

Gasoline prices and fuel economy of new vehicles in Quebec

Keywords: gasoline price, fuel economy, light duty vehicles, feebate

Mots clefs: prix de l'essence, économie de carburant, véhicules légers, malus-bonus

Abstract

We evaluate the short run impact of gasoline prices on new vehicles registrations by fuel economy using monthly data from 2002 to 2008 in the province of Quebec. We find that a gasoline price increase stimulates registration of new vehicles with a fuel consumption rate below 8.65L/100km (27.2 mpg) while it lowers those of vehicles above that limit. While the impact is modest for a large share of vehicles, we find that large gasoline price fluctuations can lead to noticeable changes in the composition of vehicles. The impact on the average fuel economy remains modest with an elasticity below -0.1. The federal feebate program had an impact of a 17% increase in sales of low-fuel consumption vehicles and a decrease of 8% of high-fuel consumption vehicles but the overall change in fuel economy was less than 1%.

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1. Introduction

In response to growing concerns over climate change, many governments around the world have adopted policies to improve the fuel efficiency of new light duty vehicles (LDV).¹ In 2007, the U.S. corporate average fuel economy standards were strengthened for the first time since 1975. The objective is now to reach an average level of 163 grams per mile of carbon dioxide for new LDV in 2025 (or equivalently 54.5 MPG or 4.3L/100km).² In 2010, Canada switched from voluntary to mandatory standards that are now aligned with regulations in the US. The European Union also moved from voluntary to mandatory limits in 2009 with a target of 95 grams of CO₂ per km for new passenger cars in 2021 (Miller and Façanha, 2014). In addition to standards, other policy instruments have been adopted to foster fuel economy such as feebate programs, gas-guzzler taxes or subsidies for alternative fuel vehicles.³ However, the effectiveness of these policies depends on the changes in the composition of the fleet of vehicles sold. For example, despite a strengthening of the CAFE standards, small improvements in the average fuel economy were achieved in the US from 1983 to 1990 when the share of light trucks and SUV increased (Knittel, 2011). Gasoline prices are often suspected to be one of the driving determinants of new vehicle sales structure by fuel economy. The idea is that car buyers use the current price of gasoline to forecast future prices, which in turn determine driving operating costs. In the US, the growing popularity of light trucks in the eighties is often related to the low gasoline prices during that period. Correspondingly, the steady increase in gasoline price from 2002 up to the financial crisis has shown to be one of the main causes for the decline of large SUV in the US (Klier and Linn, 2010). Even more recently, the sharp decline in gasoline prices at the end of 2014 has spurred fear of a renewed popularity of big and fuel inefficient vehicles.⁴

In this paper, we study these effects by estimating the short run impact of gasoline price on the composition and fuel economy of new LDV in the province of Quebec (Canada). The analysis is carried out using monthly data on new LDV registrations in the province from January 2002 up to September 2008. Specifically, we measure the differential impact of gasoline price on the monthly sales of vehicles by fuel economy. Since our analysis is conditioned on the characteristics of vehicles offered (including fuel economy), it specifically measures the short run reactions of new vehicle buyers and manufacturers to gasoline price fluctuations.⁵ In other words, we do not measure the medium and long term adjustments process such as the redesign of vehicles or technological innovations. Assessing short run effects is important as they likely determine the magnitude of the long-term adjustments. For example, if the composition of the fleet of new vehicles is unaffected by gasoline prices, it is unlikely that manufacturers will invest to improve fuel economy. Also, vehicles are durable goods that last for more than fifteen years so that short run changes have in fact long lasting consequences.

While there are ample empirical studies on the impact of gasoline price on gasoline demand and on travelled distance (see Graham and Glaister, 2004, Transportation Research Board, 2009), the evidence on vehicle fuel economy is much more limited. Some studies measure the impact of gasoline price variations on the aggregate fuel economy of the fleet. For example, Small and Van Dender (2007) estimate a reduced form system of equations for vehicle stocks, distance driven and average fuel economy using a panel of US States from 1966 to 2001. They obtain short and long run elasticities of fuel intensity with respect to gasoline price of -0.04 and -0.19 respectively. Using a similar approach on a panel of Canadian provinces over the 1990-2004 period, Barla, Lamonde, Miranda-Moreno and Boucher (2009) report short and long run elasticities of -0.04 and -0.12. It should be stressed that these elasticities are related to the impact

of gasoline price on the whole fleet rather than on new vehicles. For new vehicles, the seminal paper Berry, Levinsohn and Pakes (1995) estimates a structural model of the US demand and supply market over the 1971 to 1990 period. They find that market shares of fuel efficient vehicles are more responsive to gasoline price variations than inefficient ones. Consumer unobservable heterogeneity would explain this result as fuel efficient cars likely attract consumers that are more reactive to gasoline cost.

Other studies use household level data to estimate structural models of the vehicle market (Goldberg, 1998, West, 2004, Train and Winston, 2007). Bento, Goulder, Jacobsen and von Haefen (2009) estimate a model where consumers decide on buying a new or used vehicle, scrapping an old vehicle and distance driven. The model is estimated using a 2001 cross-section of about 20 000 U.S. households. The results suggest a long term gasoline demand elasticity at -0.35 with most of the adjustment occurring through the distance driven. They simulate the impacts of a 25 cents per gallon increase in gasoline tax which approximatively correspond to a 17% increase in gasoline price. Their results suggest very low short and long run elasticity of the fleet fuel efficiency with respect to gasoline price (less than 0.005 and 0.1 respectively). Furthermore, they find that the 25 cents gasoline tax increase would reduce the stock of vehicle by 0.5% in the short run with a fall of 1% for new cars and 0.4% for used cars. The stock of inefficient vehicles would drop by 0.5% compared to 0.4% for efficient vehicles. Overall, the study concludes that the compositional impact of gasoline price is small both in short and long run.

Recently, several papers have reexamined the gasoline price-fuel economy relationship in the U.S. using more detailed data and reduced form models. Li, Timmins and von Haefen (2009) use registration data for 20 US metropolitan areas from 1997 to 2005. They find that an increase

in gasoline price shifts the demand for new vehicles toward fuel efficient ones. Specifically, sales of new vehicles with MPG higher than 23.3 (10L/100km) would increase following a gasoline price hike while sales of vehicles with a MPG below that level would decline. The resulting fuel economy elasticity for new vehicles would be about 0.2 in the short run. They also find that higher gasoline prices delay the scrapping of used efficient vehicles while speeding the exit of inefficient vehicles. These latter two effects are however very small so that most of the fuel economy improvement is due to the shift toward more efficient new vehicles.

Busse, Knittel and Zettelmeyer (2013) examine the short run impact of gasoline price on new and used vehicles equilibrium prices and quantities by fuel economy categories. Using a very rich dataset of transactions from US car dealers from 1999 to 2008, they find that gasoline price has a relatively modest effect on new vehicles prices but a larger impact on the distribution of sales across fuel economy categories. In fact, a 1\$ per gallon increase in the price of gasoline would reduce the unit sales of the less fuel economy quartile by more than 25% and increase the unit sales of the most fuel economy quartile by more than 10%. For used vehicles, they find that the adjustment is mostly through changes in relative prices across fuel economy quartiles. They use these results to evaluate the implicit discount rates associated with consumers' valuation of fuel economy. They find little evidence of undervaluation of future gasoline costs as often suggested. Indeed, the implicit discount rate is comparable to rates on car loans.

The two former studies aggregate sales observations by fuel economy categories. This may mask within category substitutions following a gasoline price increase. Moreover, they imperfectly control for unobservable vehicle and consumer characteristics that may be correlated with gasoline prices. For example, in the late 2000, there was a renewed interest for subcompact vehicles in part because of high gasoline prices but also probably because of the need for small

vehicles suited for dense urban settings. Klier and Linn (2010) estimate the impact of gasoline prices directly at the model-year level using monthly US sales data. Their empirical strategy controls for unobserved vehicle and average consumers characteristics by including model-year fixed effects. The identification of their model rests on gasoline price changes within a model-year. The monthly level of sales of a specific model-year is assumed to be affected by the cost of driving per mile which in turn depends upon the ratio of gasoline price and MPG. In other words, the short run impact of gasoline price is assumed to be inversely proportional to MPG. Their results confirm a short run shift in the distribution of sales toward efficient vehicles following a gasoline price increase. The overall impact on the average fuel economy of new vehicles is however limited with an elasticity of fuel economy with respect to gasoline price around 0.12.

Our contribution to this growing literature is to examine the short run effects of gasoline prices on the composition of new LDV in the province of Quebec (Canada).⁶ The Quebec setting is interesting as the province has one of the most fuel efficient LDV fleets in North America. Gasoline prices could therefore have less impact than in the US as the margin for improvements is more limited. However, the higher fleet efficiency in the province could result from historically higher average gasoline prices, lower disposable income or greater concern for fuel efficiency. The responsiveness to gasoline prices could therefore be enhanced in these circumstances. Besides providing evidence in a new setting, our analysis also contributes in other ways. Our empirical specification explicitly controls for unobservable vehicle characteristics while still allowing for gasoline prices to have both positive and negative impacts on sales of different models with different fuel economy. Our data also allow for a better control for the changing mix over time in the year of a model (i.e. the Model-Year).

Our results indicate that the sales of vehicles with a fuel consumption rate below 8.65L/100km increase following an increase in gasoline price while the opposite occurs for vehicles above that limit. While the impact can be substantial for vehicles that are far from this threshold, the effect is limited for a large share of vehicles. The compositional impact is thus rather modest but large gasoline price fluctuations may have noticeable consequences. The corollary of these findings is that a large gasoline price increase is needed to counteract the growing popularity of large vehicles. For example, we evaluate that the price of gasoline should have doubled from 2002 to 2008 for the share of light trucks to remain stable. We evaluate at -0.08 the short run elasticity of the average fuel consumption rate of new vehicles with respect to gasoline prices.⁷

We are also able to test the impact of a feebate program that was set up by the Government in March 2007 and ended in December 2008. During the short period of time this feebate program was in place, eligible vehicles experienced an increase in sales of 17% after controlling for other factors. At the same time, vehicles that were subject to a low-efficiency tax at the moment of purchase suffered from a decrease of 8 to 9% in sales. Unlike the feebate, this tax is still in place nowadays. The feebate program's impact on overall fuel efficiency was rather small: it left its level practically unchanged. Among other factors, the program's short time span might have limited its scope; also, the creation of incentives to shift sales from one type of vehicles that did not qualify for the rebate to another that qualified but that was too similar to the other type did not contribute to obtain large effects on efficiency.

The rest of this paper is organized as follows. In section 2, we describe our dataset. We present the Quebec context and provide preliminary evidence in section 3. The empirical model is discussed in section 4 and the results in section 5. We evaluate the robustness of our baseline specification in section 6 and conclude in section 7.

2. The data

Our analysis uses monthly data for all new LDV registered primarily for personal usage from January 2002 to December 2008.⁸ The dataset combines information from the *Société de l'Assurance Automobile*, a governmental entity in charge of vehicle registration and insurance. Using the Vehicle Information Number (VIN), technical characteristics of the vehicles are added using data provided by *ESP Data Solutions* a private company specialized in VIN decoding. Fuel consumption rates in L/100km (*FCR*) in city and highway conditions are those reported by ESP Data Solutions which are themselves provided by the EPA. These data are complemented by those provided by *Natural Resources Canada* in the Fuel Economy Guide. The fuel consumption rates are measured in laboratory by manufacturers using two standardized protocols corresponding respectively to a city and highway environment.⁹ These two rates are then average using weights of 55% and 45% for road and highway respectively to produce a “combined” *FCR*.

The Fuel Economy Guide also classifies vehicles into nine classes: six for cars and three for light trucks. For cars, the classification is based either on interior volume (subcompact, compact, mid-size and full-size cars) or carline (e.g. two-seater, station wagon). For light trucks, the classification is based on vehicle type (SUV, van and pickups). The classification for cars presents several shortcomings for our analysis of fuel economy. For example, some very popular models in Quebec such as the Mazda 3 or Honda Civic are at the limit between subcompact and compact classes and thus switch from one category to the other depending upon the model-year. Another limitation concerns the two-seater class that combines very fuel efficient vehicles like

the Smart and fuel inefficient sport cars such as the Ford Thunderbird. We therefore modified the existing classification and group cars in three categories namely i) small and medium cars, ii) mid-size and full size cars and iii) sport cars.¹⁰

The price of gasoline corresponds to the provincial average price for regular unleaded and is based on a weekly survey of gasoline price in the province by the *Régie de l'énergie*. To obtain real prices, we use the consumer price index that excludes gasoline. All monetary values presented in the rest of this paper are expressed in 2002\$. The other main source of data is Statistics Canada for income, population, price index etc. Finally, note that we exclude from the analysis uncommon vehicles namely those for which average monthly sales are below 10 vehicles or those with positive sales for less than three months. These criteria eliminate less than 1.6% of new registered vehicles.

3. Context and preliminary evidence

Before developing the empirical model, it is useful to briefly describe the Quebec context and provide preliminary evidence. Over the 2002-2008 period, the Quebec LDV fleet grew from 3.5 to 4.1 million. The number of new vehicles registered each year varied from a low of about 350 000 in 2004 to a high of 408 000 in 2008. In 2008, the average fuel consumption rate of the Quebec fleet was 11% and 9.6% lower than the average rate observed in the US and the rest of Canada respectively.¹¹ This is due in part to the smaller share of light trucks (SUV, vans and pickups) at 31% in Quebec against 46% in the US and the other Canadian provinces.¹² Looking more specifically at new vehicles, the supply of models in Quebec is very comparable to those available in the US. However, the distribution of new vehicles registration by level of fuel efficiency appears to be quite different. For Model-Year (refer for now on as MY) 2008, over

72% of new vehicles registered were in the most fuel efficient quartile of the distribution of available models (i.e. *FCR* less than or equal to 9.3 l/100km).¹³ For comparison, Busse et al. (2013) report a share of less than 30% for this quartile in the US.¹⁴

Figure 1 depicts kernel densities of the *FCR* for new vehicles registered in calendar year 2002 and 2008. The left panel illustrates the density of the available MY (309 MY in 2002 and 272 in 2008) while the right panel shows the density of new vehicles registered (i.e. each MY is weighted by the number of new registrations). Both figures suggest fuel economy improvements. On the supply side, the mode of the distribution remains centered at about 10L/100km but the density flattens with more efficient models being offered and less gas guzzlers. On the demand side, the density of new registered vehicles clearly shifts left toward more efficient vehicles. Interestingly, the average real price of gasoline was \$1.11 in 2008 against 0.72\$ in 2002.

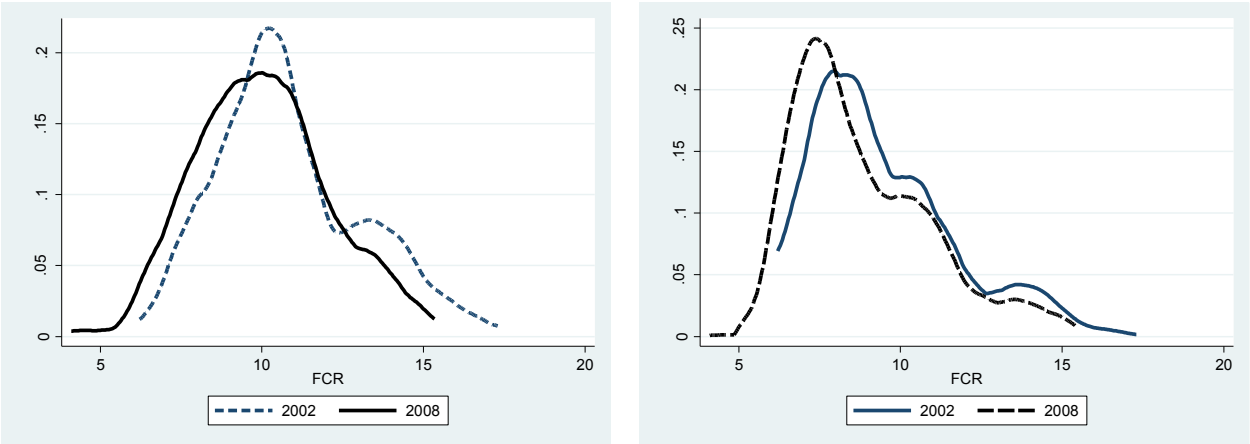


Figure 1. Kernel density of fuel consumption rate (*FCR*) offered (left panel) and registered new vehicles (right panel) for calendar year 2002 and 2008.

Source: Authors' calculations

To explore further the potential impact of gasoline prices, Figure 2 illustrates the average *FCR* of new vehicles sold each month and the corresponding monthly average gasoline price. We

observe a general downward trend in the average *FCR* but also a negative correlation between the price of gasoline and average *FCR*. Figure 3 also suggest that there is a positive correlation between gasoline price and the share of passenger cars sold while the opposite occurs for the share of light trucks. Still, the share of light trucks appears to be trending up at the end of the period despite high gasoline prices. The share of light trucks was 31% in 2002 and close to 35% in 2008. Moreover, the composition of sales in the light truck segment has been progressively changing with a continuous decline of the van category (from 11% of the sales in 2002 to 5.9% in 2008) and an increasing popularity of SUV (from 12.8% to 20%) and to a lesser extent of pickups (from 6.3% to 7.9%). These observations suggest a concomitance of both short term fluctuations associated with gasoline price and longer term changes due to technology and preferences.¹⁵

In early 2007 the Canadian government announced a rebate program for efficient vehicles. From March 2007 to December 2008, new car buyers could receive from 1000\$ to 2000\$ in rebate when buying eligible vehicles. The rebates depend upon the fuel economy and the vehicle type. For example, cars with a *FCR* of 5.5 L/100 km or less receive a rebate of 2000\$, between 5.6 and 6L/100km, 1500\$ and between 6.1 and 6.5L/100km 1000\$. Flex fuel vehicles that consume less than 13L/100 km were also eligible for a 1000\$ rebate. The program only targeted MY2006 to MY2008. In parallel, a new excise tax on fuel inefficient vehicles was introduced. It varied from \$1000 for vehicle with *FCR* between 14 and 15L/100km to \$4000 for those with a *FCR* above 16L/100km.

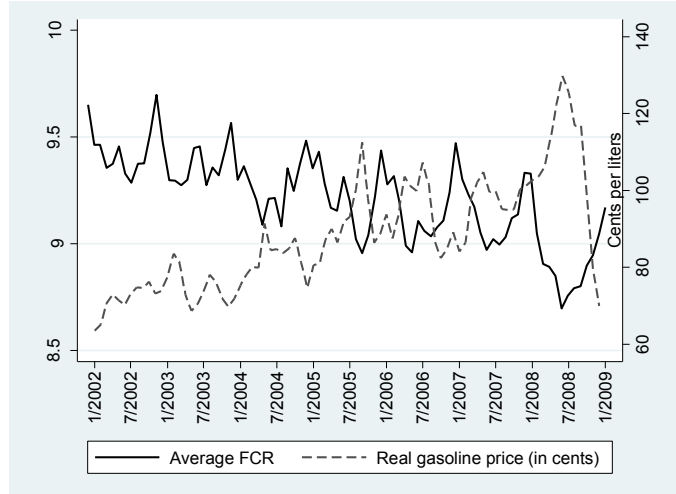


Figure 2. Average fuel consumption rate of new vehicles and average gasoline price

Source: Authors' calculations

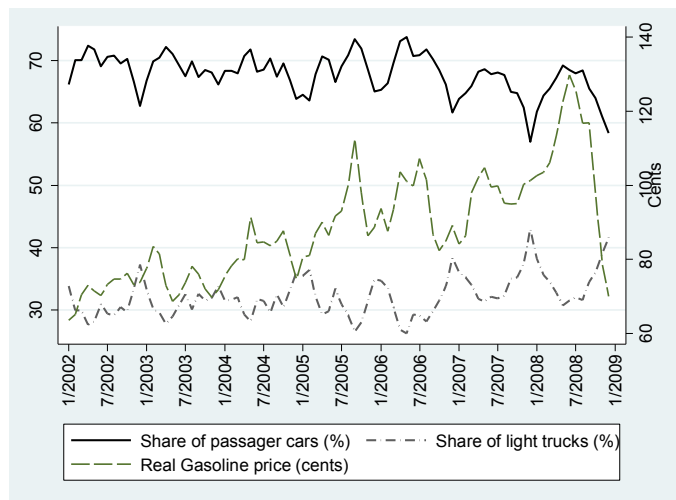


Figure 3. Share of passenger cars and light trucks sold and average gasoline price

Source: Authors' calculations

4. The Empirical Model

Following, Li et al. (2009), Klier and Linn (2010) and Busse et al. (2013), we adopt a reduced form model to examine the short run impact of gasoline price fluctuations on the composition of

vehicle sales. We adopt this approach rather than a structural model for several reasons. First and for most, this approach does not require data on vehicle prices which are often unavailable (our case) or very imprecise.¹⁶ Second, it easily allows for a large number of vehicle models when structural models often require to aggregate different vehicles into a small number of categories.¹⁷ Third, the impact of a gasoline price changes on sales structure and average fuel economy can easily be simulated. The main shortcoming however is that it cannot separate out the effects due to demand or supply adjustments.

Our model aims at testing the impact of current gasoline price (P_t^g) on the number of model j (e.g. Honda Civic) entering the fleet, as a new vehicle, during a specific month (Q_{jt}).¹⁸ The idea is that buyers use the current gasoline price to assess the vehicle expected gasoline costs over the life of the vehicle. Moreover, in order to test for a composition effect, our specification allow for the impact of gasoline to depend upon the vehicle fuel consumption rate (FCR). Formally, our model has the following structure:

$$\ln(Q_{jt}) = \theta_0 + (\theta_1 + \theta_2 FCR_{jt})P_t^g + \theta_3 \text{Rebate}_{jt} + \theta_4 \text{Tax}_{jt} + X_{jt}\gamma + \varphi_{jd} + \tau_m + \tau_y + \vartheta_{jt} \quad (1)$$

with

Q_{jt} : the number of model j registered, as a new vehicle, during month t . To be considered new, a vehicle should never have been registered before in the province. Moreover the MY should be either the current calendar year or the current calendar year plus or minus one. This account for the fact that new MYs are generally introduced at the end of the preceding year (e.g. The Honda Civic 2008 appears in September 2007). Moreover, last year MY may still be liquidated by dealers at the beginning of the following year (e.g. some Honda Civic 2006 are registered for the first time in March 2007).¹⁹

FCR_{jt} : the average fuel consumption rate of all model j entering the fleet at t expressed in liter per kilometer;

P_t^g : the real average price of regular unleaded gasoline at time t in 2002\$;

$Rebate_{jt}$: a binary variable equals to one if model j qualifies at time t for a rebate under the Federal Auto feebate program;

Tax_{jt} : a binary variable equals to one if model j is taxed under the Federal Auto feebate program;

X_{jt} : other control variables. These include a set of 6 binary variables that controls for a progressive increase in sales of new models. Specifically, I_{jti} equals 1 at time t if model j has been first introduced i months ago with $i=1$ to 6. We also control for the progressive reduction in sales for models that are programmed to end. We thus introduced E_{jti} which is set equal to 1 at t if model j is being retired in i months with $i=1$ to 6. Note that these variables only applied for the introduction or retirement of a new model not a new model-year.²⁰ We also control for time varying economic indicators that may affect vehicles sales namely the level of income measured by $\ln(gdpcap_t)$ the log of the gross domestic product per capita and $\ln(iperso_t)$ the log the average interest rate on personal loans;

φ_{jd} : fixed effects for model j year d . As already mentioned, several MY of the same model may be sold during the same month. For example, in October 2007, 1547 new Honda Civic were registered in Quebec, 828 were MY 2007 and 719 MY 2008. We define the fixed effect φ_{jd} using month t dominant MY. In our example, this means that the fixed effect φ_{jd} corresponding to the 2007 Honda Civic is set to one. Alternatively, it is possible to assign to each φ_{jd} a value that measures the share of MY d in the monthly total sales of model j .²¹ However, one issue with

this approach is that φ_{jd} may become endogenous as it is defined using Q_{jt} . Thus our baseline uses the dominant MY. The results obtained with the alternative specification are discussed in section 6.

τ_m : month-of-the-year fixed effects ($m=1$ to 12) to control for recurrent variations in sales across the year;

τ_y : year specific fixed effects (with $y=2002$ to 2008);

ϑ_{jt} : a random term that has the following structure $\vartheta_{jt} = \delta_t + \epsilon_{jt}$ with δ_t a month-of-data specific random effects (with $t=1$ to 81) and ϵ_{jt} the usual error term. We assume that both terms are normally and independently distributed with mean zero and variance σ_δ^2 and σ_ϵ^2 respectively.

We now explain in more details the main features of our empirical model. First, the impact of gasoline price on sales is indeed allowed to vary with FCR which makes it possible to test for changes in sales patterns across models with different fuel economy.²² For example, if a gasoline price increase stimulates sales of efficient vehicles at the expense of inefficient ones, θ_1 should be positive and θ_2 negative.²³

Second, our model is static implying that consumers only react to current gasoline prices. This is a very common hypothesis in the literature on the demand for new vehicles and consumer valuation of energy efficiency investments. It is appropriate if gasoline prices follow a random walk. While some empirical work provides support to this hypothesis (see Davis and Hamilton, 2004, German, 2007), recent studies seem to challenge it (e.g. Baumeister, Kilian and Lee, 2015). However, even if gasoline prices do not actually follow a random walk, our specification is still adequate if consumers form their expectations about future gasoline prices using only the

current price (*i.e.* they act as if gasoline price follows a random walk). Recently, Anderson, Kellogg and Sallee (2013) analyze this issue using the monthly *Michigan Survey of Consumers*. This survey asks a representative sample of 500 respondents to forecast the price of gasoline over a five year horizon. The results indicate that the average consumer forecasts no change in real gasoline prices with respect to the current level thereby justifying our specification. There is however one exception that is relevant for our analysis. Following the financial crisis, the price of gasoline sharply dropped from September 2008 to December 2008 (see Figure 2). Anderson, Kellogg and Sallee (2013) show that during that period, the average US consumers were expecting a 15% to 20% rebound in gasoline prices. In other words during that period, current gasoline prices were not a good measure of consumer expectations about future gasoline costs. Moreover, the automobile industry was in deep turmoil during that period with great uncertainty on the fate of several manufacturers. For these reasons, we eliminate the last three months of the year 2008 in estimating our baseline model. In section 6, we explore the robustness of our results to both the inclusion of past gasoline prices and the inclusion of the last three months of 2008.

Third, the fixed effects φ_{jd} control for model j characteristics as well as for the mean characteristics of consumers buying this model. As models are updated annually these fixed effects are also time dependant but with a time pattern that does not fit calendar year but rather production cycle (thus subscript d is different than y). The specification also includes calendar year specific effects to control for yearly variations in the car market. Hence, the identification of the impact of the gasoline price rests upon the monthly relative variations in quantities across models of different fuel economy. Moreover, the inclusion of month-of-the-year dummies insures that these variations are not linked to recurrent seasonal patterns.

Fourth, we also account for the potential correlation in the quantities of the same month by the inclusion of the random term δ_t . This correlation could result from month-specific unobservable shocks that affect the LDV market. We treat this effect as random in order to be able to identify θ_1 . This supposes the absence of correlation between δ_t and the explanatory variables including P_t^g . While this hypothesis is debatable, it should be noted that our model includes time specific variables which should hopefully limit the risk of bias due to unobservable factors. To better assess the results robustness to this hypothesis, we also present the estimations obtained when pooling the observations (i.e. ignoring δ_t) as well as those with δ_t included as fixed effects.

Finally, it should be stressed that our analysis only measures the effect of gasoline prices on sales conditional on the existing supply of vehicles (i.e. given the φ_{jd}). In that respect, we only measure the short run effect of gasoline price. In the medium and long term, the characteristics of the new vehicles proposed by manufacturers also respond to gasoline price fluctuations (Knittel, 2011).

5. Results

Table 1 presents the estimation results with column (1), (2) and (3) reporting the results obtained without including δ_t , with δ_t as random and fixed effects respectively. We note very little differences between the results in (1) and (2) except may be for the variable *pibcap*. While a likelihood ratio test rejects the null hypothesis that $\sigma_t^2=0$, it should be noted that σ_t^2 only account for 2.3% of the total variance.²⁴ Comparing (2) and (3), both specifications led to very similar results for the variables that are common to both specifications.²⁵ Obviously, this does not guarantee that the coefficients for the time varying variables such as P_t^g are not biased by time-

specific unobservable factors. Still, the simulation results (discussed below) also lead to very similar conclusions.

The main advantage of the random effects specification is that it allows to identify a threshold FCR^* such that sales of vehicles with a FCR below that limit increase with gasoline price while the opposite occurs for values above that threshold. Based on Table 1 results, FCR^* equals 8.65L/100km.²⁶ The elasticity of the quantity sold with respect to the price of gasoline is given by $(\theta_1 + \theta_2 FCR_{jv})P_t^g$. For a *Toyota Corolla* with a FCR of 6.5L/100km, the elasticity is $0.37 P_t^g$ implying that a 10% increase in gasoline price around 1\$/L stimulate sales by close to 4%. For a *Ford Taurus* with a FCR of 10.2L/100km, the price elasticity is $-0.27 P_t^g$. This suggests non-negligible sale shifting following a change in gasoline prices at least for models with FCR very different than 8.65L/100km. However, note that over 60% of new vehicles registered are within a range of the threshold such as their elasticity is below $0.3P_t^g$ in absolute value. Thus, for a large share of vehicles, the impact of gasoline price on sales is not that high.

For comparison, recall that Li, Timmins and von Haefen (2009) find a threshold at 10L/100km for the US. Also, the estimate for the coefficient θ_2 can be directly compared to the estimate obtained by Klier and Linn in the US. In the most comparable specification, they find an estimate of -25.61.²⁷ These comparisons suggest a somewhat smaller impact of gasoline price on new vehicle efficiency in Quebec than in the US. This is likely due to the fact that the Quebec sales are already oriented toward more efficient vehicles than in the US.

Table 1. Equation regression results

	(1)	(2)	(3)
P_t^g	1.50*** (0.28)	1.48*** (0.27)	-
$FCR_{jv} \times P_t^g$	-17.45*** (2.59)	-17.12*** (2.08)	-17.02*** (2.18)
<i>Rebate</i>	0.19*** (0.06)	0.17** (0.08)	0.16* (0.08)
<i>Tax</i>	-0.04 (0.05)	-0.08 (0.05)	-0.09* (0.05)
$\ln(\text{pibcap})$	2.07* (1.09)	1.16 (2.17)	-
$\ln(\text{iperso})$	0.22 (0.24)	0.21 (0.43)	-
<i>Entry and Exit dummies</i>	yes	yes	yes
<i>Model-year dummies</i>	yes	yes	yes
<i>Month of the year dummies</i>	yes	yes	yes
<i>Year dummies</i>	yes	yes	yes
δ_t	no	random	fixed
R^2	0.90	-	0.90
σ_t	-	0.06 (0.006)	
σ_ϵ	-	0.42 (0.02)	
<i>LR test for $\sigma_t=0$</i>	-	167.1 (p-value<0.0001)	

Notes: the dependent variable is the logarithm of the monthly quantity of new vehicle registrations of a specific make-model. The number of observations is 14 734. The numbers in parenthesis are standard errors of the estimated parameter. For (1) and (3), we report the robust standards errors using Hubert-White sandwich estimators. For (2), the model is estimated by maximum likelihood. Coefficients for the fixed effects and those for the entry and exit dummies (*I* and *E*) are not shown.

* Means statistically significant at the critical level of $p < 0.1$, ** at $p < 0.05$ and *** at $p < 0.01$.

Source: Authors' calculations

Turning to the impacts of the feebate program, vehicles eligible to the rebate experience on average a 17% increase in sales. On the other hand, inefficient vehicles that are surtaxed see their sales reduced by 8 to 9%. This last effect is however only statistically significant in the fixed effects specifications. The overall impact of the feebate program on fuel economy is very small. Indeed, we compute that the average fuel economy would have been less than 1% higher in the absence of this program. Moreover, this figure is likely an upper bound since it is derived assuming that the rebate only generates additional sales.²⁸ In reality, the rebate is likely shifting sales at the expense of competing models that, even if they do not qualify for the rebate, are still quite fuel efficient. While, it could be argued that the program created incentives for manufacturers to improve fuel economy, this effect has most likely been very limited as the rebate only lasted less than two years.²⁹

Income per capita has a positive impact on sales but the effect is not statistically significant. This is likely due to the lack of variability of this variable when year fixed effects are included. The same is true for the interest rate on personal loans which do not even have the expected sign. Finally, note that all the binary variables that control for the introduction and disappearance of vehicle-models are statistically significant and have the right patterns (results available upon request). Sales of new models gradually take off while those of disappearing models progressively fade away.

Simulations

To gain a better insight on the magnitude of the overall composition effect, we simulate the registration structure by vehicle category over the last 12 months of our sample period (October 2007 to September 2008) assuming that the price of gasoline had remained the same as in 2002 at \$0.72.³⁰ This actually corresponds to a 35% drop with respect to the average gasoline price that was actually prevailing during this period. The results are reported in Table 2. The drop in gasoline price would reduce by 11% the share of small and medium cars - the most fuel efficient category. For intermediate and large cars, the reduction is somewhat smaller (-5%) while sport cars experience a 10% increase in their share. Overall the share of passenger cars would drop by 7.7% from 65.1% to 60.1%. This corresponds to an arc elasticity of 0.18.³¹ At the opposite side of the classification, the light truck segment sees its share increase by 16% from 34.5% to 40.1%. The SUV and VAN shares both increase by about 10% while the pickup share jumps by 35%. The average *FCR* of new LDV would increase by 3.6% following a 35% reduction in gasoline prices implying an arc elasticity of about -0.08. More than two thirds of this increase is due to changes in the sales structure across categories and less than a third to changes in sales pattern within each category.³² Also note that the gasoline price decline would stimulate the overall sales of new vehicles by about 2.5% suggesting an arc elasticity of -0.06. This is very close to Bento et al. (2009) that finds that a 17% increase in gasoline price reduces sales of new vehicles by 1% (i.e. an elasticity at 0.06).

Another worthwhile simulation exercise is to determine what the price of gasoline in 2008 would need to have been so as to counteract the growing trend of light trucks. In the last 12 months of our sample, the share of new registered light trucks was 34.5% compared to about 31% in 2002. Gasoline price in 2008 would need to have been 1.4\$/L to drive the share of light trucks down to

31%. This is a 26% increase with respect to the actual average price in 2008 and a doubling with respect to 2002.

Overall, these results suggest a non-negligible sale shifting for vehicles that are at the extreme of the fuel economy distribution, but for the bulk of vehicles the impact is far less important.

However, as gasoline price may experience large fluctuations, these may lead to noticeable consequences on the composition of sales across vehicle classes. Still, the resulting impact on the average fuel economy remains fairly modest. The corollary of these conclusions is that a substantial gasoline price hike would be needed to neutralize the growing appeal of larger vehicles.

Table 2. Simulated shares and average FCR for the period from October 2007 to September 2008 at actual and 2002 gasoline price

Category	Shares with actual gasoline price	Shares with 2002 gasoline price	Average FCR with actual gasoline price	Average FCR with 2002 gasoline price
CARS	65.1	60	7.69	7.78
Small-Medium	40.5	36.1	7.32	7.38
Intermediate-large	24.2	23.1	8.26	8.34
Sport cars	0.8	0.9	9.82	9.86
LIGHT TRUCKS	34.5	40.1	11.09	11.29
SUV	20.1	22.2	10.39	10.51
Van	6.4	7.1	10.44	10.48
Pickup	8	10.8	13.39	13.46
All LDV	100	100	8.87	9.19

The simulations are obtained using the coefficients of the random effects model.

Source: Authors' calculations

6. Robustness Checks

In order to evaluate the robustness of our results, we investigate several alternative specifications. In the baseline specification, we find a threshold $FCR^*=8.65L/100km$ but it could be argued that this limit may have moved down over time with technological progress. To examine this possibility, we reestimate the model on a subsample starting in 2006. The results are summarized in Table 3. In fact, FCR^* is somewhat larger at $8.9L/100km$ and the simulation indicates a somewhat larger sale shift following a gasoline price drop.

Second, buying a new vehicle is a process that takes some time so that a moving average of the price of gasoline during last three months before registering may be a better indicator for the buyer anticipations about the future of gasoline prices. With this specification, the threshold gets smaller at $FCR^*=7.5L/100km$. The simulation results also indicate a somewhat larger impact on the average FCR and the share of light trucks. We also explore the introduction of lag values for the price of gasoline P^g and the interaction term $FCR_{jv} \times P^g$. Using a general to specific approach with a maximum of six months lags, the Schwarz's Bayesian information criteria is minimized at zero lag (*i.e.* the results reported in section 5). However, the Akaike's information criterion is minimized with three lags. The results with three lags are reported in Table 3. The short run impact as measured by the coefficients on the current values is not that different compared to the base specification. The cumulative effect following a long lasting gasoline price decline suggests that almost all vehicles registrations increase ($FCR^*=4.72$). However, the impact is larger for vehicles with higher fuel consumption rates so that the simulated share of light trucks (40.7%) and the average fuel rates (9.23l/100km) are not that different than in the base model.³³

Next, we explore the potential impact of the functional form by replacing P_t^g and FCR in equation (1) by $\ln(P_t^g)$ and $\ln(FCR)$. The results are relatively close to those obtained with our original specification. We also estimate equation (1) separately on the subsample of passenger cars and light trucks so that the determinants may have different coefficients for these two categories (e.g. different seasonal pattern of sales). Figure 3 illustrates the impact of P_t^g on sales as a function of FCR (i.e. $\theta_1 + \theta_2 FCR$). The light truck segment appears somewhat more reactive to gasoline price than the car segment but the overall pattern is similar and the simulations in Table 3 are very close.

In our baseline specification, we use the dominant vintage to define φ_{jd} . Alternatively, it is possible to assign to each φ_{jd} a value that measures the share of MY d in the monthly total sales of model j (see footnote 19 for an example). The results are robust to this specification change.

We also estimate the model with the data corresponding to the last three months of 2008 and thus the sharp decline in gasoline price following the financial crisis. The results in Table 3 show that the estimated threshold FCR^* becomes quite large at 10.38L/100km which leads to the questionable implication that a decline in gasoline prices lowers overall sales of vehicles. For example, a decrease in gasoline price from 1.11\$ to 0.72\$ would result in a reduction of about 9% in total vehicle sales. This result is likely due to the unstable economic environment that prevailed at the end of 2008 with low gasoline prices and depressed vehicles sales.³⁴

Table 3. Alternative specifications results for the impact of gasoline price

Alternative specifications	θ_1	θ_2	FCR*	Simulation with $P_t^g=0.72\$$ from Oct. 2007 to Sept. 2008	
				Av. FCR	Share of light trucks
(1) Baseline	1.48***	-17.12***	8.65	9.19	40.1
(2) 2006-2008	2.19***	-24.7***	8.85	9.34	42.6
(3) Moving average	1.92***	-25.47***	7.52	9.34	42.5
(4) Three lags model					
Current effect	1.25***	-14.97***	8.41	9.14	39.2
Lag one	-0.30	-0.06			
Lag two	0.15	-2.45			
Lag three	-0.17	-2.36			
Cumulative effect ⁽¹⁾	0.94***	-19.84***	4.72	9.23	40.7
(5) Log-Log	4.04***	-1.85***	8.87	9.27	41.5
(6) Passenger cars	1.13***	-13.42***	8.43	7.76	
Light trucks	2.23***	-23.23***	9.62	11.38	38.7
All LDV				9.15	
(7) Vintage	-1.56***	-17.84***	8.76	9.21	40.2
(8) Financial crisis	1.88***	-18.14***	10.38	9.18	40

Notes: * statistically significant at the critical level of $p < 0.1$, ** at $p < 0.05$ and *** at $p < 0.01$. ⁽¹⁾ The cumulative effects are the sum of the current and lag variables. The statistical significance of the cumulative effect is obtained using an F-test.

Source: Authors' calculations

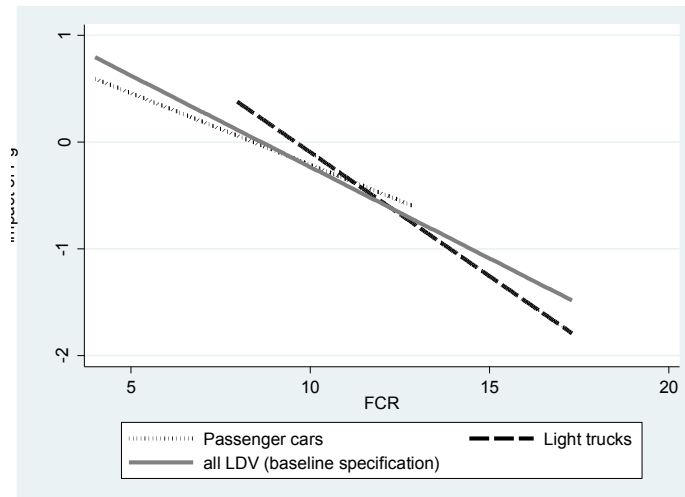


Figure 3. Impact of P_t^g on sales as a function of FCR with the base results and those on the subsamples of passenger cars and light trucks

Source: Authors' calculations

As a last robustness check, we directly estimate the impact of gasoline prices on the average fuel economy of new vehicles sold each month. This alternative model has the following structure:

$$\ln(FCR_t) = \mu_0 + \mu_1 \ln P_t^g + \mu_2 \ln(GDPcap_t) + \mu_3 \ln(iperso_t) + \mu_4 Feebate_t + \tau_m + \tau_y + \vartheta_t \quad (2)$$

In this setting, the variable *Feebate* is a binary variable which is set to one after March 2007 when the feebate program went into effect. The results of this model are reported in Table 4.

The elasticity of the *FCR* with respect to gasoline price is estimated at -0.08 which is identical to our baseline finding. The simulated 2007-2008 average *FCR* with a gasoline price of 72 cents is 9.16L/100km which is also very close to our baseline.

All these alternative specifications confirm that gasoline prices have an impact on the composition of new vehicles by fuel economy but with relatively modest consequences on the average fuel economy. This conclusion is very much in line with recent US research.

Furthermore, the composition effect in Quebec appears somewhat smaller than in the US which is likely due to the fact that Quebec fleet is already more efficient.

Table 4. Estimation results of equation (2)

<i>Ln(FCR)</i>	
<i>Ln(P_t^g)</i>	-0.08*** (0.01)
<i>Ln(pibcap)</i>	0.17 (0.20)
<i>Ln(iperso)</i>	-0.06 (0.04)
<i>Feebate</i>	0.00 (0.005)
<i>Year 2002</i>	Ref
<i>Year 2003</i>	-0.005* (0.003)
<i>Year 2004</i>	-0.015*** (0.005)
<i>Year 2005</i>	-0.013 (0.007)
<i>Year 2006</i>	-0.017 (0.01)
<i>Year 2007</i>	-0.015 (0.01)
<i>Year 2008</i>	-0.036** (0.015)
<i>R-square</i>	0.93
<i>N</i>	81

In parenthesis, robust standard deviation

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Authors' calculations

7. Conclusions

In this paper, we have evaluated the short term impact of gasoline price on the composition and average fuel economy of new vehicles registered in the province of Quebec. We find a statistically significant compositional effect: sales of efficient vehicles increase with gasoline prices while the opposite occurs for the inefficient ones. While the impact is modest for the majority of vehicles, a large gasoline price fluctuation can still lead to noticeable changes in the structure of sales by vehicle classes. The impact on the average fuel economy of new vehicles remains in any case rather modest. These results also imply that gasoline prices would have to considerably increase to counteract the growing popularity of light trucks. In fact, we evaluate that gasoline prices should have doubled for the share of light trucks in Quebec to remain stable from 2002 to 2008.

We find that the impact of the federal feebate program between 2007 and 2008 increased sales of low-fuel consumption eligible vehicles by 17% and decreased by 8 to 9% the sales of high-fuel consumption cars. These tangible gains and losses in sales contrast with the overall impact on fuel economy: it essentially remained unchanged. This was in part due to shifting sales from close substitutes where one type of vehicle qualifies for a rebate and its sales increase at the expense of very similar car models with a fuel economy just under the eligibility threshold. Another factor is the short time span of the program of less than two years.

It is important to recall that in all our results we only measure short run effects, which are essentially driven by the demand side. The medium and long run response of both consumers and manufacturers remains to be better understood.

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¹ In Canada for instance, there exist proposed increases in gasoline taxes that fall short of the second-best levels (see Wood, 2015) and rebate programs to incentivize purchases of electric vehicles (see Mercier et al., 2015). Concerns about the externalities from automobile pollution in Canada have been present for several years (see Urmetzer et al., 1999).

² See NHTSA (2012).

³ Other alternative instruments have also been put in place in Quebec such as the cap-and-trade program for emissions that is linked to California (see Barrington-Leigh et al., 2015). At a more local scale, there have also been efforts to reduce the use of vehicles when commuting but the impacts seem to be rather small (see Barla et al. 2015).

⁴ For example, D. Flavelle (2015), « Drivers trade up as gas price fall », Toronto Star, January 6, 2015 [Retrieved from: http://www.thestar.com/business/2015/01/06/drivers_trade_up_as_gas_prices_fall.html]

⁵ In the short run, manufacturers may, for example, adjust vehicle prices.

⁶ Light duty vehicles are those with a gross vehicle weight of less than 3855 kg (8500 lb.) or a curb weight of less than 2722 kg (6000lb.) (see Natural Resources Canada, 2008).

⁷ The sign of the elasticity is negative as we use the fuel consumption rate rather than MPG.

⁸ For a reason that will be clarified in section 4, our empirical model is estimated on data up to September 2008 i.e. just before the sharp drop in gasoline price caused by the financial meltdown.

⁹ These two protocols are those used in the US to assess compliance to the CAFE standards. They were developed in the late seventies and therefore do not represent very well actual driving conditions. These rates are thus adjusted upward following the procedure used by *Natural Resources Canada* (+22% for city *FCR* and +10% for highway *FCR*).

¹⁰ The last category includes subcompact, compact and two seaters that have a cylinder larger than three liters.

¹¹ For the US, the comparison is based on fuel rates reported by manufacturers (USDOT National Transport Statistics Table 4-23 and US Census, Statistical Abstract 2012 Table 1069). For the comparison with the rest of Canada, the fuel rates are measured in actual driving conditions (see Natural Resources Canada, 2008).

¹² For Canada and Quebec, the figures are for 2008 (Natural Resources Canada, 2010 and Barla, 2011). For the US, the figure is for the year 2012 (National Archives and Records Administration, 2010).

¹³ The quantile is defined on the supply of models available in 2008.

¹⁴ This figure is derived from table 7 of Busse et al. (2013, p. 238). It is based on national sales from 1999 to 2008. The quartile is redefined each year based on the available models. Comparable figures are unavailable for the rest of Canada.

¹⁵ Obviously the long term trends are also likely influenced by gasoline prices.

¹⁶ Very often only manufacturer suggested prices are available which may differ from actual transaction prices.

¹⁷ For example Bento et al. (2009) aggregate vehicles in 10 groups. Moreover, structural models à la Berry, Levinsohn and Pakes (1995) may pose serious problems of convergence as recently shown by Knittel and Metaxoglou (2014).

¹⁸ To simplify the presentation, we refer to a ‘model’ *j* when in fact it is technically a ‘make-model’ *j*.

¹⁹ Unfortunately, we cannot identify vehicles that were already registered in another province or abroad and thus are not new. This issue may be more problematic for MY corresponding to calendar year minus one. Thus, we impose that the registration of this type of vehicle should occur during the first quarter of the year to be considered as new. In other words, a 2006 Honda Civic registered in May 2007 is not considered new.

²⁰ For example, the first registered Mazda 3 appears in November 2003.

²¹ Using the same example as before we would have for October 2007 $\varphi_{Civic,2007} = \left(\frac{828}{1547}\right)$ and $\varphi_{Civic,2008} = \left(\frac{719}{1547}\right)$.

²² Li et al. (2009) use a similar functional form but to explain the quantity of vehicles by quantile of the *FCR* distribution.

²³ Alternatively $(\theta_1 + \theta_2 FCR_{jt})P_t^g$ can also be expressed as $\left(\frac{\theta_1}{FCR_{jt}} + \theta_2\right)cpk_{jt}$ with $cpk_{jt} = FCR_{jt} P_t^g$ i.e. the fuel cost of driving a km.

²⁴ In fact, the random effect model has to be estimated by maximum likelihood as the GLS estimates lead to a corner solution with $\sigma_t^2 = 0$.

²⁵ As the random and fixed effects models have different regressors, the traditional Hausman specification test is not applicable.

²⁶ This value is obtained by solving $(1.48 - 17.13 FCR) = 0$.

²⁷ We adjusted their coefficient to account for the difference in units (MPG versus L/km).

²⁸ Indeed, our model does not allow us to identify the impact of the rebate on sales of competing models that are not eligible for the rebate. Some of this impact is however likely captured in the MY fixed effects. When simulating the impact of the rebate, we implicitly assume that the rebate only generates new sales which is obviously restrictive. The same is true for the tax.

²⁹ The tax on inefficient vehicles is however still in place.

³⁰ Recall that we eliminate the last three months of 2008 so that the last twelve months of our sample start in October 2007.

³¹ The arc elasticity is computed as follows: $\frac{((65-60.1)/62.5)}{((1.11-0.72)/0.92)}$

³² To calculate these figures, we evaluate the average *FCR* using the category shares at actual price (column 2) but with the *FCR* by category at $P = \$0.72$ (column 5). This leads to 8.94L/100km. Thus, the 3.6% increase can be decomposed in 2.8% due to variations in registrations across categories and 0.8% due to changes in registrations within each category.

³³ Note that this specification implies a cumulative elasticity of the number of new registrations with respect to gasoline price of -0.7 which appears to be quite large.

³⁴ In December 2008, sales were 35% lower than in December 2007 while gasoline price was 30% lower.