Evaluating Tax Rebates for Hybrid Vehicles

Ambarish Chandra, Sumeet Gulati, and
Milind Kandlikar

University of British Columbia

Hybrid Electric Vehicles

- Hybrid Electric Vehicles (HEVs) combine an internal combustion engine with an onboard rechargable energy storage system.
  - Most HEVs also include Regenerative braking to recharge onboard battery.
- HEVs provide environmental improvements in the use-phase (Turrentine, et al, 2006).
  - The current fleet reduces carbon emissions by an average of 6 tons per vehicle over its lifetime (Reynolds and Kandlikar, 2007).

Our Objective

- To evaluate the cost-effectiveness of hybrid tax rebates

- First Step – use model level sales data to answer

  - What is the effect of provincial tax rebates on the sales of HEVs?

  - Which vehicles are crowded out in the new car market.

  - How many consumers enter the new car market due to the rebate?

Second Step

- Combine information from first step with fuel economy of HEV's, and other cars crowded out with average kilometers driven to calculate fuel savings from rebate.

- Based on expenditure on rebates calculate the cost per ton of carbon saved through the rebate.

Related Literature

- Recent support to hybrid technology has encouraged economic analysis.
  - Diamond (2006) finds that gas prices, tax incentives, and average miles significantly influence hybrid vehicle adoption.
  - Gallagher and Muehlegger (2007) find that tax incentives, gasoline prices, and changing social preferences explain 12 percent, 28 percent, and 33 percent of increase in hybrid vehicle adoption.
  - Kahn (2007) evaluates the effect of ideology on the purchase of HEV's in the state of California.
  - Sallee (2007) studies the incidence of state and federal tax incentives offered to Toyota Prius owners.
  - Berestenue and Li (2008) find that rising gas prices and government subsidies explain 17%, and 26% of the diffusion of hybrid vehicles.

Our Paper

- Is similar as: One aim is to evaluate the effect of government incentives on the purchase of HEV's.
- Is Different from all the above papers besides Berestenue and Li,
  - We have data on sales in the entire new car market.
  - We can estimate the effect of rebates on other cars: which cars did consumers switch away from?
  - We can also test if the rebate attracted entrants into the new car market.

Preview of the Results

- A $1000 increase in the rebate increased the market share of hybrids by approximately 31-38%.
  - 2006 share of hybrid car in light car sales – 0.53%
- After the rebate was implemented - approximately 26% of total sales can be attributed to the rebate.
- Intermediate passenger cars, high performance compact cars, and intermediate SUV's crowded out.
  - Other vehicle classes were not impacted.
- Average cost of CO_2 saved - $195 per ton

Hybrid Vehicle Sales in Canada

Model	2000	2001	2002	2003	2004	2005	2006	2007
Chevorlet Malibu Hybrid	0%	0%	0%	0%	0%	0%	0%	0.03%
Ford Escape	0%	0%	0%	0%	7%	17%	7%	7%
Honda Accord	0%	0%	0%	0%	1%	11%	6%	2%
Honda Civic	0%	0%	51%	61%	8%	7%	16%	14%
Honda Insight	39%	21%	14%	2%	0.3%	0.1%	0.2%	0.03%
Lexus GS450H	0%	0%	0%	0%	0%	0%	2%	1%
Lexus LS 600H	0%	0%	0%	0%	0%	0%	0%	1%
Lexus RX400H	0%	0%	0%	0%	0%	15%	9%	8%
Nissan Altima Hybrid	0%	0%	0%	0%	0%	0%	0%	2%
Saturn Aura Hybrid	0%	0%	0%	0%	0%	0%	0%	0.5%
Saturn Vue Hybrid	0%	0%	0%	0%	0%	0%	2%	4%
Toyota Camry Hybrid	0%	0%	0%	0%	0%	0%	24.2%	39%
Toyota Highlander Hybrid	0%	0%	0%	0%	0%	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: Polk Automotive Canada.

Canadian Provincial Policies

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 62K.
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 upto 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 maximum of $2000 after March 23rd, 2006.
Quebec **Policy Announced**: March 2006. PST: 7.875%	See Notes (1) below	All PST paid to a maximum of $1000 for vehicles bought after March 23rd 2006.
Manitoba **Policy announced,** November 15th 2006 **PST rate**: 7%.	See Notes (2) below	Flat $2000 rebate for all vehicles bought after November 15th 2006.

Rebate Maximums

Province\Year	2000	2001	2002	2003	2004	2005	2006
BC	$500.00	$630	$630	$630	$777	$2000	$2000
Ontario	$ 0	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$2,000.00
Manitoba	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$2000
PEI	$ 0	$ 0	$ 0	$ 0	$3000	$3000	$3000
Quebec	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$1,000.00

Rebate Variable

- Assuming that the transacted price for hybrid cars is at least as high as the base price we calculate a model specific rebate variable,

$$ R_{mvt} = \min \left\{ \eta_{vt} \left(PST_v * BP_m \right), Limit_{vt} \right\} $$

η_{vt} is the proportion of PST returned, BP is base price, and $Limit$ is the maximum PST rebate.

Hybrid Vehicles Base Prices

Model	Year	Base Price
Civic Hyrbid	2008	$ 26,350
Insight	2000	$ 26,000
Accord Hybrid	2007	$ 38,090
Prius	2008	$ 29,500
Camry Hybrid	2008	$ 32,000
Highlander Hybrid	2008	$ 41,075
Lexus GS400h	2008	$ 71,000
Lexus RX400h	2008	$ 55,050
Lexus LSh	2008	$ 125,400
Saturn Vue Greenline	2008	$ 30,790
Saturn Aura Hybrid	2008	$ 27,575
Ford Escape Hybrid	2008	$ 31,499

Data

- DesRosiers Automotive Consultants Inc. – vehicle sales counts, by make and model, by province, yearly 1989-2006.
  - Only has Toyota Prius and Honda Insight among HEV's.
- R. L. Polk Canada Inc. provide provincial sales counts for all Hybrid Models sold in Canada (until 2007).
  - These include Honda Accord,Civic Hybrid, other Toyota and Lexus Models, Ford Escape Hybrid, and the Saturn Vue Greenline.
- Fuel Economy Data from EPA
- Model Generation Data from Wikipedia.
- Province level demographics, CPI – fuel, private transport, vehicle km's, total vehicles registered from STAT Canada.

Rebating and Non Rebating Provinces
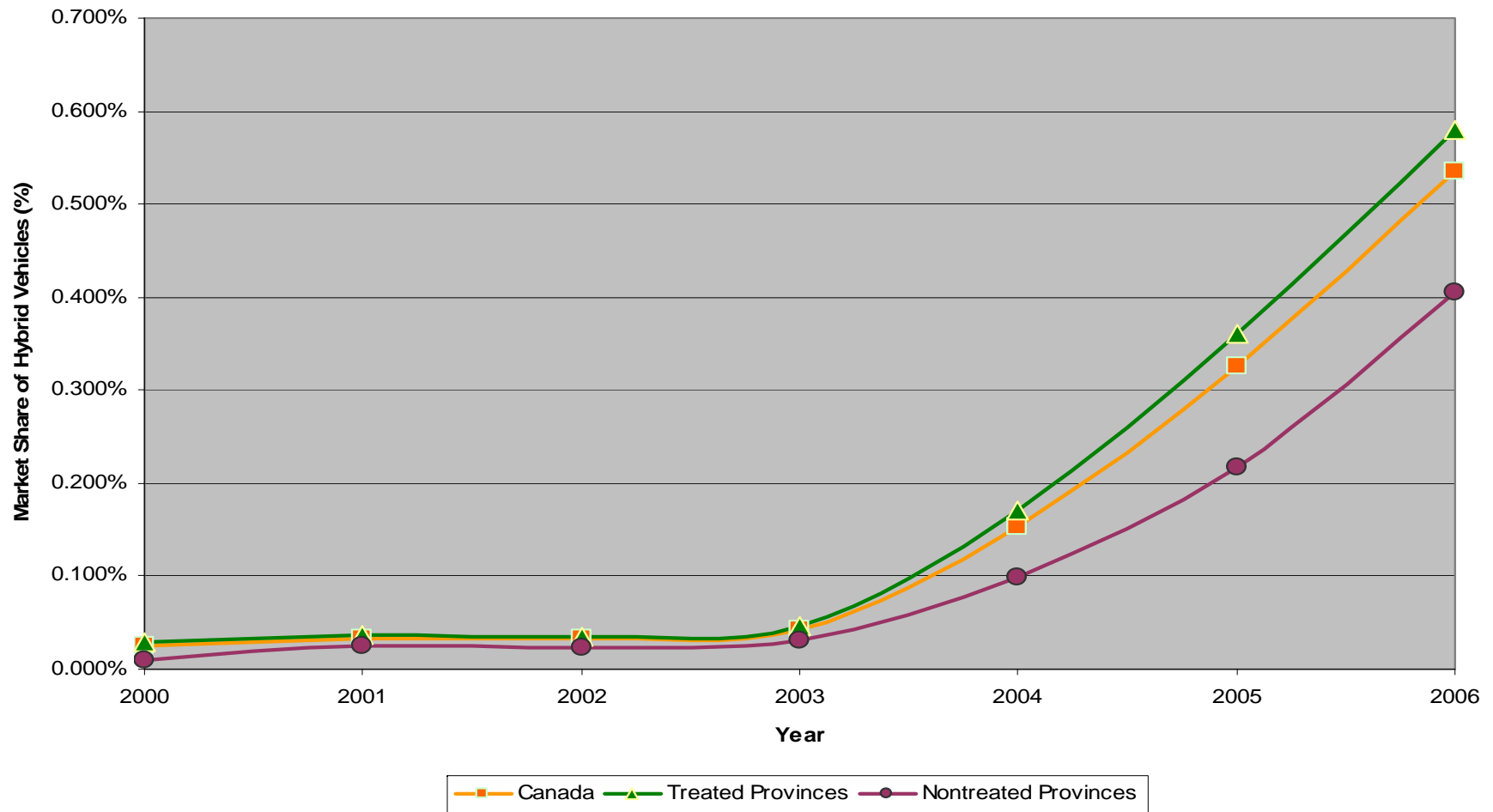
Hybrid Sales Across Provinces

| Province	Passenger Cars		Light Trucks		Total Vehicle Sales	
	Sales	Market Share of Hybrid	Sales	Market Share of Hybrid	Sales	Market Share of Hybrid
Alberta	642	0.7%	362	0.2%	1004	0.4%
BC	1499	1.5%	624	0.7%	2123	1.1%
Manitoba	207	1.0%	61	0.3%	268	0.6%
Nbrunswick	94	0.5%	21	0.1%	115	0.3%
Nfoundland	28	0.2%	16	0.1%	44	0.2%
Novascotia	150	0.5%	28	0.2%	178	0.4%
Ontario	2454	0.8%	889	0.3%	3343	0.6%
PEI	51	1.7%	7	0.4%	58	1.2%
Quebec	1053	0.4%	337	0.2%	1390	0.4%
Canada	**6178**	**0.7%**	**2345**	**0.3%**	**8523**	**0.53%**

One Should Be Concerned About

- Is our rebate variable just capturing a cross-sectional preference for hybrid cars?

  – Do Provinces that offer rebates have an inherent and unchanging preference for hybrid cars?

- Is our rebate variable capturing a Canada wide increase in the preference for hybrid vehicles?

  – In addition to the effect caused by fuel prices?

Rebates and the market share of the Second Generation Toyota Prius
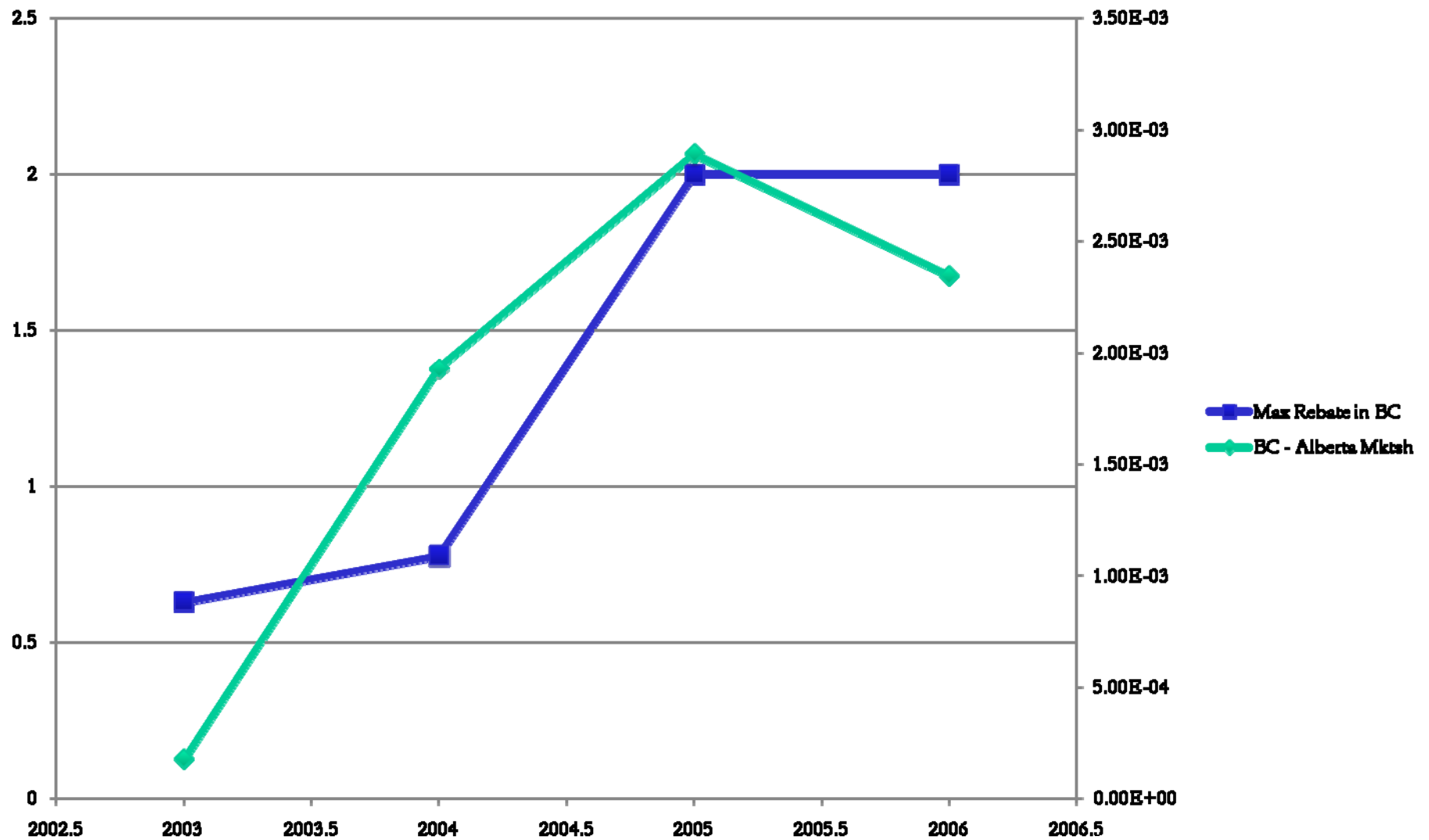
Rebates and the market share of the Seventh Generation Honda Accord
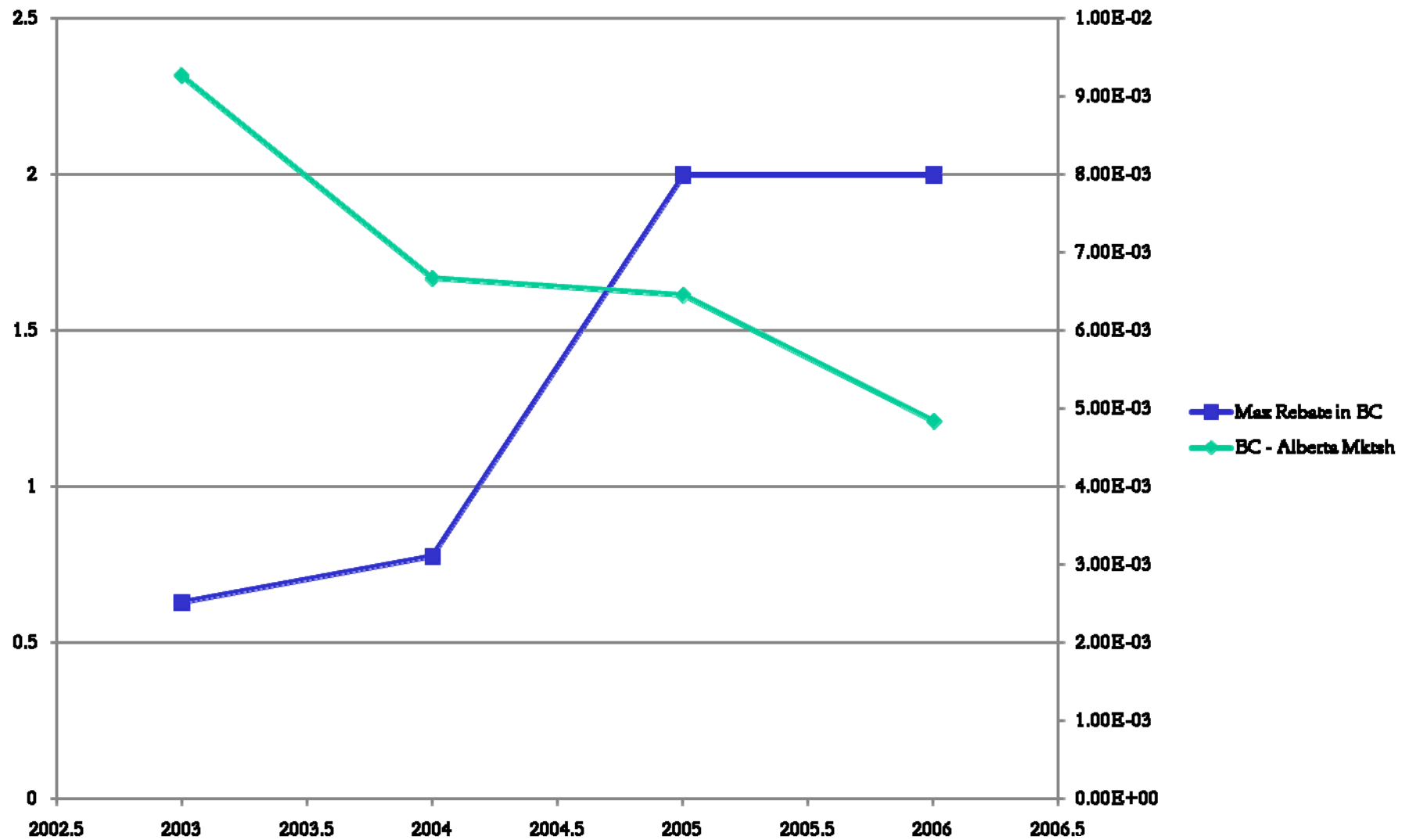
Estimating Equation

- Assuming that consumers do not switch into buying a new car from outside the market, we take the size of the new car market as given for our purposes

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

θ - model generation fixed effect and γ refers to - province, class and year fixed effects. β_1 captures the impact of the rebate.

Fixed Effects included

- Model*generation dummy captures unobserved and observed model specific attributes (including retail price)
  - Is constant across provinces

Other Fixed Effects

- A province*class year dummy
  - This will control for a time invarying preference in a particular province for a certain class of vehicles.
    - Geography, urban sprawl, education, income etc. could create such a preference.
- A class*year dummy captures preferences for a class over a particular year.
  - This will control for a time (but not space) varying preference for a particular class.
    - Will not capture local network externalities due to the presence of more hybrid vehicles.

Results with a Model Specific Variable

Depvar: Log Market Share	(1)	(2)	(3)	(4)
Weighted Rebate by Model	0.39	0.31	0.33	0.34
($1000)	(0.07)**	(0.07)**	(0.07)**	(0.07)**
Model-generation FEs	Yes	Yes	Yes	Yes
Province FEs		Yes		
Year FEs		Yes		
Province-Year FEs			Yes	
Province-Segment FEs				Yes
Segment-year FEs				Yes
Constant	-6.75	-5.54	-5.49	-6.80
	(0.01)**	(0.03)**	(0.07)**	(0.04)**
Observations	38110	38110	38110	38110
R-squared	0.00	0.09	0.09	0.21

Standard errors in parentheses. Superscripts * and ** denote significance at 5%, and 1% respectively. Sample extent: All model-generations, all years from 1989-2006. Model-specific rebates are weighted according to the monthly distribution of sales.

Results Using Rebate Maximums

Depvar: Log Market Share	(1)	(2)	(3)	(4)
Rebated Hybrids * Max Rebate	0.37	0.33	0.33	0.38
($1000)	(0.07)**	(0.07)**	(0.07)**	(0.07)**
Max Rebate	0.01	-0.02	-0.69	-0.04
($1000)	(0.01)	(0.01)	(0.03)**	(0.01)**
Model-generation FEs	Yes	Yes	Yes	Yes
Province FEs		Yes		
Year FEs		Yes		
Province-Year FEs			Yes	
Province-Segment FEs				Yes
Segment-year FEs				Yes
Constant	-6.75	-5.54	-5.49	-6.68
	(0.01)**	(0.03)**	(0.07)**	(0.04)**
Observations	38110	38110	38110	38110
R-squared	0.00	0.09	0.09	0.21

Standard errors in parentheses. Superscripts * and ** denote significance at 5%, and 1% respectively. Sample extent: All model-generations, all years from 1989-2006. Maximum rebates are weighted according to the monthly distribution of sales.

Vehicle Class

- We differentiate individual car model data by the following categories, these are:
  - Passenger Cars
    - Subcompact, Compact, Intermediate, Sports, Luxury Sports, Luxury, Luxury High End.
  - Light Trucks
    - Compact Sport Utility, Intermediate Sport Utility, Large Sport Utility, Small Pickup Truck, Large Pickup Truck, Small Van, Large Van, Luxury Sport Utility
  - Hybrid

Market Share of Hybrids and Other Categories

Size Class of Vehicles	Market Share percentage of Total Vehicle Sales	
Class	2003	2006
Passenger Cars		
Compact PC	25.4%	24.8%
Hybrid	0.04%	0.41%
Intermediate PC	17.6%	14.1%
Luxury High End PC	1.8%	1.4%
Luxury PC	2.7%	3.9%
Luxury Sports PC	0.5%	0.4%
Sports PC	2.2%	2.0%
Subcompact PC	4.1%	6.4%
Light Trucks		
Compact Sport Utility	7.0%	11.2%
Hybrid	0.0%	0.12%
Intermediate Sport Utility	6.6%	4.4%
Large Pickup Truck	12.7%	12.7%
Large Sport Utility	1.3%	1.1%
Large Van	1.7%	1.8%
Luxury Sport Utility	2.0%	2.8%
Small Pickup Truck	1.8%	3.0%
Small Van	12.5%	9.4%
Passenger Cars	865,873	863,292
Light Trucks	728,043	752,206
Total Vehicle Sales	**1,593,916**	**1,615,498**

Results with Impacts on Different Classes

Depvar: Log Market Share	(1)	(2)	(3)	(4)
Intermediate PC * Max Rebate	-0.29	-0.29	-0.29	-0.11
	(0.05)**	(0.05)**	(0.05)**	(0.05)*
Intermediate SUV* Max Rebate	-0.21	-0.24	-0.24	-0.19
	(0.06)**	(0.05)**	(0.05)**	(0.06)**
Large Sports Utility * Max Rebate	-0.17	-0.22	-0.21	-0.05
	(0.07)*	(0.07)**	(0.07)**	(0.08)
Luxury PC* Max Rebate	0.18	0.13	0.14	-0.1
	(0.06)**	(0.06)*	(0.06)*	(0.06)
Luxury High End PC * Max Rebate	0.26	0.28	0.3	-0.12
	(0.06)**	(0.06)**	(0.06)**	(0.07)
Sports PC * Max Rebate	-0.2	-0.16	-0.16	-0.13
	(0.06)**	(0.06)*	(0.06)*	(0.07)*
Small Van * Max Rebate	-0.11	-0.14	-0.14	-0.1
	(0.06)	(0.06)*	(0.06)*	(0.06)
Rebated Hybrids * Max Rebate	0.32	0.27	0.28	0.28
	(0.08)**	(0.08)**	(0.08)**	(0.08)**
Max Rebate	0.06	0.04	-0.61	0.05
	(0.04)	(0.04)	(0.05)**	(0.04)
Model FEs	Yes	Yes	Yes	Yes

Regression Results

- Provinces that gave a rebate saw an increase in the market share of HEV's.

- Reduced form results imply that

  - Intermediate Cars, Intermediate Sports Utilities and Sports Cars always lose from the rebates.

Counterfactuals

- The cost per tonne saved ranges from $128.9 in Ontario in 2001 to $270 in the province of BC in 2006.

- Across all provinces and years, the average cost per tonne of CO_2 saved is approximately $195.

- The corresponding cost for a litre of gasoline saved ranges from 31 cents in Ontario, 2001 to 65 cents in BC, 2006 with a Canada average of 47 cents a litre (the 2006 average price for a litre of gasoline in the major urban centers of Canada was $1.01).

- BC and PEI are more expensive than the average, while Quebec is below the average.

Conclusions

- We find that the rebates are not cost effective in any province if compared with the price of purchasing a tonne of carbon dioxide credits on the Chicago Climate Exchange (2.15 US dollars or approximately 2.6 Canadian dollars on January 30th 2009).

- It is also higher than the average price of a futures contract for a tonne of carbon dioxide settled in the European Climate Exchange in 2008 (at 25.50 Euros, or approximately 40 Canadian Dollars given the average exchange rate for 2008).