

The Trade Bias of Tax Rebates for Hybrid Vehicles *

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Abstract

In 2005 over 83% over all Canadian HEV sales were vehicles made in Japan. Are tax rebates supporting Hybrid Electric Vehicles (HEVs) implicit support for foreign over domestic car manufacturers? In this paper we estimate the international trade impact of Canadian HEV rebates. We find that these rebates have a differential impact on HEV sales depending on country of assembly, and shift consumers away from American passenger vehicles and European light trucks and vans. We also find that producers extracted between fourteen and thirty-seven percent of the HEV subsidies via higher transaction prices.

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1 Introduction

Concern over global warming and energy security has led governments in Canada and the United States of America to introduce incentives encouraging the sale of Hybrid Electric Vehicles (HEVs). In the year 2000, the province of British Columbia was the first in Canada to offer a provincial sales tax rebate to support the sale of HEVs. By 2006, five additional provinces had implemented similar sales tax or cash rebates. In 2007, the Canadian federal government announced a two year eco-auto program encouraging the sales of fuel efficient and alternative fuel cars through cash rebates.

Canada is not alone in subsidizing HEV purchases. The US federal government introduced personal income tax credits for HEVs in the year 2005 and by the year 2007, thirteen state governments had implemented tax incentives for their purchase. Additionally in the USA, several state and local governments offer benefits such as unrestricted access to high occupancy lanes, free parking, reduced registration fees and exemptions from emission testing. This widespread support indicates that North American governments believe hybrid technology to be an important component in their efforts to reduce fuel use in transportation.

Hybrid electric vehicles are supplied predominately by overseas firms. For example, in 2005 over 83% of all HEV sales in Canada and over 91% of all HEV sales in the US were produced by Japanese manufacturers. In the same year, Ford was the only domestic manufacturer producing a HEV, and this too was built on technology licensed from Toyota. The fact that the HEV market is dominated by foreign firms raises concerns that North American HEV subsidies favour foreign-manufactured vehicles, shifting market share away from domestic autos. Concerns such as this led the US federal government to introduce a phase out period for its personal income tax credits. These credits were to be phased out by manufacturer when its HEV sales exceeded 60,000 units (see Lazzari 2006 and Leonhardt 2006).

In this paper we ask several related questions. Did Canadian HEV subsidies raise or lower Japan's share of the Canadian HEV market? Did those subsidies raise or lower Japan's share of the Canadian market for passenger vehicles in general? Who ultimately gained from the subsidies; specifically, by how much did HEV subsidies raise producer prices and lower net consumer prices?

As indicated, we examine the impacts of HEV subsidies on both HEVs and non-HEVs. This is

important for assessing the impact of HEVs on the auto market as a whole, as well as for assessing trade impacts. The most popular HEVs are from Japan. Yet HEV subsidies need not promote imports at the expense of domestic makes. Subsidies to HEV purchases will induce some new buyers to the automarket, but its main effects are to induce consumers to substitute HEVs for conventional vehicles. If, for example, HEV subsidies induce buyers to substitute away from *Japanese* non-HEVs, then Japan's share of the Canadian auto market may stay the same or even fall. One of the goals of this paper is to test the net impact of HEV subsidies on net imports in the passenger vehicle market as a whole.

We build a two period model of an oligopolistic auto market and ask how subsidies to a subset of vehicles—HEVs—affect market share and consumer and producer prices for HEVs and non-HEVs. We begin by analyzing the response of a single firm to a rebate. We consider a series of scenarios. In the first, the firm produces an established good. In the latter scenarios, the product is nascent and there are intertemporal spillovers from the first to second period both in terms of reduced search costs as in Sallee (2008) and network effects. We show that, in its high cost period, the producer of a good may choose to price units at below cost so as to reap network benefits from product adoption and to position the good in a comparable product class. This model is useful in that it can explain several stylized facts of HEV markets, namely, waitlists and negative profits. If first period sales are sufficiently costly, the producer may choose to operate off its demand curve, voluntarily creating waitlists, even in the absence of capacity constraints.

We then consider a variant of the model in which the firm has multiple competitors, producing, alternately, HEVs and non-HEVs. We conduct a comparative static analysis to show that a first-period rebate to HEVs shifts market share away from non-HEVs and lowers net consumer prices for HEVs, but has an ambiguous effect on seller prices. Our model generates some stark empirical predictions that we take to the data.

We test our hypotheses using fleet and transaction level data from Canadian provinces in the last decade. Provincial rebates for HEV purchases in Canada are an excellent subject for analysis. Provincial governments offered rebates of different values at different times, and often varied the value of the rebate offered during the period we analyze. In addition, as most rebates (except in one

province) are a reduction or a waiver of the provincial sales tax, they also vary across HEV models within a given year.

The primary data we use is vehicle purchase and lease data by model, year and province in Canada from 1989 to 2006. We also use data on the characteristics of models and of provinces. Due to the richness of the data, and the wide variation in rebate programs both temporally and cross-sectionally, we are able to use straightforward estimation techniques without imposing strong assumptions or unnecessary structure on the data generating process. Identification is achieved by comparing a model's share of sales over time within the same province, as well as across provinces, while varying the presence and amount of rebates. We control for model characteristics that are time-invariant, province level preferences for vehicle segments, as well as time-varying preferences for vehicle segments.

The share of hybrid vehicles in total light vehicle sales in Canada for 2005 was 0.35%. Our preliminary results indicate that a \$1000 increase in the provincial sales tax rebate increases the market share of hybrid passenger made in North America by approximately 53% and that of hybrid cars made in Japan by 23%. We also find that the increased sales of HEVs crowded out cars made in the US and Sweden and light trucks and vans made in Germany, Japan and the UK. Sales of conventional vehicles assembled in other countries were unaffected by the rebate.

We also examine the effects of HEV subsidies on transaction and net consumer prices. We use a sample of transaction level data that covers 20% of new vehicle sales in Canada from May 1st, 2004 until April 15th, 2009. The data comes from JD Power's Power Information Network (PIN), and includes variables such as transaction price, vehicle cost, finance, lease, and trade-in measures.

Through this paper we present a comprehensive analysis of the international trade impacts of provincial rebates for purchasing HEVs in Canada. Compared to other papers studying the impact of rebates to HEVs (as discussed in Section 2 below), we have two main advantages. First, our data spans the entire automobile market and not just sales of HEVs. Second, our policy variable varies across province, time and make and model of HEV. This allows us to estimate the origin of cars crowded out by the rebate. Our analysis thus offers useful insights into the international trade impacts of HEV rebates, an important consideration for policymakers in Canada and the United States. who

are looking to maintain, expand or implement such programs in the future.¹

2 Related Research

There have been a number of recent studies analyzing the impact of government incentives on HEV sales. Diamond (2008) uses monthly US state registration data for HEVs to evaluate the relative impact of state incentives and gasoline prices on HEV adoption. He finds that while gasoline prices have a very strong relationship with hybrid vehicle adoption, government incentives have a weaker link. Gallagher and Muehlegger (2008) also use quarterly sales data on HEV models for US states to study the relative effect of tax incentives, gasoline prices, social preferences and other non-monetary incentives (for example, preferential access to high occupancy lanes and parking etc.). The authors attribute 6% of existing hybrid sales to tax incentive schemes, approximately 33% to personal (social) preferences, and 27% to rising gas prices. They report that sales tax incentives have a much greater effect on the demand for hybrid vehicles than income tax incentives and find that single-occupancy HOV access is correlated with substantial hybrid adoption in the state of Virginia, but not in other states. Sallee (2008) studies the incidence of state and federal tax incentives offered to Toyota Prius owners. He finds that a majority of state and federal tax incentives are captured by consumers, rather than producers. This is despite the fact that the Prius market was characterized by excess demand. Similar to the papers above, one of our aims is to evaluate the impact of tax rebates on HEV purchases. However, there is also a very important difference; in our paper we include data on the sales of cars other than hybrids. Thus, in addition to estimating the increase in hybrid vehicle sales from tax rebates, we can also estimate the origin of vehicles crowded out due to these rebates. This allows us to understand the international trade impact of these rebates, something the above papers do not attempt to estimate.

There are other papers studying HEVs and the reasons (besides government incentives) behind their adoption. For example, Kahn (2007) evaluates the effect of ideology on HEV adoption in

¹As the Canadian and US automobile markets are fairly well integrated we believe that the results from this study are relevant for policymakers both in the US and Canada. The integration of both markets is due in part to similar consumer preferences and available products, but also due to the Canada-United States Auto Pact of 1965 (see http://www.canadianeconomy.gc.ca/English/economy/1965canada_us_auto_pact.html, accessed on January 23rd, 2009, for more information).

the state of California. Using data on a community’s share of green party voters as a proxy for community environmentalism, Kahn concludes that environmentalists are more likely to purchase HEVs than non-environmentalists. In a project for the California Department of Transportation, Cao and Mokhtarian (2004) determine the factors that could influence the future demand for alternative fuel vehicles (including HEVs) and find gasoline prices to be a very significant factor (see Diamond, 2008, for a comprehensive list of articles studying HEVs).

3 Model—Single Firm

We begin our analysis by looking at the pricing and sales choices of a single firm selling its product over two periods. Throughout the paper we will use uppercase to denote first period values and lowercase to denote those for the second period. For example, let Q and P indicate quantities sold and prices received by the seller in the first period. C measures marginal production costs; first-period profits are thus $Q[P - C]$, while $q[p - c]$ measures second period profits. We allow C and c to differ. Demands are isoelastic in the current price of the good: $D = \tilde{P}^{-\epsilon}AB$ and $d = \tilde{p}^{-\mu}ab$ where $\epsilon > 1$ $\mu > 1$ are both constants and $\tilde{P} = P - S$, $\tilde{p} = p - s$ are consumer prices, where S and s are first and second period rebates. The variables B and b will be used in Section 4 when we introduce competing firms. For now we’ll treat B and b as exogenous to the firm.

We assume A is a constant while a is endogenous, reflecting intertemporal spillovers from the first to second period. When a new vehicle type—HEVs—are introduced into the market, we expect there will be two types of intertemporal spillovers. For one, there are likely to be network effects. The more drivers there are in the first period who have a positive experience with a new model, the more favourable the word of mouth regarding that product.² Similarly, the more units sold, the more experience mechanics will have working with that model, lowering expected costs of maintaining cars of that model in future periods. We account for network effects by allowing a to be a non-decreasing function of Q .

There may also be search costs affecting demand. As argued in Sallee (2008), buying a car involves

²Heutel and Muehlegger (2009) estimate the extent to which hybrid diffusion impacts new hybrid purchases, finding a positive diffusion elasticity of between 0.4 and 0.8 for the Prius and a small *negative* diffusion effect for the Honda Insight (with elasticities of -0.06 to -0.03).

many steps, including reading product reviews, test driving the vehicle, and negotiating a transaction price with a dealer. Accordingly, most potential buyers fully investigate only a few brands and makes when considering a new car purchase. If, for example, a new make carries a high base³ price during its introduction period, reviewing agencies are likely to compare the vehicle to others similarly priced, notably those in the Luxury class. For most HEVs, this comparison would be unfavourable, as they offer fuel economy but not many Luxury attributes. As a consequence, a high first-period seller's price is likely to dampen a new model's demand in the second period *holding constant the model's second period price*. To allow for this sort of search cost, we assume a is non-increasing in P .

To be concrete, we assume a takes the following form:

$$a(P, Q) = \alpha(P) - \beta Q^{-v} \tag{1}$$

with $\alpha' \leq 0 \leq \alpha''$ and $\beta > 0 < v$.⁴ Notably, we don't model learning by doing. Our model could easily accommodate learning by doing by allowing c to be a decreasing function of Q , and this spillover would act similar to the network effect, giving the firm an incentive to sell units in the first period at below marginal cost (or, more accurately, at below marginal cost + markup). Instead, we assume that c is exogenous and sufficiently below C such that second period sales are profitable.

3.1 Pricing Decisions

The firm chooses prices and quantities to maximize $\pi \equiv Q[P - C] + \delta q[p - c]$ subject to demand, where $\delta \leq 1$ is the discount factor. We solve this as a two-period problem for the firm, deciding first what price it'll charge in the second period, and then choosing first period price and quantity.

In the second period, the firm solves

$$\max_{p,q} q[p - c] \quad \text{s.t. } q \leq d.$$

³For our theoretical analysis we abstract from detailing options, delivery, and other charges that raise the pre-tax/rebate price faced by consumers. We will commonly refer to this price as the "seller's" price.

⁴When the good is durable, first period sales may instead impede second period demand. This possibility is standard textbook fare and we don't consider it further.

We assume c is sufficiently low and so each firm prefers to operate than shut down and so the constraint $q \leq d$ binds. Substituting in for q using the constraint, differentiating with respect to p , setting equal to zero and rearranging gives the standard markup rule:

$$\frac{1}{\mu} - \frac{p-c}{\tilde{p}} = 0. \quad (2)$$

As is commonly the case when demand is isoelastic, the firm's second period price is independent of the scalar terms a and b . We can thus write the firm's second period profit as $a(P, Q)g$ where $g \equiv \tilde{p}^{-\sigma} b [p - c]$ is independent of first period choices.

In the first period, the firm solves

$$\max_{P, Q} Q[P - C] + \delta a(P, Q)g \quad \text{s.t. } Q \leq D$$

taking the arguments of g as independent of its first period choices.

Suppose the firm chooses to operate along its demand curve. Substituting in for D , the first order condition for an interior optimum is

$$\frac{d\pi}{dP} = \underbrace{\left[\frac{1}{\epsilon} - \frac{P-C}{\tilde{P}} \right]}_{\text{markup gap}} \underbrace{\epsilon \tilde{P}^{-\epsilon} AB}_{=Q} + \delta g \underbrace{\left[\alpha' - \beta [AB]^{-v} \epsilon v \tilde{P}^{\epsilon v - 1} \right]}_{\text{intertemporal spillovers} \geq 0} = 0. \quad (3)$$

As per the rightmost term, raising P lowers second-period demand, both directly and indirectly by reducing the network of the firm's goods in use. Cognizant of these spillovers, the firm will sacrifice first period profits and set P below that proscribed by the standard markup rule. Of course, for established firms that don't experience any intertemporal spillovers—i.e. for whom $\alpha' = 0 = b$, the firm chooses P such that $\frac{1}{\epsilon} - \frac{P-C}{\tilde{P}} = 0$.

Differentiating $\frac{\partial \pi}{\partial P}$ with respect to P gives

$$\frac{\partial^2 \pi}{\partial P^2} = -\frac{Q\epsilon}{P-S} \left[\underbrace{1 - \epsilon \frac{P-C}{\tilde{P}}}_{(+)\text{ by FOC}} + \frac{C-S}{\tilde{P}} \right] + \delta g \left[\alpha'' - \beta \epsilon v [\epsilon v - 1] \tilde{P}^{\epsilon v - 2} A^v B^v \right] \equiv \Delta. \quad (4)$$

A sufficient condition for the second order condition for an interior optimum to hold locally is $v > 1/\epsilon$, something we assume from here onward.

3.1.1 Operating Off the Demand Curve

The prospect of network externalities and other intertemporal spillovers may lead a firm to choose a low first period price. With this will come high first period demand. Whether the firm wants to satisfy this demand depends on whether it is actually covering its costs.

Suppose, for example, that C is sufficiently high that, at the P satisfying equation (3), π_1 is negative: the firm is pricing below marginal cost. This is plausible if the intertemporal spillovers and potential second period profits are sufficiently large—which requires in turn that second period costs are low enough to render operations profitable. In this case, the firm may prefer to move off its demand curve, offering fewer units for sale than is demanded at the seller’s price. Specifically, if the solution to the unconstrained optimization problem

$$\max_{P,Q} Q[P - C] + \delta a(P, Q)g \quad \text{s.t. } Q \leq D_1$$

does not violate the demand constraint, then the firm will choose Q and P jointly satisfying

$$Q = \delta g \alpha'(P) \quad \text{and} \tag{5}$$

$$P - C = -\delta g \beta v Q^{-[v+1]} \tag{6}$$

and there will be excess first-period demand at the firm’s chosen price.

What we see is that the firm is willing to sell some units at a loss in the first period if there are positive network effects in the second. (If instead b or v were zero, the firm would elect an arbitrarily low first-period price but sell zero units.) The firm may choose to constrain the number of units sold, though, if the marginal network payoff is small relative to per unit losses. In this case, the firm chooses to price first-period goods at below their market clearing price, losing money on each unit that it actually does sell. This can occur without capacity constraints. From the firm’s perspective,

waitlists can be completely voluntary.⁵

3.2 Consumption Subsidies

Governments at all levels have offered rebates (in the form of rebates and tax exemptions) to consumers of HEVs in the early days of their introduction. In this section we analyze how a change in the first period subsidy affects equilibrium price and quantity.

A change in S has no effect on the price charged in the second period and g is unchanged. How the subsidy affects first-period prices—consumers’ and the producer’s—and quantities consumed depends both on the strength of the intertemporal spillovers and on whether the firm is on or off the demand curve.

Consider the case where the firm is off its first period demand curve. In this case, Q and P are jointly defined by equations (5) and (6) which are independent of the consumer’s price. That is, the firm does not extract any of the subsidy rents, leaving the seller’s price and quantity sold unchanged. In this setting, the subsidy is a pure transfer to consumer’s lucky enough to obtain the undersupplied good.

Next consider the case where the firm is operating on its demand curve (either at a first period profit or loss). Partially differentiating (3) with respect to S and making use of the envelope theorem, we can write

$$\frac{dP}{dS} = \frac{-\epsilon Q \left[\frac{P-C}{P-S} \right] + \left[\frac{1}{\epsilon} - \frac{P-C}{P-S} \right] \epsilon^2 Q + \delta g [\epsilon v - 1] \beta \epsilon v [P - S]^{\epsilon v - 1} A^v B^v}{-[P - S] \Delta}, \quad (7)$$

where $\Delta < 0$ as noted in (4). When there are intertemporal spillovers, the subsidy impacts the firm’s pricing strategy on three dimensions. To begin with, the subsidy raises the quantity sold, which raises the opportunity cost of underpricing first-period output and argues for a higher price. The increase in current sales also walks the firm up its (concave) network curve, lowering the marginal return from additional first-period sales, again arguing for a higher P . Finally, the subsidy effectively reduces the

⁵This result has an interesting policy implication. In Sallee’s (2008) setting with capacity constrained firms, subsidizing producers directly would not have affected first period sales. In our setting, it would reduce first-period loss margins, inducing more supply.

firm's costs of delivering the product to consumers, and the firm has an incentive to adjust the price it charges accordingly. If the firm is initially losing money (i.e. $P < C$), this adjustment also argues for a higher P , and we see that a subsidy unambiguously raises the seller's price.

However, if instead the firm is initially covering its first period costs, the markup readjustment argues in favour of a *lower* seller's price, and it is possible that the firm responds to a rebate by charging a lower seller's price.

This result—that a firm may respond to a rebate by lowering its seller's price—isn't an obscure possibility. Indeed, if there are no intertemporal spillovers then, when demand is isoelastic, the firm will lower its price unambiguously. The logic is simple. Firms with market power set base prices so that consumer prices equal marginal cost multiplied by 1 plus a markup rate. If the firm's implicit cost of delivering the good to consumers falls, it behooves the firm to reduce the price faced by consumers, dropping it by both the reduction in costs *plus the associated markup*. In our setting—in which the consumers price is the seller's price less the subsidy—we would thus expect to see $P - S$ fall by more than the change in S . That is, we'd expect P to fall too.

To be clear, this unambiguous prediction—that the firm will lower its seller's price if there are no intertemporal spillovers—is not general. It depends in part on the isoelastic nature of demand. If, for example, the demand elasticity was instead endogenous then the rise in Q would alter the markup rule as well, possibly arguing in favour of a higher price.⁶

The lesson we should draw from this is that there is no reason to expect that a firm with market power will try to extract rebates by raising seller's prices. Indeed, it may well be that a monopolist wants to lower its price, even when there are no intertemporal spillovers.

What should be clear, though, is that a consumption subsidy will lower consumer prices, raising quantity demanded/supplied *if the firm is operating along its demand curve*: differentiating $P - S$ with respect to S using (7) gives

$$\frac{d\tilde{P}}{dS} = \frac{dP - S}{dS} = \frac{dP}{dS} - 1 = \frac{\delta g\alpha'' - \frac{\epsilon_Q}{P-S}}{-\Delta} < 0 \quad (8)$$

⁶Indeed, when demand is linear, the change in the elasticity dominates and subsidies raise seller's prices.

while

$$\frac{dQ}{dS} = \frac{dQ}{d[P-S]} \frac{d[P-S]}{dS} = \frac{\epsilon Q}{P-S} \frac{\delta g \alpha'' - \frac{\epsilon Q}{P-S}}{\Delta} > 0. \quad (9)$$

As noted earlier, if instead the firm is operating off its demand curve, a first period subsidy has no effect on either the first period seller's price nor quantity sold.

4 Multiple Firms

Canadian governments offer a series of rebates and tax exemptions for hybrid electric vehicles (HEVs). In this section we assess how these subsidies are likely to impact sales and prices of HEVs and conventional vehicles. We take as starting point the model from the previous section, assuming now that there are two firms, J and N (mnemonics for Japan and North America), that produce HEVs, and a third firm, E —a mnemonic for Europe—, which produces a conventional vehicle. As before, we denote first period values using uppercase letters and second period with lowercase; let subscripts denote firm-specific variables. Because HEVs were quite new to the market, we assume HEVs are subject to the intertemporal spillovers described above, while the non-HEV has no spillovers.⁷

There is consensus that Toyota and other HEV producers were losing money on its Prius initially⁸, and that there were waitlists for the Prius both in Canada and the United States.⁹ In contrast, there is little evidence of waitlists for North American HEVs such as the Ford Focus. Accordingly, we will analyze the model with the maintained assumption that N is operating on its demand curve while J is off.

Following the previous section's model, we assume the demand facing firm i is isoelastic in its own price, and decreasing in the consumer price of its competitors *if there are no waitlists for the competitor's product*; if instead a competing product is waitlisted, demand is decreasing in the quantity of the competing good available. Specifically, we assume $B_J = B_J(P_N, P_E)$, $B_N(P_E, Q_J)$, $B_E(P_N, Q_J)$

⁷Specifically, we assume $S_J = S_N = S > 0 = S_E = s_J = s_N = s_E$ and $\alpha'_E = 0 = b_E$.

⁸It remains an open question as to when the Prius finally became profitable. Toyota Chairman Hiroshi Okuda reportedly claimed the Prius was already profitable in 2002 (Lovins 2004, p.30, fn. 178), while the LA Times reported in 2009 that Toyota had said in 2008 "that it was finally making money on the Prius after nearly a decade producing it". (Bensinger 2009)

⁹In Canada and the US, the industry average "Days to Turn" (DTT) are 58 and 60, respectively. For the Prius, annual average DTT were as short as 12 and 3 days in each country.

with each function increasing (decreasing) in the price (quantity) of substitute goods; e.g. $\frac{\partial B_N}{\partial P_E} > 0 > \frac{\partial B_N}{\partial Q_J}$.

Given this context, we can offer the following proposition.

Proposition 1 *A marginal increase in the HEV subsidy S will*

1. *have no effect on P_J, P_E, p_J, p_N, p_E or Q_J ,*
2. *lower \tilde{P}_N but have ambiguous impact on P_N ,*
3. *raise Q_N , and*
4. *lower Q_E .*

Proof Firms J , N and E maximize the discounted profits:

$$\pi_J = Q_J[P_J - C_J] + \delta p_J^{-\sigma_J} [\alpha_J(P_J) - \beta_J Q_J^{u_J}] b_J(p_N, p_E) [p_J - c_J]$$

$$\pi_N = \tilde{P}_N^{-\epsilon_N} A_N B_N(P_E, Q_J) [P_N - C_N] + \delta p_N^{-\sigma_N} [\alpha_N(P_N) - \beta_N Q_N^{u_N}] b_N(p_E, p_J) [p_N - c_N]$$

$$\pi_E = P_E^{-\epsilon_E} A_E B_E(\tilde{P}_N, Q_J) [P_E - C_E] + \delta p_E^{-\sigma_E} a_E b_E(p_N, p_J) [p_E - c_E]$$

In the second period each firm takes the first period prices and quantities of all firms as given, and takes the second period prices of other firms as exogenous. Because demands are isoelastic in each firm's own price, each firm chooses its price according (2) (adjusted to add subscripts indexing firms); similarly, because E does not experience intertemporal spillovers, it similarly sets its first period price according to this same rule:

$$\frac{C_E}{P_E} - \frac{\epsilon_E - 1}{\epsilon_E} = 0 \tag{10}$$

J , in contrast, chooses Q_J and P_J such that it operates off its demand curve, satisfying (5) and (6) (modified to include subscript J s). Finally, N chooses P_N so as to satisfy (3) (again modified to include subscripts). Equilibrium quantities are defined by

$$Q_E = P_E^{-\epsilon_E} A_E B_E(P_N - S, Q_J) \tag{11}$$

$$Q_N = \tilde{P}_N^{-\epsilon_N} A_N B_N(P_E, Q_J) \quad (12)$$

$$q_J = p_J^{-\sigma_J} [\alpha_J(P_J) - \beta_J Q_J^{-\nu_J}] b_J(p_N, p_E) \quad (13)$$

$$q_E = p_E^{-\sigma_E} a_E b_E(p_N, p_J) \quad (14)$$

$$q_N = p_N^{-\sigma_N} [\alpha_N(P_N) - \beta_N Q_N^{-\nu_N}] b_N(p_E, p_J) \quad (15)$$

This system is block recursive, with P_E and p_J, p_N, p_E defined, respectively, by (10) and firm-specific variants of (2). P_J and Q_J are jointly defined by equations (5) and (6) and depend on p_J, p_N and p_E but not on other first period variables. Second period quantities, q_J, q_E, q_N are defined by equations (13), (14) and (15) and second period prices. Finally, P_N is defined by (3) and depends on variables P_E, Q_J, p_N, p_J, p_E .

Notably, the only equations affected by the subsidy S are (3), (11), (12) and (15). As per the recursive nature of the model, it follows that a change in S leaves equilibrium values of $p_J, p_E, p_N, P_E, P_J, Q_J, q_J, q_E$ all unaffected. Moreover, we can invoke (7), (8) and (9), confirming that a rebate lowers the consumer price of good N and raises quantity consumed; whether the seller's price for product N rises or falls with the subsidy is ambiguous. Further, invoking the chain rule we have that

$$\frac{dQ_E}{dS} = \frac{\partial Q_E}{\partial [P_N - S]} \frac{d[P_N - S]}{dS} = \underbrace{\frac{Q_E}{B_E}}_{(+)} \underbrace{\frac{\partial B_E}{\partial [P_N - S]}}_{(+)} \underbrace{\frac{d[P_N - S]}{dS}}_{(-)} < 0.$$

Q.E.D.

In sum, our model predicts that a first period subsidy to hybrid electric vehicles will raise sales of type N HEVs, have no effect on type J HEVs, and lower sales of type E non-HEVs as consumers substitute toward (relatively) cheaper, available HEVs.

If we take the model literally, and view the “subsidy” period as the first period of the model, then the offer generates the following testable hypotheses.

Empirical Prediction 1 *A subsidy to Hybrid Electric Vehicles will*

1. *Raise sales of non-waitlisted HEVs*
2. *Lower sales of non-HEVs*
3. *Have no effect on sales of waitlisted HEVs*
4. *Have no effect on price of waitlisted HEVs and non-HEVs*
5. *Have ambiguous impact on seller's price of non-waitlisted HEVs*

5 Policy Background

5.1 Hybrid Electric Vehicles

Hybrid-electric vehicles (HEVs) are a proven means to reduce fuel consumption when compared to an equivalent conventional Internal Combustion Engine (ICE) vehicle (Hermance and Sasaki, 1998). Consequently, HEVs provide environmental improvements in the use-phase (Turrentine, et al, 2006), and according to Reynolds and Kandlikar (2007) the current fleet reduces carbon emissions by an average of 6 tons per vehicle over its lifetime. Such benefits come from the use of a smaller, more efficient ICE; an electric motor that either enhances or substitutes the torque of the ICE during the drive cycle; and regenerative braking which captures dissipative energy and uses it to recharge the Nickel metal hydride battery used to power the electric motor.

Since HEVs were first introduced to the Canadian market, automotive manufacturers have offered an increasing variety of model types. While in 2000 only two models (Honda Insight and Toyota Prius) were available, in 2007 thirteen were available. Until 2004, hybrid-electric engine technology remained the exclusive domain of the smaller car segments, with most sales being captured by the Toyota Prius. Since then this technology has been extended to other segments and HEVs now extend from compact cars (Honda Civic Hybrid), to intermediate cars (the Toyota Prius and Camry) and luxury Sports Utility Vehicles (SUVs) such as the Lexus RX 400h. Hybrid SUVs are a sharply increasing segment, and in the Canadian market hybrid SUVs made up approximately 28% total hybrid sales in 2006 (see Table 1). In addition to the growing diversity of model offerings, HEV annual sales continue

Model	2000	2001	2002	2003	2004	2005	2006	2007
Chevrolet Malibu	-	-	-	-	-	-	-	0.03%
Ford Escape	-	-	-	-	7%	17%	7%	7%
Honda Accord	-	-	-	-	1%	11%	6%	2%
Honda Civic	-	-	51%	61%	8%	7%	16%	14%
Honda Insight	39%	21%	14%	2%	0.30%	0.10%	0.20%	0.03%
Lexus GS450H	-	-	-	-	-	-	2%	1%
Lexus LS 600H	-	-	-	-	-	-	-	1%
Lexus RX400H	-	-	-	-	-	15%	9%	8%
Nissan Altima	-	-	-	-	-	-	-	2%
Saturn Aura	-	-	-	-	-	-	-	0.50%
Saturn Vue	-	-	-	-	-	-	2%	4%
Toyota Camry	-	-	-	-	-	-	24%	39%
Toyota Highlander	-	-	-	-	-	12%	10%	4%
Toyota Prius	61%	79%	35%	37%	83%	37%	24%	19%
Total Hybrid Sales	426	495	513	671	2303	5124	8924	14828

Source: R. L. Polk Canada Inc.

Table 1: Shares of the HEV market in Canada

to grow both in numbers and as a proportion of the total light-duty vehicle sales. In 2000 HEV sales represented only 0.03% of total light vehicle sales in Canada; by 2006 this proportion had risen dramatically to 0.53% (from 426 cars sold in 2000 to 8924 cars sold in 2006). Toyota dominates the Hybrid market with the Prius, Camry and Lexus models capturing approximately 70% of the market share in 2006. The Toyota Camry Hybrid was the highest selling hybrid model in Canada in 2006 with approximately 24% of the market share of all hybrid vehicles sold.

5.2 Tax Rebates for Hybrid Electric Vehicles in Canada

Before the Canadian federal eco-auto program (awarding cash rebates to fuel efficient vehicles) was announced in 2007, five Canadian provinces, British Columbia (BC), Manitoba, Ontario, Prince Edward Island (PEI), and Quebec were already providing tax or cash rebates of varying amounts for hybrid vehicles (see Table 2 for more details). The province of British Columbia was the first to institute a sales tax rebate for HEVs. In August 2000, the provincial government of BC announced a 30% refund of the Provincial Sales Tax (PST) (up to a limit of \$500) for all HEVs purchased or leased. This maximum was raised to \$1000 in 2001. In 2005 the government changed the rebate to a point of sale exemption of all of the PST applicable up to a maximum of \$2,000. This rebate officially expired

on April 1st, 2011. However, as it was based on the PST, in practice it ended once the Harmonized Sales Tax (HST) was implemented on July 1st 2010. The province of Ontario instituted the next HEV sales tax rebate. All hybrid electric vehicles purchased or leased after May 10th 2001 were allowed a rebate of up to \$1000 of the Retail Sales Tax (RST). For vehicles purchased after 23rd of March, 2006, this limit was doubled to \$2000. These rebates also ended as Ontario adopted the HST on July 1st 2010. In 2004, the smaller province of Prince Edward Island instituted the most aggressive rebate. It allowed all HEVs purchased or leased after March 30, 2004 a rebate of up to \$3,000 of the paid PST. This rebate is still available currently. The province of Quebec allowed all HEVs purchased or leased after March 23, 2006 a rebate of the PST paid up to a \$1,000. This maximum limit was increased to \$2,000 on February 20, 2007. The rebate program ended on January 1st, 2009. In Manitoba, residents who purchase or lease an eligible hybrid vehicle after November 15th 2006 receive a check of \$2000 in the mail. This program is also currently in effect. The remaining five Canadian provinces do not offer tax rebates or subsidies for the purchase or lease of HEVs.

With the exception of the Manitoba program, the provincial rebates are refunds on provincial taxes paid. Thus, to calculate the dollar value of the rebate we need the sales price of the HEV sold.

We have price data from individual transactions only for years 2004-2009. Rather than restrict our attention to just these years, we instead use the base price for the HEV model in each year to calculate the value of the rebate. Consider the following assumption.

Assumption A 1 *The transacted price of the vehicle is at least as high as its base price.*

We believe this assumption is reasonable as transacted prices add delivery and destination charges and the price of options to the base price. The only complication can be from dealer incentives, as these are sometimes deducted from the price of the car at transaction. Given a high demand for most hybrid vehicles we expect dealer incentives to be smaller than delivery, destination and options charges. We then calculate the value of the rebate paid to a hybrid car model during year t (R_{mvt}) as follows:¹⁰

¹⁰For the province of BC we have to account for an exemption to an increase in the PST to a Luxury Tax given to hybrid vehicles. For vehicles that are priced between \$55,000 and \$58,000 sold in BC the formula is amended to: $rebate_{mBCt} = \min\{(PST_{BC} * BP_m), Limit_{BCt} + (Lux_{BC} - PST_{BC})BP_m\}$. The additional term added captures the loss in revenue from the exemption granted to hybrid vehicles. In our data this additional term is relevant for only one hybrid model, the Lexus RX400h sold in 2005 and 2006.

Province	Vehicle Eligibility	Rebate Amount and Timing
British Columbia Policy announced: August 2000 PST rate: 7%, with graduated increases for vehicles over \$55K.	All hybrid vehicles with regenerative braking (Cars and SUVs eligible)	30% of tax paid up to \$500 for vehicles bought before July 31st 2001. 30% of PST paid up to maximum of \$1000 after July 31st 2001. A point of sale reduction of all PST till a maximum of \$2000 after Feb. 16th 2005 Additional rebates in PST (reductions in graduated increase of PST over 7%) for hybrid vehicles over 55K (see Note 1)
Prince Edward Island Policy announced: March 2004 PST rate: 10%	All Hybrid Vehicles are eligible	All the PST paid until \$3000, for vehicles bought after March 30th 2004.
Ontario Policy announced: May 2001 PST rate: 8%	All hybrid passenger cars (with regenerative braking) eligible 2001, SUVs eligible 2002.	PST rebate up to a maximum of \$1000 for cars bought after May 10th 2001. Hybrid SUVs and trucks included June 18th, 2002. A point of sale reduction of all PST till a max of \$2000 after March 23rd, 2006.
Quebec Policy Announced: March 2000 PST: 7.875%	See Notes (2) below	All PST paid to a maximum of \$1000 for vehicles bought after March 23rd 2006 and before February 21st 2007. All PST paid to a maximum of \$2000 for vehicles bought after February 22nd 2007 and before January 1st 2009.
Manitoba Policy announced, November 15th 2006 PST rate: 7%	See Notes (3) below	Flat \$2000 rebate for all vehicles bought after November 15th 2006.

Notes:

1. People buying light vehicles which are priced greater than \$55,000 have to pay a higher PST rate. This rate increases by 1% for the first \$1,000 over \$55,000 and continues to increase by 1% for every additional \$1,000 to a maximum of 10% (for vehicles costing more than \$57,000). For hybrid vehicles the graduated increases come with an additional exemption of \$7,000 on the threshold. This implies that the PST does not increase for hybrid vehicles till their price reaches \$62,000.
2. Cars eligible for a rebate in Quebec are: 2005 & 2006 Honda Insight; 2005-2007 Toyota Prius; 2007 Toyota Camry Hybrid; 2008 Ford Escape Hybrid (two-wheel drive); 2005- 2007 Honda Civic Hybrid; 2005 Honda Accord Hybrid; 2007 Nissan Altima Hybrid
3. Cars eligible for a rebate in Manitoba are: Honda Insight; Lexus GS 450H; Lexus RX 400H; Toyota Camry Hybrid; Toyota Highlander Hybrid; Toyota Prius; Chevrolet - Silverado 1500 LS Hybrid; Ford Escape Hybrid; GMC Sierra 1500 SLE Hybrid; Honda Accord Hybrid; Honda Civic Hybrid; Saturn VUE Green Line

Table 2: Tax Rebates for Hybrid Vehicles in Canadian Provinces

$$R_{m\nu t} = \min\{\eta_{m\nu t}(PST_{\nu} * BP_{mt}), Limit_t\}, \quad (16)$$

where the subscript m denotes model, ν denotes province, and t denotes year. Variable $\eta_{\nu t}$ is the proportion of PST (provincial sales tax) returned to the consumer on purchase of the hybrid vehicle, BP denotes the base price of the model, and $Limit$ denotes the maximum PST rebate possible in that province and year (see Appendix Table A-3 for the stated limit across provinces and years).¹¹ In 2006, PEI had the highest maximum rebate per hybrid with BC being second. We also calculate the maximum rebate possible for an HEV (relative to its base price) in province v at time t ($R_{\nu t}$),

$$R_{\nu t} = \max_m \{R_{m\nu t}\}. \quad (17)$$

The tax rebates we analyze are introduced or modified in different months of the year. As our data are annual, in order to relate annual vehicle sales to rebates we need to adjust the rebate variable for the month of introduction or modification. Thus, we assign sales based weights to the rebates (both $R_{m\nu t}$ and $R_{\nu t}$) using data on the monthly distribution of light vehicle sales in Canada (obtained from Statistics Canada).¹² This monthly distribution is strikingly similar across different years with January being the lean sales month with usually only 5-6% of the year's light automotive sales and either May, or June being the peak sales month, with approximately 10-11% of yearly sales. We base our sales weights on the average monthly distribution of light vehicle sales in 2006-2007.¹³ In Table 3 we list the sales weight adjusted (for month of introduction or modification) maximum rebate for

¹¹Given Assumption 1, the rebate calculated from equation (16) is the minimum rebate earned by the HEV model m in province v at time t .

¹²For robustness we try another alternative where we assume that the rebate is in place for the entire year if it is implemented on or before the month where the median light vehicle is sold in 2006. This month is July (for both 2006 and 2007). Thus if the rebate is implemented on or before July of the year, it is valid for the entire year. However if implemented later than July we assume that there was no rebate offered that year. This only impacts Manitoba, where the median adjustment implies that we assume there is no rebate offered in 2006. Corresponding results from this specification are presented in the Appendix and are referenced after the respective table in the text.

¹³The sales weights we use are: 0.4 for BC's extension of the rebate maximum on July 31st 2001 (calculated as 60% of all automotive sales are made by the 31st of July in 2006-2007). 0.91 is the sales weight to BC's extension of the HEV rebate to CAD 2000 on February 16th 2005 (as only 9% of sales are made by the 15th of February). While BC introduced its policy in August, all HEVs sold previously were also eligible for the rebate and thus we do not have to adjust this rebate for the date of introduction. Other sales weights are: 0.66 for Ontario's policy introduced on May 10th 2001, 0.82 for the point of sale policy introduced on March 23rd, 2006. The sales weight is 0.80 for the provincial rebate introduced in PEI on March 30th 2004; is 0.82 for Quebec's rebate policy introduced in March 2006, and is 0.11 for Manitoba's policy introduced in November 2006.

Province\Year	2000	2001	2002	2003	2004	2005	2006
British Columbia	500	630	630	630	777	2000	2000
Ontario	0	1000	1000	1000	1000	1000	1817
Manitoba	0	0	0	0	0	0	226
Prince Edward Island	0	0	0	0	2388	3000	3000
Quebec	0	0	0	0	0	0	817

Source: Calculated by authors assuming that the HEVs price equals its base price.

Table 3: Sales Weighted Maximum Rebates (Canadian Dollars)

HEVs across provinces for 2000-2006 (from equation 17).¹⁴

6 Market Share — Data and Empirical Strategy

6.1 Data

The primary sales data used in our analysis are generously provided by DesRosiers Automotive Consultants Inc. The data include vehicle sales figures, by make and model, for each province, and for each year from 1989 to 2006.¹⁵ The sales data are not disaggregated within models by engine type, or drive train. Thus, if a model has a hybrid variant, its sales are not separately identified. For this reason we supplement the DesRosiers data with data on hybrid vehicle sales by make and model, for each province, and for all years provided by R. L. Polk Canada Inc. Among HEVs, the DesRosiers dataset provides sales data for the Toyota Prius and Honda Insight (which are hybrid cars with distinct model names and until 2002 were the only hybrid cars available). The dataset from Polk provide us with numbers for the Toyota Prius, the Honda Insight and all other hybrid models sold in Canada.¹⁶

The DesRosiers dataset classifies each vehicle as either a passenger car or as a light truck or van, and then each of these segments are further classified into sub-segments as defined by the Automobile Industry in Canada. Passenger Cars are classified into: Subcompact, Compact, Intermediate, Sports, Luxury Sports, Luxury High End. Light Trucks are classified into: Compact Sport Utility, Interme-

¹⁴Due to the luxury tax exemption granted for HEVs the maximum rebate possible for a HEV in the province of BC in years 2005-06 is substantially higher than the maximum limit. However, this applies only for a single luxury model the Lexus RX 400h. Thus in years 2005-06 we adjust the maximum from equation (17) to the stated maximum of \$2000 in Table 3 and in the formal analysis that follows.

¹⁵We drop three observations with negative sales numbers. As our data are dealer reported sales figures, these could be dealer adjustments of inventory with their manufacturers.

¹⁶The intersection of the two datasets also allows us to verify consistency in sales numbers across the two datasets.

Vehicle Segment	Share of Total Vehicle Sales	
	2003	2006
Passenger Cars	54.34%	53.41%
Light Trucks and Vans	45.66%	46.59%
Total Vehicle Sales	1,593,916	1,615,498

Source: Authors' Calculations.

Table 4: Market Share for Passenger Cars and Light Trucks and Vans

diate Sport Utility, Large Sport Utility, Small Pickup Truck, Large Pickup Truck, Small Van, Large Van, Luxury Sport Utility. For our analysis we utilize the larger classification where each vehicle is classified as either a passenger car or a light truck or van. In Table 4 we list the market share across the two broad categories: passenger cars, and light trucks and vans for years 2003 and 2006. The market share are relatively stable with light trucks and vans having approximately 54% of the market in both years.

To understand the international trade impacts we need to supplement the above data with information on the country of assembly for each vehicle model. This is drawn from several sources. Vehicle descriptions in Wikipedia provide a starting point, this is then verified with information from Wards automotive yearbooks, and automobile manufacturing association websites whenever possible (for example the Japanese automobile manufacturers webpage www.jama.ca provides the country of assembly for each Japanese vehicle model sold in Canada). If a model is assembled in several countries but is also produced in Canada (for example the Honda Civic) we assume that the country of assembly is Canada. Market shares for countries for two years, 2000 and 2006 are listed in Table 5. Japan and South Korea have gained significant market share in the Canadian market since 2000, while Canadian manufacturing has lost ground substantively.

We obtain fuel economy data for each model from the US Environmental Protection Agency's database available online at www.fueleconomy.gov. This database provides fuel economy indicators disaggregated for each model by engine and transmission. We aggregate the data to match our model-based sales data, and keep four statistical moments by vehicle model (minimum, maximum, mean and median) for the distribution of two fuel economy indicators (Combined MPG guide, and Unrounded Combined MPG EPA) for each model. We obtain gasoline prices, the Consumer Price

Country	Share of Total Vehicle Sales	
	2000	2006
Canada	31.4%	19.9%
Germany	2.5%	3.0%
Japan	9.0%	13.5%
Mexico	3.4%	5.2%
South Korea	3.6%	7.2%
Sweden	0.5%	0.5%
UK	0.2%	0.2%
USA	49.2%	49.6%
Rest of the World	0.2%	0.8%
Total Vehicle Sales	1,549,392	1,615,498

Source: Authors' Calculations.

Table 5: Market Share across Assembly Countries

Index (CPI) for transportation with its components including a CPI for gas prices, provincial GDP, number of families, the age distribution of population by Province, average vehicle kilometers driven for light duty vehicles (vehicles up to 4.5 tons) for each province and year, and total light vehicle sales in Canada by month and year from Statistics Canada. We obtain base prices for all HEV models from the website for Sympatico, MSN Autos (<http://en.autos.sympatico.msn.ca> - accessed September 22nd 2008). We incorporate information on model generations, which are major overhauls of the same model. For example, the first generation of the Honda Accord sold as the Honda Accord model year 1976 to 1981, and the eighth (current) generation started selling as the Honda Accord model year 2008. Our empirical specification treats different generations of the same car as different models, allowing for varying consumer preferences across model generations.¹⁷

6.2 Background for the Estimating Equation

In Figure 1 we graph the difference in the market share of the Prius Liftback (the second generation of the Prius sold in North America) in the two provinces of BC and Alberta. BC offers rebates for the purchase of hybrid vehicles while Alberta does not. We also plot the maximum rebate offered

¹⁷Information on model generations (major overhauls of the same model) were initially gathered from Wikipedia (www.wikipedia.org), and then cross-checked by using the EPA's fuel economy data (as major overhauls are associated with significant differences in fuel economy) and also cross-checked with information from Ward's Automotive Yearbooks (1989-2006) which details other model characteristics such as horsepower, dimensions, weight and price.

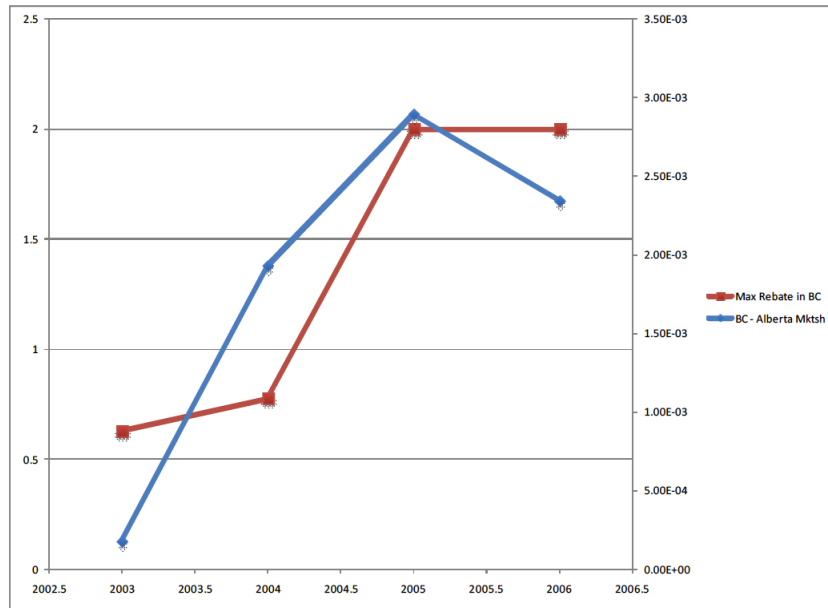


Figure 1: Relating HEV Rebates to the Market Share of Individual Models (BC Maximum Rebate measured from left axis, Ratio of Prius Marketshare in BC relative to Alberta) measured from right axis

in BC for the same time period (from Table 3). Note that this maximum rebate also corresponds to a difference in rebates between BC and Alberta. A correlation between the two series is visually apparent. The first Prius is sold in year 2003 (when BC was offering a maximum rebate of up to \$630) and the difference in market share between the two provinces rises sharply as the rebate rises after 2004. Our estimation is designed to capture the average of this relationship by vehicles produced in different countries.

HEV adoption in Canada differs across provinces. In Table 6 we illustrate the HEV market share across Canadian provinces from the year 2006. The province of PEI had the highest share of hybrid vehicles sold, with BC a close second, Manitoba third and Ontario fourth. Note all four of these provinces also provide tax rebates for purchasing hybrid vehicles. Among the rebating provinces only Quebec has a HEV market share that is lower than the national average of 0.53%.

We also find that import shares differ across different provinces. In Figure 2 we illustrate how rebating provinces seem to have a uniformly higher import share from countries other than Canada, USA and Mexico (NAFTA members). Further, imports from all non-NAFTA countries show a consistent upward trend from 2000.

Province	Passenger Cars		Light Trucks		Total Vehicle Sales	
	Sales	Market Share of Hybrids	Sales	Market Share of Hybrids	Sales	Market Share of Hybrids
Alberta	642	0.70%	362	0.20%	1004	0.40%
BC	1499	1.50%	624	0.70%	2123	1.10%
Manitoba	207	1.00%	61	0.30%	268	0.60%
Nbrunswick	94	0.50%	21	0.10%	115	0.30%
Nfoundland	28	0.20%	16	0.10%	44	0.20%
Novascotia	150	0.50%	28	0.20%	178	0.40%
Ontario	2454	0.80%	889	0.30%	3343	0.60%
PEI	51	1.70%	7	0.40%	58	1.20%
Quebec	1053	0.40%	337	0.20%	1390	0.40%
Canada	6178	0.70%	2345	0.30%	8523	0.53%

Table 6: Market Share of Hybrid Cars across Provinces (2006)

The above figure points to two potential issues relevant to our estimation. If there are reasons other than provincial rebates leading to this higher share in import shares we need to include them in our analysis. If we do not, there is a possibility of mis-attributing their effect to the provincial rebate. The second issue derives from the fact that the import market shares for HEVs increase sharply for all provinces after 2000. This is approximately the same time that HEV rebates also rose sharply across the rebating provinces. If there are factors other than provincial rebates contributing to this increase and if we do not account for them, we might mis-attribute their impact onto the rebate.

7 Empirical Specification and Results

The first question we address is whether the rebate attracted new consumers to the new car market. However, we find that the rebates had no effect on the number of new cars sold. We present evidence to this effect in Appendix A.1. In fact, per capita sales of new cars remain remarkably constant over provinces and time, with approximately 4.2% of the population buying a new vehicle each year; this percentage is unaffected by the presence and amount of rebates.

This implies that the HEV rebates only affected the choice of new cars by altering the market shares of various models. Given this information we derive the estimating equation based on the following assumptions. We assume that unobserved and observed model specific attributes (including

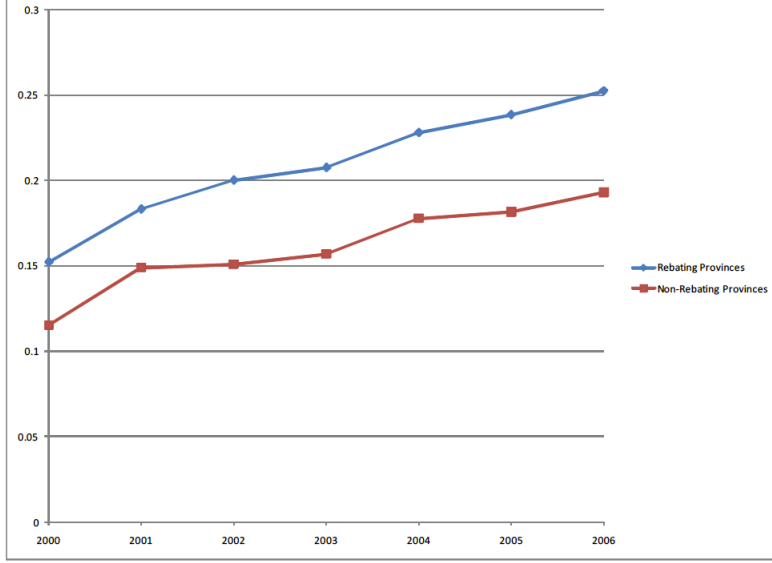


Figure 2: Average Import Shares (from non-NAFTA countries) across Rebating and Non-Rebating Provinces

the relative retail price) remain constant across a generation of a model and can thus be captured by a model*generation fixed effect. We then include province*country of assembly fixed effects to capture provincial preferences for vehicles from certain regions. Since vehicle imports from different countries usually have similar characteristics in terms of vehicle segment (luxury cars from Germany, high end sports cars from Italy), vehicles from a certain country might be appropriate for a province based due to its geography, demographics, and density etc. This allows us to control for innate unchanging preferences that might cause the share of imports to be higher in rebating provinces over non-rebating provinces. We then assume that observed attributes of passenger cars/light trucks and vans assembled in a certain country remain constant over a year. To capture this we include a country*year fixed effect. This country*year effect captures changing preferences for the set of vehicles produced in a country across different years in our data. This allows us to capture changing preferences towards imports in the most flexible manner possible.

The first estimating equation we present is the following:

$$\ln(s_{mvt}) = \beta_0 + \beta_1 R_{mvt} + \theta_m + \gamma_{vct} \quad (18)$$

where s_{mvt} is the market share of a model (m) in a province (v) in year (t). θ refers to a model

generation fixed effect and γ refers to a combination of province, country of assembly and year fixed effects. The coefficient β_1 captures the impact of the rebate on the market share of the average hybrid model in our data. For all regressions presented in the main text of this paper we employ the rebate variable adjusted for the month it was introduced or changed using a weight corresponding to the proportion of vehicles sold after that month (this is described in Section 5.2).

For this equation there are three sources of identification. The first is variation across the 10 Canadian provinces, since only a subset of provinces offered tax exemptions for hybrid vehicles over the last decade. Moreover, those that offered these exemptions started doing so at different points in time, thus creating considerable variation within any given year in the number of provinces with such programs. The second source is variation within provinces across years, due to the fact that rebating provinces have gradually increased their average maximum rebate over time. Within-province variation in the amount of rebates is considerable. The final source of identification is variation across car models within a given province and year. This is because rebates are generally a reduction in provincial sales tax, which is a percentage of the vehicle's sale price. Thus, even within any given province and year, hybrid vehicles of differing values will have different rebate amounts associated with them. This final source of identification is only employed in the regressions that use model-specific rebates, and is not available in specifications that use province-wide maximum rebates.

Our second and preferred¹⁸ estimating equation presented uses the maximum rebates offered in each province. Unlike equation 18, which estimates average impact of HEV rebates on HEV sales across five provinces offering rebates estimation using the maximum rebate offered across provinces allows us to estimate a more disaggregate impact of the rebates. We interact the maximum rebate offered (R_{vt}) with a broad classification of vehicle types (hybrid, or conventional, further classified into cars or light trucks and vans) and country of assembly (see nine countries listed in Table 5). This interaction can potentially give us 36 different coefficients for the rebate variable which would correspond to the average impact of HEV rebates by country of assembly and type of car (hybrid, or conventional, and passenger car, or light trucks and vans). For example this will give us the average impact of HEV rebates on the sales of hybrid light trucks and vans assembled in the USA. This would

¹⁸By using R_{vt} as the independent variable, we are able to test the impact of HEV subsidy programs (in general) on sales of non-HEVs.

also allow us to estimate the average impact of HEV rebates on the sales of conventional light trucks and vans assembled in the USA (and likewise for other countries).

Let R_{vt} represent the rebate maximums for province v and time t , let I_i $i = h, n$, represent indicator variables that switch on whether the vehicle is a subsidized hybrid (h), or a non-hybrid conventional vehicle (n). Let I_j , $j = r, l$ represent two indicator variables that indicate vehicle segments, for now we categorize vehicles into whether it is a passenger car (r), or a light truck and van (l), and finally let I_c be a set of indicators for the 9 countries of assembly in our data. For any one data point only one combination of the three indicator variables will have a one at the same time and thus will contribute to the estimation of the average impact of the rebates for that combination. Formally, our estimating equation is thus:

$$\ln(s_{mvt}) = \beta_0 + \sum_i \sum_j \sum_c \beta_{ijc} (R_{vt} * I_i * I_j * I_c) + \theta_m + \gamma_{vct} \quad (19)$$

where s_{mvt} is the market share of a model (m) in a province (v) in year (t). θ refers to a model generation fixed effect and γ refers to a combination of province, country of assembly and year fixed effects. The coefficient β_{ijc} captures the impact of the rebate on the market share of the vehicle model that belongs to hybrid classification i , vehicle segment classification j , and is assembled in country c . For all regressions presented in the main text of this paper we employ the rebate variable adjusted for the month it was introduced or changed using a weight corresponding to the proportion of vehicles sold after that month.

7.1 Results

Results from estimating equation 18 are presented in Table 7. The coefficient on the rebate has a positive value for the relevant hybrid model in the year and province that the rebate is offered. We run four specifications, all of which include model generation fixed effects. In addition to model generation fixed effects, the first specification only includes the rebate, the second includes country of assembly and year fixed-effects, the third includes province*country of assembly fixed-effects and the final specification includes province*country of assembly fixed-effects and country of assembly*year

Depvar: Log Market Share	(1)	(2)	(3)	(4)
Weighted Rebate by Model (\$1000)	0.39 (0.07)**	0.42 (0.07)**	0.29 (0.07)**	0.29 (0.07)**
Model-generation FEs	Yes	Yes	Yes	Yes
Country of Assembly FEs		Yes		
Year FEs		Yes	Yes	
Province-Country FEs			Yes	Yes
Country-year FEs				Yes
Constant	-6.75 (0.01)**	-6.51 (0.03)**	-6.21 (0.07)**	-6.67 (0.04)**
Observations	33778	33778	33778	33778
R-squared	0.00	0.09	0.15	0.17

Standard errors in parentheses. Superscripts * and ** denote significance at 5% and 1% respectively. Sample extent: All 9 countries of assembly, all years from 1991-2006. Model-specific rebates are weighted according to the monthly distribution of sales.

Table 7: Regression Results: Model Specific Rebates

fixed-effects.¹⁹ We find that the hybrid rebate increases the share of hybrid vehicles in a positive and significant manner in all four variations. In addition, the coefficient value remains stable, varying between 0.29 and 0.41.

Next, in Table 8 we present results for the regression with the maximum provincial rebate offered with all countries included (see equation 19). We interact the maximum rebate offered with the country of assembly and type of vehicle. As there are only two countries where hybrids are produced for sale in Canada (the USA and Japan) we do not have to estimate 36, but only have to estimate 22 interaction parameters for the rebates. We find that HEV cars & light trucks and vans both experienced an increase in sales from the Rebates. However, we find that the impact was uniformly larger for HEVs produced in the USA than for those produced in Japan. We find that these rebates reduce passenger car imports from Sweden (vehicle manufacturers such as the Saab, Volvo amongst others) and the USA. They also reduced light truck and van sales from Germany, Japan and the UK. Vehicle imports from other countries were not impacted. The table reported includes fixed effects corresponding to column (4) from Table 7. In other words, we include fixed effects that control for time (but not across province) varying preferences for vehicles from different countries, we also include fixed

¹⁹We use data from years before the introduction of the rebate programs to better estimate model fixed effects and province-class fixed effects. Results are similar if we restrict the sample to the years 2000-2006.

effects that control for spatially (across province but not time) varying preferences for vehicles from different countries. This ensures that we do not mis-attribute to our rebate coefficients provincial preferences for vehicles from particular countries, nor the Canada-wide increase in preferences for foreign-made vehicles.

Country	Coefficient on Rebate Variable (std. error)	
	Hybrid Cars	Hybrid Light Trucks and Vans (LTVs)
Japan	0.23267** (0.09108)	0.28849* (0.15166)
USA	0.52983* (0.28219)	0.34223** (0.16031)
	Conventional Cars	Conventional LTVs
Canada	-0.05091 (0.04699)	0.02171 (0.05311)
Germany	0.06073 (0.06157)	-0.55584** (0.24441)
Japan	0.01962 (0.04255)	-0.08931* (0.04883)
Mexico	0.13472 (0.08619)	-0.08580 (0.09043)
South Korea	-0.06229 (0.05635)	0.00097 (0.08196)
Sweden	-0.21655* (0.13064)	-0.18740 (0.15150)
UK	-0.19902 (0.15590)	-0.41486** (0.15426)
USA	-0.11486** (0.02834)	0.03305 (0.02317)
Rest of the World	0.06901 (0.12744)	0.17685 (0.14947)

Regression includes model generation Fixed Effects (FE's), Province-Country FE's, country-year FE's
Standard errors in parentheses. Superscripts * and ** denote significance at 5% and 1% respectively.
33778 observations, includes vehicle sales counts by province from all 9 countries of assembly and years 1991-2006.
Model-specific rebates are weighted according to the monthly distribution of sales.

Table 8: Regression Results: Maximum Rebate interacted with Country of Assembly

8 Preliminary Analysis of Prices—Data and Empirical Strategy

The data on vehicle sales transactions is from JD Power's Power Information Network (PIN). PIN data includes more than 250 key observations for each vehicle transactions such as transaction price, vehicle cost, profit, finance, lease, and trade-in measures. This is probably the definitive dataset providing the transaction price of the vehicle. Our sample of the PIN includes information on more than 20% of new vehicle sales from the May 1st, 2004 till April 15th, 2009.

In our first round we evaluate the impact of hybrid rebates on the pre-tax/rebate price paid for the vehicle by the customer. Using the PIN data we construct a pre-tax/rebate transaction

price variable that includes cash rebates, the dealers perceived over/under payment for the trade-in vehicle (PIN calculates the over/under payment based on an estimated value of the vehicle traded in provided by the dealer), cost of all factory installed and dealer installed options and any other discounts provided. It does not include sales or other taxes paid for purchase by the customer. We regress this transaction price on the cost of the vehicle to the dealer (this cost includes the costs of options and the factory assembled vehicle as paid by the dealer), indicators to signal whether this was a cash, leased, or financed sale (cost and type of sale together explain most of the variation in transaction price), month and year fixed effects, and a model-year-cylinder-door fixed effect. The model-year-cylinder-door fixed effect captures unobserved and observed model-specific attributes such as horsepower, engine type, body type, fuel economy, interior comfort, exterior appearance, brand, model perceptions etc. The variable of interest is the rebate received for the hybrid vehicle. This is calculated based on the program descriptions in Table 2. As our transaction price variable is inclusive of all options it is the price on which taxes are calculated. We can use this variable to calculate the tax owed, and thereby the subsidy the vehicle is eligible for. This computed subsidy is used as a regressor to ascertain how it impacts the transaction price.

We run several versions of the regression using several permutations of variables in addition to the rebate variable. Results are given in Table 9

The first three columns include a variety of fixed effects, and deliver similar coefficients on the rebate variable, all of which are statistically significant at the 1% level. Based on the point estimates in columns one through three, a \$1000 HEV rebate raises the price by about 1%. The average HEV price in our sample is \$36,863. On such a car a \$1000 HEV rebate would raise the price by approximately \$369, or 37% of the rebate value.

The fourth column includes the dealer's vehicle cost as an independent variable. Notably, the effect of the rebate on the final transaction price falls to a third its earlier value, suggesting the rebate raises transaction prices by .39% when accounting for dealer costs, or around 14% of the subsidy for the statistically average vehicle in our sample.

We can interpret these figures—fourteen and thirty seven percent—as lower and upper bounds on the rate at which producers extract rebate rents. Dealer cost incorporates a number of variables,

Depvar: Log Transaction Price	(1)	(2)	(3)	(4)
Rebate by Model (\$1000)	0.01021 (6.58)**	0.01027 (6.63)**	0.01213 (7.98)**	0.00396 (4.64)**
Cost of Vehicle (\$1000)				0.02804 (1392.88)**
Cash Purchase Indicator	-0.03258 (104.25)**	-0.03295 (105.42)**	-0.03854 (125.12)**	-0.01577 (82.64)**
Leased Indicator	0.00884 (32.91)**	0.00825 (30.67)**	0.00293 (11.04)**	0.00332 (20.61)**
Model-Year-Cylinder-Door FEs	Yes	Yes	Yes	Yes
Province FEs	Yes	Yes	Yes	Yes
Month FEs		Yes	Yes	Yes
Year FEs			Yes	Yes
Constant	10.30765 (2683.85)**	10.31202 (2668.84)**	10.50024 (2683.47)**	9.46539 (4183.43)**
Observations	1116825	1116825	1116825	880726
R-squared	0.0503	0.0518	0.0876	0.7117
F statistic	3935.18	2338.72	3448.69	67694.58

Absolute value of t-statistics in parentheses. Superscripts * and ** denote significance at 5% and 1% respectively.

Table 9: Impact of HEV rebates on pre-tax/rebate transaction price

most notably profits earned by the manufacturer and the costs of producing the vehicle delivered. *If* we knew that a consumer would buy the exact same car when getting a rebate as she would without the rebate, then we could interpret our findings as suggesting that dealers extract 14% of rebate rents and manufacturers another 23%. But it might well be that, when presented with a rebate, the consumer allocates some of her windfall gains to buying a fancier vehicle, opting for higher quality seats, more speakers, and other perks. If consumers are indeed upgrading their vehicles in response to the rebate, then dealer cost would also rise *even if manufacturer profit was unchanged*. Accordingly, we cannot assume that the full extent of the rebate-induced rise in transaction prices identified in columns (1)-(3) reflects rent extraction. Instead, we view 37% as the upward bound on the fraction of rebate rents extracted by producers.

9 Discussion, Conclusions and Directions for Future Work

Two core questions guide the research presented in this paper. Have HEV rebates shifted market share away from North American manufacturers toward Japanese firms, the dominant producers of HEVs? Who were the ultimate recipients of the HEV rebates: HEV consumers or auto manufacturers?

Guided by these questions, we build a multi-firm oligopoly model and assess how HEV subsidies should affect equilibrium prices and market share in theory. We then take our predictions to sales and transaction price data to estimate the trade and incidence impacts of HEV rebates.

Theoretically, we find there is no reason to expect that firms—even those with market power—will respond to rebates by raising base prices. We also show that waitlists may occur even in the absence of capacity constraints.

Empirically, we show that Canadian HEV rebates shifted market share toward HEVs at the expense of non-HEV cars from the US and Sweden, and non-HEV Light Trucks and Vans from Germany, Japan, and the UK. We also find that sellers extracted some of the HEV rebates by raising transaction prices: between fourteen and thirty-seven percent.

We take from these exercises the following conclusions. Firstly, there is evidence that HEV rebates drive consumers to substitute away from non-HEVs to hybrids. Secondly, a sizable portion of HEV rebates accrue to consumers, not producers. Thirdly, HEV rebates do have trade impacts. Our evidence suggests the shift in market share toward HEVs comes at the expense of conventional European SUVs and North American passenger vehicles. There is no evidence that the HEV rebates simply cause consumers of Japanese imports to switch from one Japanese make/model to another. These results should be of interest to policymakers in both Canada and the United States, as they suggest that the majority of HEV rebates are not being repatriated by Foreign suppliers, but that some new HEV purchases come at the expense of purchases of domestic non-HEV light trucks and vans.

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A Appendix

A.1 Aggregate regression

We estimate an equation where the dependent variable is total light vehicle sales in province v at time t (constructed by aggregating all model sales for a province v in time t)

$$\ln(\text{sales}_{vt}) = \beta_0 + \beta_1 R_{vt} + \beta_2 Z_{vt} + \gamma_{vt} + \epsilon_{vt}. \quad (20)$$

The independent variables are: maximum rebate offered in province v at time t , provincial demographics (Z_{vt}) which include a CPI for private transportation (the index includes gasoline prices), gross domestic product, population, province and time fixed effects (γ_{vt}). Results from the estimation of this equation are presented in Table A-1. The data spans ten provinces from 1989 to 2006. We find that the rebate did not impact overall light vehicle sales and thus did not induce consumers to buy vehicles when they would not have done so otherwise.²⁰

Depvar: Log Total Sales	(1)	(2)	(3)
Maximum Rebate	0.06 (0.02)**	-0.02 (0.01)	0 (0.01)
CPI Transportation (1000)			0.22 (2.75)
Population 18 + (millions)			0.08 (0.02)**
GDP per Capita (1997 \$)			31.00 (4.97)**
Year FEs		Yes	Yes
Province FEs	Yes	Yes	Yes
Constant	Yes	Yes	Yes
Observations	180	180	180
R-squared	0.05	0.73	0.81

Standard errors in parentheses. Superscripts * and ** denote significance at 5% and 1% respectively. Sample extent: All 10 provinces, all years from 1989-2006.

Table A-1: Province level Panel Regression of Total Sales

²⁰This result is robust to changes in the dependent variable to either light vehicle sales per capita, or a log version of sales per capita. It is also robust if we use an indicator variable for the existence of a tax rebate for hybrid vehicles

A.2 Additional Tables

This section contains additional tables referenced in the main text and in the appendix.

Model	Year Introduced
Ford Escape Hybrid	2004
Honda Accord Hybrid	2004
Honda Civic Hybrid	2002
Honda Insight	2000
Saturn Vue Greenline	2006
Toyota Prius	2000
Toyota Highlander H	2005
Lexus RX 400H	2005
Toyota Camry H	2006
Lexus GS 450H	2006

Table A-2: Hybrid Models included in Data

Province\Year	2000	2001	2002	2003	2004	2005	2006
British Columbia	500	1000	1000	1000	1000	2000	2000
Ontario	0	1000	1000	1000	1000	1000	2000
Manitoba	0	0	0	0	0	0	2000
Prince Edward Island	0	0	0	0	3000	3000	3000
Quebec	0	0	0	0	0	0	1000

Source: Authors' Calculations.

Table A-3: Maximum Rebate possible to a Hybrid Car