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Effect of socio-economic factors on EV/HEV/PHEV adoption rate in Ontario

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ABSTRACT

As a response to the threat of pollution and greenhouse gas emissions, Alternative Fuel Vehicles (AFVs), namely, Electric Vehicles (EVs), Hybrid Electric Vehicles (HEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) have been invented. The purpose of this study is to analyze the impact of socio-economic factors on AFV adoption rates in Ontario between the years 2012 to 2050. This paper focuses on analyzing EV, HEV and PHEV popularity in Ontario and discusses various socio-economic factors affecting adoption rates. The number of light duty vehicles sold in the future is initially forecasted. In the next step, a penetration function is developed which consists of two parts; the diffusion rate and the socio-economic factors. Three general scenarios are considered when deploying the penetration function. Each scenario presents the weight assigned to the diffusion rate and the socio-economic factors. The socio-economic section is developed by using the historical trend of the all-in costs of vehicles over the time period of years 1996–2012. Vehicles' all-in costs depend on drivers' age, gender, location, monthly insurance, daily driving distance, and traffic, in addition to production year, make, model, trim, body and transmission of vehicles. In this study, aggressive, average and mild all-in costs are studied for the adoption rates for male and female drivers separately. Overall, our results indicate that EV, HEV and PHEV adoption will increase substantially in the future, comprising of approximately 30%–38% (dependent on the considered scenario) of the total conventional vehicles sold by 2050.

1. Introduction

The transportation sector contributes approximately 25% to greenhouse gas (GHG) emissions in Canada as published by Canada's action on climate change website. As a response, Electric Vehicles (EVs), which operate solely on electricity have penetrated the automobile market (Zhang et al., 2013). Hybrid Electric Vehicles (HEVs) are also another type of low emission vehicles that comprise of two or more power sources (Emadi et al., 2008). Plug-in HEVs (PHEVs) include battery packs of high density, which allow them to run longer than the HEVs and could also be recharged via cable plug-ins (Emadi et al., 2008). For drivers who need more range coverage of up to 500 km occasionally, Extended Range Electric Vehicles (EREVs) are perfectly suited. This class of vehicles run on their internal combustion engines when the battery is depleted and is close to reaching a state of minimum charge, in order to recharge it (Eberle and von Helmolt, 2010; Tuttle and Baldick, 2012). According to Table 1, HEVs are much more popular than EVs in

Abbreviations: AFVs, Alternative Fuel Vehicles; AIC, all in cost; EDU, number of graduated students; EMP, number of people employed; INC, income; LRMs, linear regression models; NLRMs, non-linear regression models; POP, population size; PwC, PricewaterhouseCoopers firm; VEH, light duty vehicles.

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Table 1
Number of EV and HEV units sold in Canada (2005–2009).

Year	2005		2006		2007		2008		2009	
Vehicle type	EVs	HEVs	EVs	HEVs	EVs	HEVs	EVs	HEVs	EVs	HEVs
Units sold	11	6053	18	13,253	21	25,783	29	45,703	41	59,541

Canada (Walwijk, 2009; Abkemeier, 2012). The main reason for this is likely due to the range anxiety concerns of consumers regarding EV adoption (Daziano, 2013).

GoodCarBadCar auto sales data sources present the sales of a number of the more popular models of EVs and HEVs over the recent years as indicated in Table 2. Nissan Leaf has the most sales (645 units) as a popular EV brand in Canada, since it is the first all-electric car built in large quantities with an affordable price, besides I-Miev sold 300 units. Among HEVs, Prius V stands out, mainly because of its high fuel efficiency of 4.5 L/100 km which is mentioned on the official Toyota website. As for PHEVs, several automobile manufacturers have started producing them commercially in 2010 (Ahmadi et al., 2012) with the Toyota Prius Hybrid having the most sales in Canada at 193 units from Sept 2012 to May 2013. As for EREVs, the Chevrolet Volt has higher sales than others. In Ontario, considering the fact that the government is supporting EV and PHEV adoption by giving incentives of up to $8500 to their customers, and also because the Ontario Ministry of Transportation is envisioning a future with 1 out of every 20 vehicles on Ontario roads being electric vehicles, EVs and PHEVs will have a significant increase in popularity in the near future (Ministry of Transportation). This study focuses on analyzing EV, HEV and PHEV adoption rate through various socio-economic factors in Ontario from the years 2012 to 2050.

Estimating the adoption of technological innovations has been the subject of academic and practical interest since the 1960s (Eggers and Eggers, 2011). Factors that influence adoption rates include the risk the consumer believes he/she might be taking, the methods of the innovator's marketing and the innovation's cultural effects (Eggers and Eggers, 2011). For the purpose of this paper, the innovation of EVs, HEVs and PHEVs is the subject of interest. Studies have confirmed that economic factors such as the costs of vehicle purchase, its fuel and electricity consumption, and external factors such as government incentives affect the Alternative Fuel Vehicle (AFV) adoption rate. In addition, the households and target group of AFVs' characteristics such as their age, income level and their environmental consciousness, plus vehicle attributes also affect the adoption rate (Eggers and Eggers, 2011; Musti and Kochelman, 2011). Although AFVs reduce dependence on fossil fuels, which decreases GHG emissions, there are still barriers preventing these innovations from being adopted on a large scale (Egbue and Long, 2012). These challenges include the consumers' tendency to resist adopting new unknown technologies and therefore federal policy decisions addressing their concerns have major impacts. The economical factor of cost was presented to be ranked ahead of the sustainability and environmental factors when it came to adopting EVs, HEVs and PHEVs (Egbue and Long, 2012; Tran et al., 2013).

Forecasting AFV penetration is more complicated than the usual market forecasts due to various reasons. The first reason is that EVs and PHEVs have only been introduced into the market in recent years, and not enough sales data are available for study. Another reason is that to adopt EVs and PHEVs, a behavioral change in the consumers would be required. This includes refueling their vehicle at a gas station and/or charging by plugging it in. Only a few studies have attempted to investigate the extent to which consumers are willing to accept these changes. Furthermore, the change in fuel type creates controversy regarding the use of past CV and HEV sales data (Al Alawi and Bradley, 2013).

Yabe et al. (2012) forecasted the rate of EV/PHEV market penetration. Factors such as battery learning curves, geographic distribution of daily travel distances and an optimal power generation planning model for charging electric vehicles were used to determine the rate. Their forecast indicates that only a quarter of the vehicles shares in 2050 will be EV/PHEV in Japan. This market share forecast is sensitive to battery development and initial prices of vehicles. Wu et al. (2012) explored regional growth patterns of light-duty passenger vehicles in three developed areas in China. In addition, several scenarios for the penetration of HEV, PHEV and EV were developed for the 2010–2030 time period. Socio-demographic characteristics of AFVs were employed to evaluate proper type of AFVs for a specific region. It was found that HEV penetration reduced carbon emissions more in coal electricity producing intensive regions, while PHEV and EV were better suited for regions with cleaner electricity production methods.

Ahmadi et al. (2012) studied PHEV penetration and its impact on Ontario's Electricity Grid. For this purpose, both linear and non-linear (LRMs, NLRMs) long-term regression models of electricity load demands were forecasted for the years 2012–2030. For the forecasting models various variables in the climate, economic, and demographic sectors were considered and the number of PHEVs was calculated based on different penetration levels. Richardson (2013) reviewed current literature on different types of EVs, the electric grid

Table 2
Units of HEVs sold in Canada.

	Hybrid Electric Vehicles				
Vehicle Brand	Ford C-max Hybrid (Sep 2012–May 2013)	Honda CR-Z (Aug 2010–May 2013)	Honda Insight (Jan 2010–May 2013)	Toyota Prius C (Jan 2010–May 2013)	Toyota Prius V (Oct 2011–May 2013)
Units sold	883	1104	2299	3658	5717