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Backcasting energy saving and CO2 emission reductions by using feebates system in Japan

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**Backcasting energy saving and CO2 emission reductions
by using feebate system in Japan**

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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 (CO₂) 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 CO₂ emission reduction by vehicle gross weight group.

1 Introduction

1.1. Overview of Japanese strategy for CO₂ reduction and the trend in the year 2000.

The Japanese transport sector has been required to reduce carbon dioxide (CO₂) emissions by 16% by 2010. The new strategy of CO₂ 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, CO₂ 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 CO₂ 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 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.

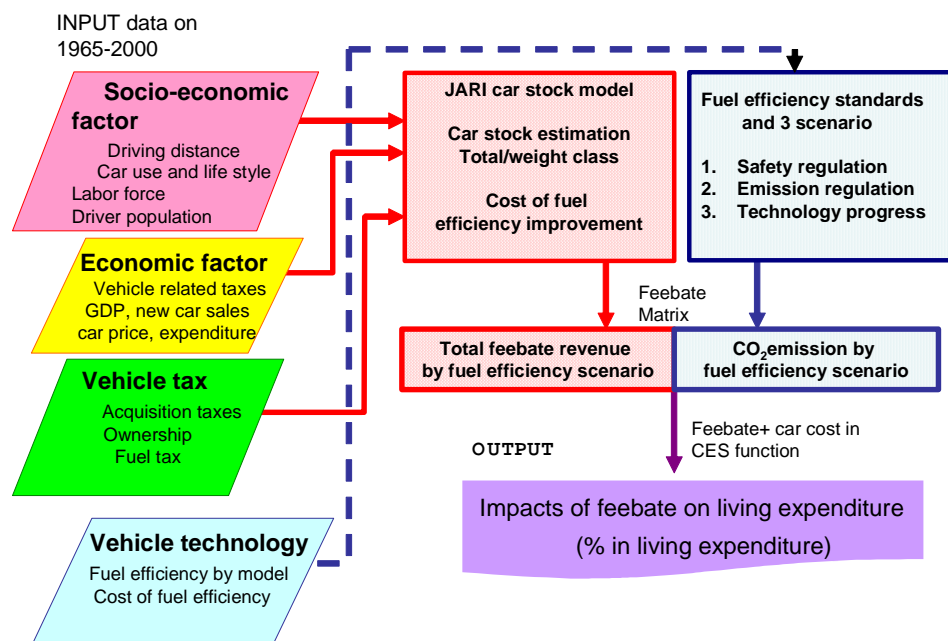


Figure 1 JARI car stock model

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

Scenarios	Summary of the description
Regulation	Fuel economy standard 2010 + Safety + Noise + Emission standard 2005
Environment	Estimation of Environmental Agency
Technology	Maximum rate of technological improvement

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.

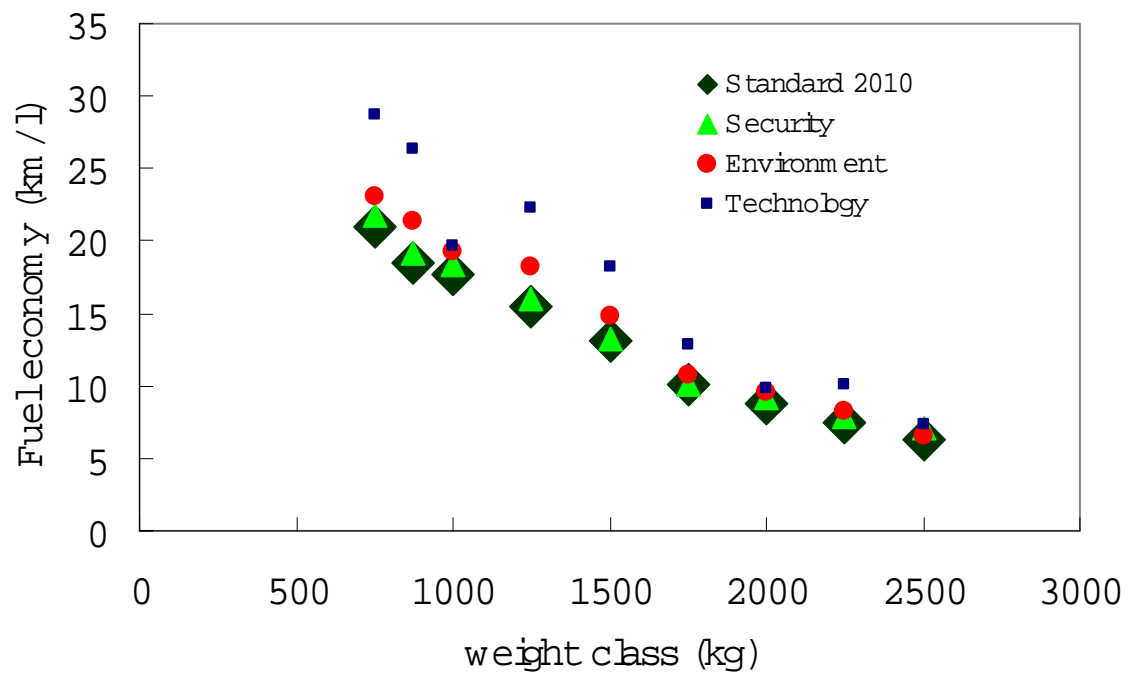


Figure 2 Fuel efficiency scenarios

2.3. Feebate level per vehicle by scenario

What level is optimal for fuel economy scenarios in terms of CO₂ 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.

$$CS = \sum_{\ell=1}^9 cs_1 + cs_2 + cs_3 + + cs_9 \quad (1)$$

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 1999⁴ 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.

⁴ Minato Kiyoyuki. (1999). *JARI Report 1999*. Tsukuba: Japan Automobile Research Institute.

$$FR = \sum_{i=1}^n [FE_{real} - FE_{standard}] * fee_n * cs_k \quad (2)$$

FR : feebates revenue

FE_{real} : fuel economy of a car

$FE_{standard}$: fuel economy standard

fee : cost of fuel economy improvement

cs : Car sales by category k : number of car by category $k=1\sim9$

n : improvement rate $n=1-4$

If severer fuel efficiency standard is introduces, CO₂ 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 CO₂ emissions. Technology scenario reduces by 24.8% from BAU.

How about the levels of fee and rebate change ? The feebate⁵ 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”.

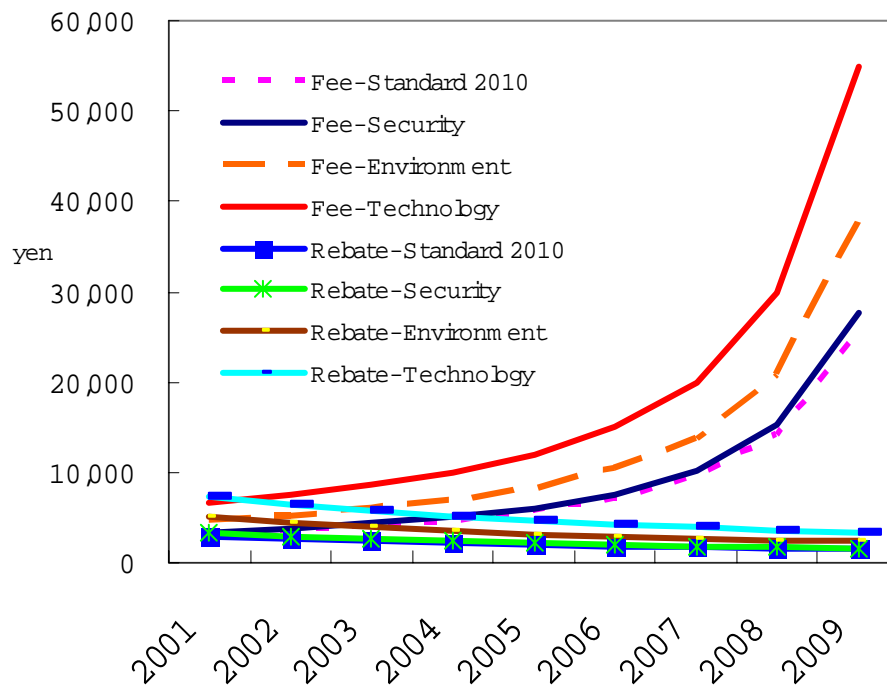


Figure 3 Fee and rebate per vehicle by 2009

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 side⁶. In the long run, car manufactures will tend to produce more

⁶ U.S. Department of Energy. (1995). Effects of feebates on vehicle fuel economy, carbon dioxide emissions, and consumer surplus. February, IX-X.

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 3 .

$$U = \gamma(\delta X^{-\rho} + (1 - \delta)Y^{-\rho})^{-\frac{1}{\rho}} \quad 3$$

X : average price of a private vehicle

Y : annual maintenance cost

U : annual cost for a private vehicle

ρ : elasticity

δ : coefficient of vehicle diffusion

γ : 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.

$$\log U_t^* = \beta_0 + \beta_1 \log X_t + \beta_2 \log Y_t + \beta_3 \log \left[\frac{X_t}{Y_t} \right]^2 + \varepsilon_{t1} \quad (4)$$

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

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

Where,

$$\beta_0 = \log \gamma \quad \beta_1 = \delta \quad \beta_2 = 1 - \delta$$

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

U : utility (annual purchase cost of private car)

X : price of private car

Y : maintenance cost of private car

ε : disturbance

t : time

θ is adjustment speed. $0 \leq \theta \leq 1$ $\theta = 0.8$

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

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

(6)

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

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' .

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

(7) (4.034) (1.888) (21.923) (0.831)

(7.223)

‘ car price + fee, car price -rebate
 $R^2 = 0.981$ *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 survey⁷ 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

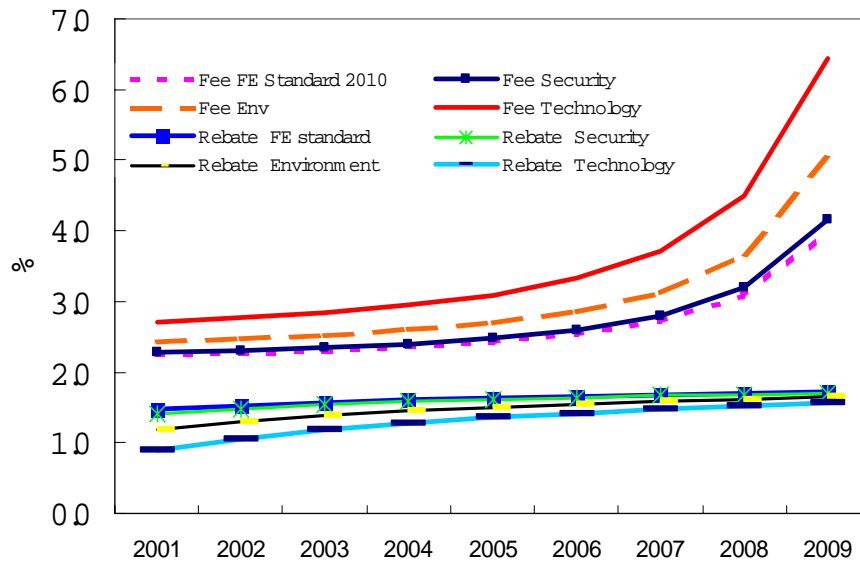


Figure 4 Impact of feebates on living expenditure

4CONCLUSION

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 CO₂ 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)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
750	362232	344917	326194	306004	284290	260988	236037	209369	180917	177073	118377
875	640710	662516	685063	708378	732486	757415	783192	809846	837408	865907	895376
1000	916280	947463	979708	1013051	1047528	1083179	1120042	1158161	1197576	1238334	1280478
1250	1194240	1202607	1211032	1219517	1228061	1236665	1245329	1254054	1262839	1271687	1280596
1500	973540	974514	975488	976464	977440	978418	979396	980375	981356	982337	983319
1750	403724	404127	404531	404936	405341	405746	406152	406558	406965	407372	407779
2000	47476	47523	47571	47618	47666	47714	47761	47809	47857	47905	47953
2250	8673	8682	8691	8699	8708	8717	8725	8734	8743	8752	8760
2500	629	630	630	631	632	632	633	634	634	635	635

APPENDIX 2 **Feebates** revenue (1995 US \$)

	IW750kg	IW875kg	IW1000kg	IW1250kg	IW1500kg	IW1750kg	IW2000kg	IW2250kg	IW2500kg
Standard	44490856	40671067	83207136	1.28E+08	1.21E+08	50127162	5897387	1010050	78058
2010									
Regulation	47961226	57619872	84173170	1.28E+08	1.21E+08	50130822	5899883	1078750	78250
Environment	51917261	67292479	91157178	1.41E+08	1.21E+08	50203564	5904875	1078750	78250
Technology	53693125	67292479	94239071	1.44E+08	1.21E+08	50213875	5904875	1078750	78250

APPENDIX3 Fee and rebate per vehicle

	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fee-Standard 2010	313	352	403	470	565	707	943	1416	2571
Fee-Security	336	379	433	506	608	760	1015	1523	2774
Fee-Environment	460	517	592	691	829	1037	1384	2075	3787
Fee-Technology	663	746	853	997	1197	1497	1998	3000	5494
Rebate-Standard 2010	287	256	250	211	193	179	166	155	146
Rebate-Security	325	289	260	236	216	199	185	173	162
Rebate-Environment	499	437	389	351	319	293	270	251	234
Rebate-Technology	728	637	567	510	464	425	393	365	340

APPENDIX 4 Impact on living expenditure: Change of annual purchase cost in living expenditure

(%)

Purchase cost/living expenditure)%		2001	2002	2003	2004	2005	2006	2007	2008	2009
Fee	FE Standard 2010	2.2	2.3	2.3	2.4	2.4	2.5	2.7	3.1	4.0
	Security	2.3	2.3	2.3	2.4	2.5	2.6	2.8	3.2	4.2
	Environment	2.4	2.5	2.5	2.6	2.7	2.9	3.1	3.7	5.0
	Technology	2.7	2.8	2.8	2.9	3.1	3.3	3.7	4.5	6.4
Rebate	FE standard	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.7	1.7
	Security	1.4	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.7
	Environment	1.2	1.3	1.4	1.5	1.5	1.5	1.6	1.6	1.6
	Technology	0.9	1.1	1.2	1.3	1.4	1.4	1.5	1.5	1.6

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