Backcasting energy saving and CO2 emission reductions

by using feebate system in Japan
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Synopsis

This paper outlines an attempt to design a model of CO₂ reduction: “feebate”.

The impact of feebate is evaluated by change in living expenditure.

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Abstract

After the Kyoto Conference (COP3), the Japanese transport sector was required to reduce carbon dioxide (CO$_2$) emissions by 16% by 2010. The Japanese government has decided to improve the fuel economy standard in 2010 by improving it by an average of 22.8%. However, Japanese consumers tend to prefer heavier passenger cars such as four-wheel drive or recreational vehicles. Because of the difficult target of COP3, environmental policy should involve not only automotive technologies but also non-technical measures.

Since Japanese vehicle taxes are expensive compared to other OECD countries, we would like to introduce the “feebate”, a word composed from “fee” and “rebate”, as a “Green Tax” at the acquisition stage. The feebate system charges a fee for less fuel-efficient vehicles and refunds for vehicles more fuel efficient than the fuel efficiency standard. This system is a market based alternative by fuel efficiency standards so that it can be tax neutral. Acquisition tax does not affect to environmental sustainability. Since social marginal cost has increased more and more, it is not always realistic to impose all the costs at the motoring tax level. The feebate system could partially share the social marginal cost and might mitigate the rebound effect at the motoring stage.

We use the data set from 1995-2001 on fuel efficiency by vehicle type and the fuel efficiency standards of 1995. The contribution of this paper will be to propose a combination of feebate rate and CO$_2$ emission reduction by vehicle gross weight group.
Introduction


The Japanese transport sector has been required to reduce carbon dioxide (CO$_2$) emissions by 16% by 2010. The new strategy of CO$_2$ reduction of the Japanese government emphasizes modal shift, fuel economy improvement and the top runner method as measures. In these technical measures, the Japanese government reduces the acquisition tax for clean energy vehicles, such as electric or natural gas powered vehicles. The government started a labelling system in 2000 of from 1 to 3 stars according to emission and fuel standards. Vehicles with environmentally higher performance receive more stars. In 2001, the government linked the 3 star to the vehicle taxation system Japan also offers a separate reduction in the acquisition tax and vehicle taxes for vehicles that meet certain emission and fuel economy targets. The tax incentives for low-emission vehicles raised the sales of low-emission vehicles by 63% from 2000 to 2001. However, CO$_2$ emissions are growing rapidly. The emissions have increased by 21% in 2000 from the level of 1990, which means that Japan has to reduce 4% more than that estimate.

There are several reasons why CO$_2$ emissions have increased rapidly. First, GDP and other factors affect car ownership and car ownership affects vehicle kilometre distance. Second, the average fuel economy has improved so that the consumer may drive longer distance (The rebound effect). Third, a tax reform of the year 1989 let consumers purchase heavy passenger vehicles. Since 1994, sales of sport utility vehicles (SUV) have boomed and so energy consumption and annual
traffic volume have increased.

The Japanese national strategy may have expected too much from on technological progress. The question arises as to to what extent these relationships are modified by transportation and environmental policies. This paper is an attempt to introduce a non-technical system called “Feebate” to complement the technical measures.

Figure 1  JARI car stock model

2. Fuel economy regulation in Japan

2.1 Total marginal CO₂ emissions by fuel regulation scenario

There are only two fuel efficiency regulations and one voluntary agreement all over the world. The US regulation “CAFE” set average fuel efficiency as a standard level. European voluntary agreement set a unique limit of CO₂ emission for each vehicle. The most significant characteristic of Japanese fuel economy regulation is
nine standards by nine weight class categories. The government concerned equality between weight classes to carry out the standard by weight class. On April 1st, 2000, new Japanese fuel economy standards for gasoline and diesel passenger cars were carried out toward a 2010 goal 16% of CO2 reduction.

The disadvantage of the Japanese regulation is the low incentive for weight reduction because the heavier car category has a lower improvement rate. Some manufacturers may shift their products to the heavier category. This would make it easier to respect the fuel efficiency regulation. Weight reduction requires high research and development costs.

Another disadvantage of the Japanese regulation is the lack of integration between the fuel efficiency regulation and other regulations, which affect increases in weight and fuel consumption. The proposed scenarios are more severe fuel economy values for gasoline passenger cars, because the scenarios integrate road security and emissions gas regulations. Here are the three scenarios developed from the fuel economy standard of 1995. Each scenario has a different technological improvement and diffusion rate (Table 1).

Table 1: Scenario description

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Summary of the description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulation</td>
<td>Fuel economy standard 2010 + Safety + Noise + Emission standard 2005</td>
</tr>
<tr>
<td>Environment</td>
<td>Estimation of Environmental Agency</td>
</tr>
<tr>
<td>Technology</td>
<td>Maximum rate of technological improvement</td>
</tr>
</tbody>
</table>
Figure 2 is the result of the scenario descriptions. Scenarios “regulation” and “technology” are based on data of the MOT report. The Scenario “environment” is made by using the data of the Environmental Agency Report.

The Scenario “regulation” supports technologies based on safe car bodies, safety devices, and ITS technologies in the market. The scenario “environmental regulation” includes emission gas regulation and noise regulation. Through noise control by both vehicle technology and road infrastructure, the noise of motor vehicles cruising on roads could be reduced by 2 to 3 decibels.
2.3. Feebate level per vehicle by scenario

What level is optimal for fuel economy scenarios in terms of CO\textsubscript{2} reduction? In this section, optimal feebate levels will be calculated. The following equations (1) and (2) describe the simulation of feebate revenue based on the fuel economy scenario.

The total of car sales 2000-2010 is estimated by JARI model. Under the total car stock, each weight class is maximized the number of car (1). According to the JAMA market survey for passenger vehicles, the report point out that the life style has something to do with car choice. For example, housewives tend to drive mini cars. Elderly men prefer compact type of vehicle. Their preferences are weighted under the total number of vehicle.

\[ CS = \sum_{i=1}^{9} cs_1 + cs_2 + cs_3 + \ldots + cs_9 \]  \hspace{1cm} (1)

With respect to the cost of fuel economy improvement, the Department of Energy in the US estimates the costs of the parts. With respect to technological progress, JARI report 1999\textsuperscript{4} and JAMA estimate the rate of improvement. Using these two kinds of data, we estimate the average cost of fuel-efficiency improvement. It costs 1995US $84 per vehicle to improve fuel economy by 1 %. It costs 1995US $89 for a 2-3 % fuel efficiency improvement. It costs US$101 for 4 % in fuel efficiency improvement. It costs US 1995 $125 for more than 4% in fuel economy improvement. Using sales of the year 1995 and their fuel economy values, we can determine feebate revenue by vehicle weight.

\[ FR = \sum_{i=1}^{n} \left[ FE_{\text{real}} - FE_{\text{standard}} \right] * fee_i * cs_k \]  

**FR**: feebates revenue  
**\( FE_{\text{real}} \)**: fuel economy of a car  
**\( FE_{\text{standard}} \)**: fuel economy standard  
**fee**: cost of fuel economy improvement  
**\( cs \)**: Car sales by category  
\[ k: \text{number of car by category} \quad k = 1\sim9 \]  
**n**: improvement rate  
\[ n = 1\sim4 \]

If severer fuel efficiency standard is introduces, CO\(_2\) emissions will be reduced. The safety regulation scenario reduces by 2.3% per year from the fuel efficiency standard 2010 (BAU). Environment scenario reduces by 11.5% of CO\(_2\) emissions. Technology scenario reduces by 24.8% from BAU.

How about the levels of fee and rebate change? The feebate\(^5\) system adjusts prices of new cars in favour of fuel consumption. Gas-guzzlers are charged fees. Gas sippers get rebates. Feebate encourages both consumers and producers to choose fuel-efficient vehicles. In the short term, price incentives encourage consumers to buy cheaper, more fuel-efficient vehicles. Demand-side responses influence total vehicle sales. This effect is reflected in the sales-weighted average of fuel consumption.

**Figure 3** is a result of our calculation on fee and rebate per vehicle. The closer to the year 2010, the higher the fee the consumer has to pay. The level of rebate does not climb as high when compared to the fee level, but it may be an incentive to buy a less energy consumptive car. When the costs are divided by the number of cars in the upper range of each scenario, which is the rebate by scenario.

\(^5\) The feebate term is a combination of “fee” and “rebate”.

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9
Figure 3 Fee and rebate per vehicle by 2009

3 IMPACT OF FEEBATES ON LIVING EXPENDITURE

3.1. Estimates of private car and maintenance expenditure

If consumers became aware of the advantages of purchasing fuel-efficient cars, producers would manufacture fuel-efficient cars. The incentives of feebate also affect the supply side\(^6\). In the long run, car manufactures will tend to produce more

fuel-efficient cars because feebates may help pay for additional fuel-economy technology.

If optimal feebate levels are introduced in Japan, how will it impact living expenditure? In this section, we discuss the effects of changes of annual vehicle purchase costs on living expenditure per household. Impacts on living expenditure must be different on fee and rebate sides in the case that a consumer buys a vehicle once between 2001 and 2010.

The trend of expense per household could be expressed as a Constant Elasticity System Function (CES function). The CES function provides us for the elasticity, coefficient of vehicle diffusion and coefficient of efficiency, which determine annual cost for a private vehicle. Supposing that the cost of a private car consists of purchase $X$ and maintenance costs $Y$.

\[
U = \gamma (\delta X^{-\rho} + (1 - \delta)Y^{-\rho})^{-\frac{1}{\rho}}
\]

$X$: average price of a private vehicle  
$Y$: annual maintenance cost  
$U$: annual cost for a private vehicle  
$\rho$: elasticity  
$\delta$: coefficient of vehicle diffusion  
$\gamma$: coefficient of efficiency

For the projection from 2001 to 2010, the expenditure on a private car increased at average rate of 6.7% between 1976 and 1998. The function is linearized by Taylor’s series. While price change will influence expenditure in the same period in the static model, the time lag between price change and expenditure will be considered in the dynamic model. This is because car purchase cost increases when the income of the previous year increases. The time lag “polynomial distributed lag
model” $U_{t-1}$ is integrated in equation (4). If the car price changes, the effect of car price is supposed to influence purchase cost next year.

$$\log U^*_t = \beta_0 + \beta_1 \log X_t + \beta_2 \log Y_t + \beta_3 \log \left[ \frac{X_t}{Y_t} \right]^2 + \varepsilon_{t1}$$  \hspace{1cm} (4)$$

where $\log U^*_t$ is estimated expenditure in period $i$.

$$\log U_t - \log U_{t-1} = \theta (\log U^*_t + \log U_{t-1}) + \varepsilon_{t2}$$  \hspace{1cm} (5)$$

Where,

$\beta_0 = \log \gamma \hspace{1cm} \beta_1 = \delta \hspace{1cm} \beta_2 = 1 - \delta$

$\beta_3 = -\frac{1}{2} \rho \delta (1 - \delta)$

$U$: utility (annual purchase cost of private car)

$X$: price of private car

$Y$: maintenance cost of private car

$\varepsilon$: disturbance

$t$: time

$\theta$ is adjustment speed. $0 \leq \theta \leq 1 \hspace{0.5cm} \theta = 0.8$

From (5) and (6), it yields (7)

$$\log U_t = \theta \beta_0 + \theta \beta_1 \log X + \theta \beta_2 Y + \theta \beta_3 \left[ \log \left( \frac{X}{Y} \right) \right]^2 + (1 - \theta) \log U_{t-1} + \varepsilon_t$$  \hspace{1cm} (6)$$

where $\varepsilon = \theta \varepsilon_{t1} + \varepsilon_{t2}$

The estimation of the dynamic model is as follows: ( ) = t value. Under the feebate system, the fee is added to the car price, while the car price is reduced on the rebate side in $X'$.

$$Log U_t = -4.686 + 0.663 \log X' + 0.306 \log Y + 0.340 \left[ \log \left( \frac{X}{Y} \right) \right]^2 + 13.7 \log U_{t-1} + \varepsilon_t$$  \hspace{1cm} (7)$$

(4.034) (1.888) (21.923) (0.831) (7.223)
\[ R^2 = 0.981 \quad Adjusted \ R^2 = 0.976 \]

Durbin Watson statistics = 2.45

In order to estimate impacts on living expenditure, data of the annual report on the family income and expenditure survey is used for purchase cost projection toward 2010. In 1995, most real fuel economy on new gasoline passenger car sales was below the fuel economy standard of 2010. All new cars are supposed to clear the fuel economy standard of 2010 or the three scenarios by 2010.

The annual expenditure on gasoline passenger car purchase was between 1.51% and 1.84% during 1987-1995. Introduction of the feebate system diversifies expenditures of the gasoline passenger car between the fee and rebate sides. A consumer who buys a gas sipper vehicle reduces expenditure to less than 1.84%. A consumer who buys a gas-guzzler vehicle has to pay more than 1.84%.

It is clear that a more severe standard, or FE scenario, allows higher CO reduction. However, higher reduction requires a higher fee. The exponential curves are fee levels. The linear curves are rebates. The rebate level is not high enough, but imposition of the fee may be an incentive, in itself, to buy a more fuel-efficient car. When a consumer buys a better FE car, he/she can reduce living expenditure purchase costs. If we look at the figure by time intervals, we see the fee level increase by 2-3 times from 2001 to 2009. Rebate levels grow 1.3-1.7 times from 2001 to 2009.
CONCLUSION

Technological progress and diffusion rates determine fuel economy scenarios towards 2010. Exogenous factors, such as safety and noise, are added (Security Regulation scenario). The Japanese Environmental Agency’s scenario follows the same scenarios without the security and noise factors (Environment scenario). The technological scenario is developed simply by technological advancement (Technology scenario). Following the classification of top runner methods, three different scenarios of fuel economy improvement are introduced in the simulation of feebate. Since new car sales depend on consumer preference, drivers’ genders and generations are integrated for the projection. The feebate distorts car price, which impacts living expenditure.

Feebate levels are determined by CO$_2$ emissions of each fuel economy scenario.
More severe fuel economy scenarios emit less CO₂. Among the three scenarios, the technology scenario is the severest. However, reduction cost will increase in order to stabilize the CO₂ level by 2010. In consequence, the technology scenario has the highest feebate level. For those who buy fuel-efficient vehicles, car price is reduced by the feebate system. For those who buy less efficient vehicles, car price will be raised. Since Japan has to complete the target by 2010, impacts on living expenditure will gradually increase by 2009.

For further development of the model, some issues, such as follow-up, should be considered. Fuel efficiency does not mean CO₂ reduction directly. A consumer who buys a fuel-efficient vehicle may drive longer distances. That causes increase of CO₂ emissions. For reduction of CO₂ emissions, feebate should be combined with not only acquisition tax, but also other vehicle taxes. With respect to technological aspects, clean energy vehicles such as hybrid vehicles and fuel cell vehicles will be launched into the market. The vehicle tax system should be reformed to encourage consumers to buy clean energy vehicles. In this paper, the consumer side is the focus. Impacts on intra-industry or inter-industry should be evaluated, too.
APPENDIX 1  New car sales projection (the number of cars)

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APPENDIX 2  Feebates revenue (1995 US $)

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### APPENDIX 3 Fee and rebate per vehicle

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### APPENDIX 4 Impact on living expenditure: Change of annual purchase cost in living expenditure (%)

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