FEATURE ARTICLE

THE COSTS AND BENEFITS OF FUEL-EFFICIENT CARS: HOW HIGH ARE THE RETURNS?

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EXECUTIVE SUMMARY

- This article examines the costs and benefits of buying a car that is more fuel-efficient.
- Our findings suggest that fuel-efficient cars tend to be more expensive – a 10 per cent increase in fuel efficiency is associated with a 0.6 per cent increase in price. However, fuel savings from fuel-efficient cars, paid across the lifetime of the car, are likely to outweigh this price premium.
- Taking into account the rebates and surcharges under the newly-introduced Carbon Emissions-based Vehicle Scheme (CEVS), we find that the returns to investing in a fuel-efficient car rise significantly. This suggests that the CEVS could help to incentivise more buyers to purchase fuel-efficient car models.

The views expressed in this paper are solely those of the authors and do not necessarily reflect those of the Ministry of Trade and Industry or the Government of Singapore.

BACKGROUND

As part of Singapore's efforts to combat climate change, the Land Transport Authority (LTA) introduced the Carbon Emissions-based Vehicle Scheme (CEVS) in January 2013 to encourage consumers to buy car models which are more carbon efficient. The CEVS gives buyers of carbon-efficient cars a rebate which is used to offset against the vehicle's Additional Registration Fee (ARF). From July 2013 onwards, buyers of carbon-inefficient car models will also face a registration surcharge.

To understand the possible impact of the CEVS on consumers' incentive to purchase carbon-efficient cars, we first estimate the returns to buying a fuel-efficient (and hence carbon-efficient) car in the absence of the CEVS. This takes into account the upfront costs of purchasing the car, as well as the fuel savings derived from driving a more fuel efficient car. We then incorporate the rebates and surcharges provided under the CEVS to examine the extent to which the CEVS will help to raise the returns to buying a fuel-efficient car.

THE COSTS AND BENEFITS OF BUYING FUEL-EFFICIENT CARS

The key benefit of buying a fuel-efficient car compared to one that is less efficient is that the car owner will be able to save money on fuel. However, these fuel savings may be eroded by higher upfront costs if fuel-efficient cars are more expensive than the less efficient ones.

To ascertain the costs and benefits of purchasing a fuel-efficient car, we should ideally compare the prices and fuel savings of cars which are similar in all aspects except for their fuel efficiency. However, it is not possible to find such "identical" cars for comparison among the car models sold in 2011.

Our strategy is thus as follows. <u>First</u>, we estimate the price premium that fuel efficiency commands through an econometric model. <u>Second</u>, using the regression results, we find out what the price premium would be for a hypothetical car that is 10 per cent more fuel efficient than each of the existing car models. <u>Finally</u>, we compare this price premium with the fuel savings that the more efficient car can generate to obtain the returns to investing in a fuel-efficient car.

Fuel-efficient cars are more expensive…

Finding the price premium that comes with fuel efficiency is not as straightforward as simply comparing the prices of two car models with different degrees of fuel efficiency. This is because apart from fuel efficiency, a car offers a bundle of different features like engine capacity, body type and brand, all of which would have an impact on the price of the car. To illustrate, the difference in the Open Market Value (OMV) of two hypothetical models, Car A and Car B, in Exhibit 1 is $16,000. While the latter is more fuel efficient, the higher price may also be due to bundled features such as a retractable roof and larger engine capacity.

Exhibit 1: Comparative Illustration

Car Model	Car A	Car B
OMV ($)	55,000	71,000
Fuel Consumption (l/100km)	10.2	7.7
Engine Capacity (cc)	2,400	4,000
Body Type	Sedan	Convertible

Hence, to isolate the impact of fuel efficiency on car prices, we run a hedonic regression that controls for other key attributes of the car, including engine capacity, transmission type and brand. Our regression utilises data on all cars purchased in Singapore in 2011.[1]

We report the full regression results in Annex A. As expected, we find that fuel-efficient cars tend to be more expensive than less efficient ones, holding other attributes constant. On average, a 10 per cent increase in fuel efficiency leads to a 0.6 per cent increase in the OMV and consequently, the basic cost of the car which includes the ARF and other fees.

…but returns to investing in a fuel-efficient car are generally positive due to fuel savings

We next compute the price premium associated with a 10 per cent improvement in the fuel efficiency of the various car models.

As an illustration, suppose that Car C is similar to Car A in all aspects, except that it is 10 per cent more fuel efficient. Based on the regression results, the greater fuel efficiency will result in Car C being $820 more expensive than Car A (Exhibit 2). However, the improved fuel efficiency will also lead to greater fuel savings. Assuming an annual mileage of 19,100 km (based on the average mileage in Singapore), we estimate that fuel savings can add up to $1,360 over the lifespan of the car, which is assumed to be 5 years.[2] In Net Present Value (NPV) terms, the fuel savings net of the higher upfront cost of buying Car C will amount to $540, if we assume a discount rate of 10 per cent[3] (details of the formula used to compute the NPV are in Annex B).

[1] Source: Land Transport Authority.
[2] Data on average lifespan and average annual mileage are from LTA. We assume that the mileage and lifespan do not change with fuel efficiency (i.e., there is no rebound effect). The petrol prices used in the computation are based on the International Energy Agency's projections of future oil prices.
[3] Verboven (1999) finds that discount rates vary between 5 – 13 per cent for car purchases in Europe, while Busse, Knittel and Zettelmeyer (2012) find that they range from 0 - 20 per cent for car purchases in the United States.

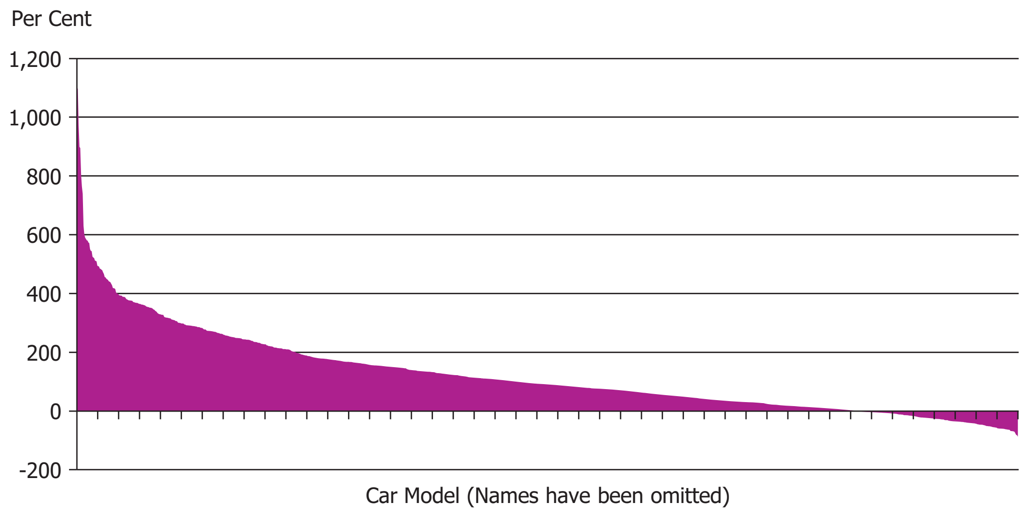
Exhibit 2: Illustration of Costs and Benefits

Car Model	Premium ($)	Total Fuel Savings ($)	Net Present Value of Benefits ($)
Car C, which is 10 per cent more fuel-efficient than Car A	820	1,360	540

To a car buyer, the return on investment (ROI) of switching to Car C from Car A – defined as the NPV of the benefits of buying Car C divided by the price premium of Car C over Car A – is then 66 per cent. The positive NPV and ROI suggest that the consumer will enjoy net monetary benefits from buying the car that is more fuel efficient, i.e., Car C.

Doing the same computation for all the car models in the dataset, we find that the NPV and ROI are positive for 83 per cent of the car models purchased in 2011 (see Exhibit 3 for the ROI). While this is an encouraging result, our assessment is that there may be scope to tilt the balance further in favour of fuel-efficient cars to incentivise the purchase of such cars. There are two reasons for this. First, the median NPV works out to only $510, implying that the net benefits of fuel-efficient cars are small in many cases. Second, even though the net benefits are positive in the majority of cases, the benefits in the form of fuel savings will only accrue to the buyer over 5 years, whereas the higher cost of the car has to be paid upfront.

Exhibit 3: Average ROI from raising fuel efficiency by 10 per cent



Source: Authors' calculations

COSTS AND BENEFITS OF FUEL-EFFICIENT CARS WITH CEVS

Introduced in January 2013, the CEVS will give carbon-efficient cars a rebate to be offset against the vehicle's ARF, while the less efficient cars will face a registration surcharge.[4] The details of the scheme are summarised in Exhibit 4.

Exhibit 4: CEVS Rebates and Surcharges Schedule

Band	Carbon Emissions (CO_2 g/km)	Rebate* ($)	Surcharge ($)
A1	0 to 100	20,000	
A2	101 to 120	15,000	
A3	121 to 140	10,000	
A4	141 to 160	5,000	
B	161 to 210	0	0
C1	211 to 230		5,000
C2	231 to 250		10,000
C3	251 to 270		15,000
C4	271 & above		20,000

* Subject to a minimum ARF payable of $5,000.

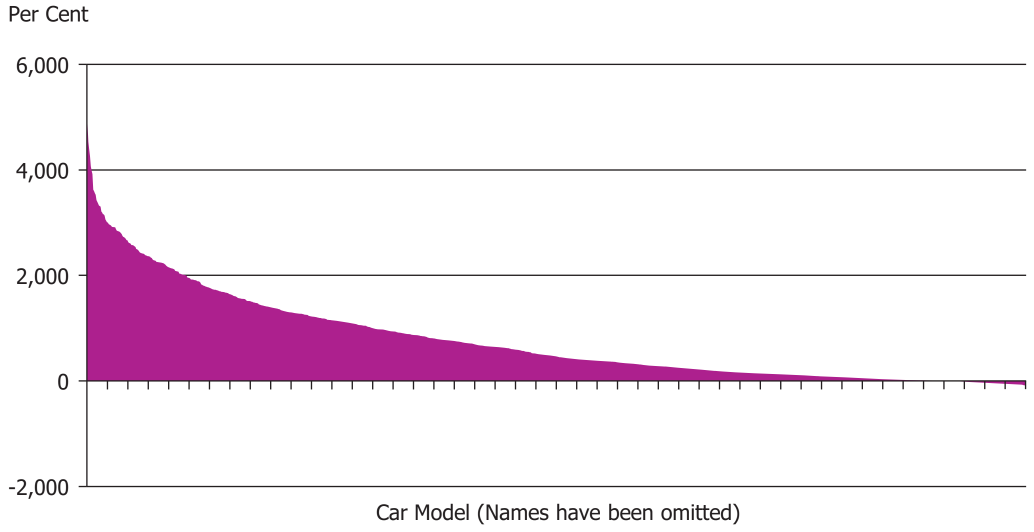
Using fuel efficiency as a proxy for carbon efficiency, we repeat the earlier simulation, where we increase the fuel efficiency of all car models by 10 per cent, but this time incorporating the CEVS rebates and surcharges. We find that the NPV of the benefits as well as the ROI increase significantly when a buyer switches to a car that is more fuel efficient, holding other attributes constant (Exhibit 5). This is because the more efficient car is likely to be in a better rebate/surcharge band, thus leading to savings of $5,000 or more.[5]

Specifically, with the CEVS, the median NPV of the benefits of switching to a more fuel efficient car rises from $510 to $5,030. Moreover, the NPV and ROI are negative for only 8.5 per cent of car models, compared to 17 per cent without the CEVS. These, along with the fact that the rebates/surcharges are paid upfront, suggest that the CEVS could indeed incentivise more consumers to switch to fuel-efficient cars.

[4] While rebates will apply to new cars, taxis and newly imported used cars registered with effect from 1 January 2013, surcharges will be levied from 1 July 2013.

[5] We assume for simplicity that car sellers will not absorb any part of the CEVS rebates for the more fuel efficient cars by raising the price of the car. There is some evidence to support this. For instance, Sallee (2011) studied the incidence of tax incentives for the Toyota Prius in the US, and found that both federal and state incentives were fully captured by consumers.

Exhibit 5: Average ROI from raising fuel efficiency by 10 per cent under the CEVS



Source: Authors' calculations

CONCLUSION

Using a hedonic regression, we find that, on average, a 10 per cent increase in fuel efficiency leads to a 0.6 per cent increase in the OMV of the car. Despite this, the returns to investing in a fuel-efficient car are often positive, as the fuel savings that will accrue to the car owner tend to offset the higher price for most car models. In our simulation, 83 per cent of car models purchased in 2011 enjoy a positive return from a 10 per cent increase in fuel efficiency.

However, when consumers switch to cars that are more fuel efficient, they often have to sacrifice certain attributes. For example, fuel-efficient cars tend to have a lower engine capacity. Such considerations may affect the consumer's decision on whether to purchase the fuel-efficient car.[6] Nevertheless, our findings suggest that the CEVS will likely increase the monetary returns to investing in a fuel-efficient car significantly. The CEVS may thus go some way towards helping to incentivise more consumers to purchase fuel-efficient cars.

Contributed by:

Kenny Goh, Senior Economist
Huang Jianyun, Senior Economist
Ow Wei Yi, Research Assistant
Economics Division
Ministry of Trade and Industry

[6] For example, Ewing and Sarigöllü (2000) found, in a discrete choice experiment in Canada, that vehicle performance characteristics were critical to car buyers' choices.

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ANNEX A: REGRESSION RESULTS

To estimate the price premium that fuel efficiency in a car commands, we run the following hedonic regression that controls for other key attributes of the car, including engine capacity, transmission type and brand:

$$\log(OMV_i) = \beta_0 + \beta_1 \log(fuel_i) + \beta_2 \log(cc_i) + \delta D_i + \varepsilon_i$$

Where

OMV_i	=	open market value of car
$fuel_i$	=	rate of fuel consumption, represented in litres per 100km
cc_i	=	engine capacity
D_i	=	a matrix of dummy variables representing the following:

- Type of propellant: biofuel, diesel, hybrid
- Whether the vehicle is a taxi
- Body of car: MPV, SUV, cabriolet, convertible, coupe, hatchback, limousine, pickup, roadster, wagon
- Brand of car: 49 different brands were included
- Year of manufacture
- Type of transmission: CVT, manual, semi-automatic

The regression results are as follows:

Variables	Coefficient		
	(1) Basic log (OMV_i)	(2) With dummy variables $\log(OMV_i)$	(3) Personal transactions only $\log(OMV_i)$
$\log(fuel_i)$	-0.459***	-0.124***	-0.0594***
$\log(cc_i)$	1.802***	1.269***	1.215***
Dummy variables included?	No	Yes	Yes
Constant	-2.348***	1.571	1.143***
Observations	22,144	22,141	18,663
R-squared	0.651	0.924	0.924

* Significant at 10% significance level
** Significant at 5% significance level
*** Significant at 1% significance level

Specification (1) is a basic regression incorporating only the OMV_i and $fuel_i$ variables. Specification (2) adds the entire suite of dummy variables. Specification (3) restricts the data set to only cars sold for personal use, with corporate purchases, such as taxis, dropped from the data set.

ANNEX B: NET PRESENT VALUE (NPV) OF BENEFITS OF DRIVING A FUEL-EFFICIENT CAR

The following formula is used to calculate the NPV of switching from a particular car model i to a version of the same car that is 10 per cent more fuel efficient:

$$NPV_i = PV\,(fuel\ savings) - PV\,(premium)$$

$$= \sum_{(t=0)}^{5} \left[\frac{(F_1\text{-}F_2)(P_t)}{(1+r)^t} \right] - (C_2 - C_1)$$

Where

F_1	=	annual fuel consumption of car i
F_2	=	estimated annual fuel consumption of car i with 10 per cent greater fuel efficiency
P_t	=	price of fuel in year (2011 + t)
r	=	discount rate, assumed to be 10 per cent
C_1	=	total basic cost of car i
C_2	=	estimated total basic cost of car i with 10 per cent greater fuel efficiency

F_1 and F_2 are calculated as follows:

$$F_1 = \textit{rate of fuel consumption of car i} \times \textit{mileage}^7$$

$$F_2 = (0.9 \times \textit{rate of fuel consumption of car i}) \times \textit{mileage}$$

Similarly, C_2 is calculated as follows:

$$C_2 = (1 - 0.1\beta_1\ )\ C_1$$

Where β_1 is the coefficient on log ($fuel_i$) obtained from the regression in Annex A.

[7] Assuming a fixed annual mileage of 19,100 km, which is the average annual mileage estimated by LTA. Rate of fuel consumption is in litres per 100 km.