009; Egbue and Long 2012), by increasing the benefit of fuel cost savings (Krupa et al. 2014).

Driving range refers to the longest distance a vehicle can travel before recharging or refueling is required. Limited driving range remains an obstacle to EV adoption (Franke and Krems 2013; Krause et al. 2016). Egbue and Long (2012) suggest that driving range is the top factor influencing EV purchase – and most consumers believe EV range is not sufficient for their daily travel due to limited battery capacity. Driving range is an important differentiator between battery electric vehicles (BEVs) and PHEVs. Unlike BEVs, which rely solely on battery power, driving range of PHEVs match that of ICE vehicles. *Charging infrastructure* is another important element for influencing adoption of EVs. While particularly critical for BEVs, lack of charging stations may also be a barrier to adoption of PHEVs in Winnipeg (CAA 2017).

Incentives play an important role in stimulating EV adoption. Availability of public charging stations, access to high-occupancy vehicle (HOV)/car pool lanes (Dumortier et al. 2015; Krause et al. 2016) and free or preferred parking (Langbroek et al. 2016) should make EVs more attractive. Other EV-friendly policies include tax breaks (Dumortier et al. 2015; Krause et al. 2016) and direct cash rebates (Larson et al. 2014). From November 2006 to October 2010, the Manitoba government offered a $2,000 rebate to people for purchasing certain EVs (Antweiler and Gulati 2013). In 2009, the U. S. government enacted tax credits to encourage PHEV adoption in America (Skerlos and Winebrake 2010).

Higher education levels have been found to positively influence intentions to purchase EVs (Potoglou and Kanaroglou 2007). The National Academies Press (2015) reported BEV and PHEV buyers, compared to ICE buyers, have higher incomes and are more likely to be college graduates. Krause et al. (2016) found a positive link between level of education and EV purchase intentions – and an insignificant link between income and intentions. Langbroek et al. (2016) also found the link between income and intentions to be insignificant. Thus, the research results on relationships between demographic factors and EV purchase intentions are mixed, particularly with respect to income and education.

Driving pattern often refers to daily or annual driving distance. Hoen and Koetse (2014) identified annual driving distance as the single most important predictor of EV preferences within the Netherlands; longer driving distance decreases willingness to consider EVs, likely due to "range anxiety."

Guided by the literature, the following hypotheses will be tested:

H1: Greater environmental concern increases PHEV purchase intentions.

H2: Experience with EVs positively influences PHEV purchase intentions.

H3: Stronger influence of favorable vehicle features increases PHEV purchase intentions.

Methodology

Survey methods and regression techniques were used to test these three hypotheses. The first part of the questionnaire contains five 5-point Likert scale items, covering environmental concern; awareness of, familiarity with and knowledge about PHEV features; and purchase intentions. A question on experience with PHEVs is next. Participants were asked whether they have rented, test-driven or own a PHEV. The third part covers attitudes towards nine PHEV features, rated on 5-point scales, from very low (1) to very high (5) influence. Finally, the last section covers demographic and lifestyle characteristics.

The survey targeted an expert group (members of MEVA, the Manitoba Electric Vehicle Association), and a non-expert group. MEVA provides information and promotes EV adoption in Winnipeg, and has around 40 members (http://manitobaev.ca/). The non-expert group is composed mostly of students and staff working at the University of Manitoba. Thus, this group is similar to the sample used by Egbue and Long (2012). Non-experts are generally less familiar with PHEVs, vis-à-vis experts.

Manitoba has several jurisdictional advantages in promoting PHEVs. The province has among the lowest electricity rates in North America (Manitoba Hydro 2017). Manitoba also generates the most renewable electricity in North America (IEM 2011), largely by hydro power. PHEV drivers should be attracted to low electricity rates and renewable power generation. Furthermore, Winnipeg has 19 Level 2 and five Level 3 (battery) charging stations (CAA 2017). While Level 2 stations take 4-8 hours to recharge; Level 3 (DC fast charging system) need only 30-60 minutes.

Two methods of survey distribution were used: during a group meeting and on-line. Questionnaires were distributed to MEVA members during their monthly meeting on May 26, 2016. Twenty MEVA members attended the meeting and 16 questionnaires were completed, for a response rate of 80 percent. An on-line version of the questionnaire was also created using Qualtrics, and distributed to all other MEVA members and the non-expert group. Eight more MEVA members completed the survey by early June.

A *snow-balling* sampling method, adapted from Potoglou and Kanaroglou (2007), was used to reach the non-expert group. A link to the questionnaire, with a request that only Winnipeg residents participate, was posted on chatting software WeChat and Facebook. Ultimately, 59 completed questionnaires were accepted for analysis: 24 from the expert group (MEVA members) and 35 from the non-expert group.

Results

The sample includes 41 males (69.5%) and 18 females (30.5%); thus, women are under-represented. This gender imbalance is similar to other EV empirical studies, e.g. Egbue and Long (2012), in which females comprised 29% of the sample.

As expected, experts are significantly more aware of, familiar with and knowledgeable about PHEVs and their features compared with non-experts (see Table 1). The experts also express greater concern about the environment. Perhaps this concern inspires their membership in a group like MEVA. While experts also have higher average intentions to purchase, this difference is not statistically significant. Since the sample is rather small and the two groups do not differ on the dependent variable, they are combined for further hypothesis testing.

Table 1. Awareness, Familiarity, etc. by Group

Items*	Mean		t stat.	p-value
	Expert	Non-expert		
Eco-concern	4.54	3.91	2.59	.006
Awareness of PHEVs	4.50	3.34	4.28	.000
Familiarity with PHEVs	4.27	3.06	4.27	.000
Knowledgeability about PHEVS	3.85	2.46	4.49	.000
Purchase Intention**	2.77	2.31	1.45	.151

*1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree

**"My next car will definitely be a PHEV."

The hypotheses were tested using regression analysis, with purchase intentions as the dependent variable. H1 argues that greater environmental concern increases PHEV purchase intentions. The questionnaire asks how strongly consumers agree or disagree with the following statement: "I am very concerned about global warming and the environment."

H2 asserts that experience with EVs positively influences PHEV purchase intentions. The questionnaire classifies participants into three categories, based on experience with PHEVs. Finally, H3 proposes that greater influence of certain vehicle features increases PHEV purchase intentions. The instrument includes nine vehicle features, measured across five levels from very low (1) to very high (5) influence.

Driving range (average rating of 4.07/5) and fuel savings (4.07) are the most influential features, followed by vehicle price (3.92), charging station availability (3.90) and operating costs (3.88). Next come reduced GHG emissions (3.64) and rebates/incentives (3.63). Manitoba currently offers no financial incentives to car drivers who purchase PHEVs. The least influential features are gas prices (3.37) and better parking (3.03). It is notable that gasoline prices during the survey period were relatively low compared to prices several years earlier. Further, the City of Winnipeg offers very little in terms of more convenient parking for EV drivers. Thus, here and now, it is not surprising that these features have relatively low influence.

Principal components analysis was used to study dimensionality of the nine vehicle features (Hair et al. 1987). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.702, well above 0.5; and Bartlett's test of sphericity is significant (approximate Chi-square = 183.72; p-value = .000). So, factor analysis appears suitable and useful for this data set (Yong and Pearce 2013). A three-factor solution was adopted based on study of the scree plot and the eigenvalue $\geq$ 1.0 criterion. These extracted components, which explain 69 percent of the variance, were subjected to Varimax rotation with Kaiser Normalization.

Hair et al. (1987) suggest that factor loadings greater than 0.50 "are considered very significant." Thus, in the current study, only loadings above 0.50 were used to assign variables to factors (see Table 2). After rotation, the three components are interpreted as follows. Component 1 describes car driver consideration of *economic* attributes; i.e. car price, operating costs, rebates and parking rates. Component 2 represents *environmental* attributes; fuel savings and reduced GHG emissions. Finally, component 3 is interpreted as a *convenience* dimension, including driving range and charging station availability. Gas price is the only feature not clearly aligned with one of the three factors. As noted above, gas prices were relatively low during the study period, compared to several years earlier.

Table 2. Factor loadings, rotated component matrix

Item	1	2	3
Vehicle price	.740	.402	-.048
Operating costs	.687	.495	.150
Fuel savings	.257	.872	.162
Reduced GHG emissions	.002	.777	-.267
Gas prices	.171	.494	.433
Charging station availability	.275	-.044	.770
Driving range	.053	.010	.884
Rebates/incentives	.788	.130	.242
Free parking	.744	-.097	.190

Table 3 shows regression results, testing H1, H2 and H3. As shown in Table 3 (a) and (b), respectively, the three independent variables explain nearly 25% of the variance in purchase intentions (adjusted R-square = .23) and overall fit between the data and model is significant (F = 6.597; p-value = .001). Table 3 (a) also presents evidence indicating there are no issues of autocorrelation in the regression residuals, since the Durbin-Watson statistic is near 2.0. Table 3 (c) includes collinearity statistics (VIFs near 1.0) that suggest an absence of multi-collinearity among the independent variables.

Table 3. Regression of intentions on eco-concern, experience and vehicle features

(a) Model Summmary

R	R-Square	Adjusted R-Square	Std. Error of the Estimate	Durbin-Watson
.521	.272	.231	1.048	1.909

(b) ANOVA Results

	Sum of Squares	d.f.	Mean Square	F	p-value
Regression	21.723	3	7.241	6.597	.001
Residual	58.172	53	1.098		
Total	79.895	56			

(c) Coefficient Estimates

Independent variable	Std. Beta	t	p-value	VIF
Eco-concern (H1)	.340	2.878	.003	1.018
Experience (H2)	.305	2.544	.007	1.044
Economics (H3)	.374	3.093	.002	1.062

H1 is supported by the data, i.e. environmental concern is significantly and positively related to PHEV purchase intentions. The t-statistic (2.878; p-value = .003, for a one-tail test) is significant at the .01 level of alpha. This result aligns with the findings of other recent studies (e.g. Krause et al. 2016). H2 tests the influence of experience with PHEVs on purchase intentions. As shown in Table 3 (c), this hypothesis is also supported – purchase intentions increase with EV experience (t = 2.544; p-value = .007). This result confirms prior findings as well (e.g. Skippon et al. 2016).

Recall that the nine vehicle features were reduced to three factors using principal components analysis. These three factors were interpreted as economic, environmental and convenience influencers of PHEV perceptions. The environmental and convenience factors were found to be insignificant as predictors of purchase intentions. Thus, they are not present in the final regression model. Only the economic factor (component 1 in Table 2) remains in the regression equation, having significant influence on purchase intentions (t = 3.093; p-value = .002), providing support for H3. Economic variables appear to trump the influence of energy conservation, emission reduction and convenience, as Winnipeg drivers form PHEV purchase intentions. This result aligns with Krupa et al. (2014): i.e. financial benefits are more important than environmental benefits.

Conclusion

In summary, the regression analysis revealed that environmental concern, experience and economic factors (the "3 Es") are all significant predictors of PHEV purchase intentions. Consumers expressing greater concern about the environment, having more experience with PHEVs and perceiving stronger influence of economic factors (e.g. car price and operating costs) have higher intentions to purchase. Though economic features of the vehicles appear to trump convenience and environmental features, overall environmental concern is an important predictor of intentions.

This study also found an interesting relationship between household income and environmental concern. Both high income (4.00/5) and low income (4.06/5) participants expressed lower environmental concern compared to middle income (4.58/5) participants. Potoglou and Kanaroglou (2007) report a similar result – medium income buyers were more likely to select hybrids over conventional vehicles. Perhaps the low income earners are too busy "making ends meet" and high income earners are too busy making money to have high environmental concern. Future research should investigate reasons for this apparent nonlinear income/environmental concern phenomenon.

There are some limitations to this study. Similar to other EV studies, the sample may not represent the population (of Winnipeg, in this case), in terms of age, gender, education and income. In future research, more people across age and income groups should be surveyed. A special effort for a balanced sample of female and male car buyers is also needed. Further, the results may not be generalizable to other cities in Canada. Data could be collected from folks in Calgary, Montreal, Toronto, Vancouver, etc. All of these jurisdictions differ in terms of government incentives offered, winter temperatures, electricity generation methods, average household incomes, etc.

Practical implications

Practical implications follow from the significance of the "3 Es." Government agencies and auto makers are advised to educate consumers about environmental issues, such as emissions; create opportunities for people to test-drive or otherwise experience EVs; and focus on economic variables in designing, making and promoting these vehicles.

Provincial and municipal governments could consider offering EV owners cash rebates or tax breaks and free parking, respectively. Further, consumers should be encouraged and educated to view car purchase and use from a total cost of ownership (TCO) perspective (Drive Electric Manitoba 2013; Dumortier et al. 2015; Letmathe and Suares 2017) rather than focusing largely on purchase price.

The federal and provincial governments have an important role in raising general public awareness about climate change, GHG emissions, and other environmental issues. Government agencies and auto makers should disseminate information about environmental issues, as well as the ability of PHEVs to reduce fuel consumption, emissions, noise levels, etc. Consumer education about the environment and alternative cars (in terms of economic and environmental impact) can start in the public schools. Folks should start to understand the facts long before they become car buyers and drivers.

Finally, financial incentives might be offered to facilitate EV adoption. As noted above, from November 2006 to October 2010, Manitoba offered a $2,000 rebate for the purchase of certain EVs (Antweiler and Gulati 2013). Unlike other provinces (British Columbia, Ontario and Quebec), Manitoba currently offers no such financial incentives. The Government of Manitoba, which generates low-cost electricity from renewable sources, is advised to consider resurrecting rebates to reduce effective PHEV purchase price.

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