Impact Analysis on Gasoline Demand and CO_2 Emissions of the Reduction in Expressway Toll, Free Expressways and Repeal of Temporary Tax on Gasoline

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Summary

The toll on expressways is reduced as one of the economic stimulation packages of the Japanese government. The effect, however, is disputable. There are two competing views on the effect on gasoline demand and carbon dioxide (CO_2) emissions, which is related to climate change. One is that this measure increases gasoline demand and CO_2 emissions and another is that this measure decreases them. In this paper, the effect on gasoline demand and CO_2 emissions of the reduction in expressways toll is analysed quantitatively using a gasoline demand model. Additionally, the effect on gasoline demand and CO_2 emissions by free expressways and by a repeal of the temporary taxes on gasoline is estimated.

The current reduction in expressways toll may seem not to lead to significant increase in gasoline demand due to the recession. It, however, is estimated that the reduction in toll actually increases gasoline demand by about 1.3% (0.8 GL per year, or 1.8 Mt of CO_2 per year).

If expressways become free of charge, gasoline demand is estimated to increase by about 7.2% (4.1 GL per year, or 9.6 Mt of CO_2 per year). If the temporary taxes on gasoline are repealed and the taxes are reduced to the principal rates, gasoline demand is estimated to increase by about 3.1% (1.8 GL per year, or 4.1 Mt of CO_2 per year). If both of these two measures are enforced, gasoline demand is estimated to increase by about 10.5% (6.0 GL per year, or 14 Mt of CO_2 per year). In this case, CO_2 emissions from the transport passenger sector are estimated to increase by about 10 Mt - 14 Mt depending on how much traffic will be shifted to passenger cars from other modes. This is equivalent to an increase of about 0.8% - 1.1% of Japan's all greenhouse gases emission in the base year of the Kyoto Protocol (1990).

Launch of consistent policies toward reduction of greenhouse gases emissions is more important now as the very severe emission target, reduction by 25% from 1990 level, has been announced even being premised on the formulation of a fair and effective international framework by all major economies and agreement on their ambitious targets.

1. Introduction

The toll on expressways is reduced as one of the economic stimulation packages of the Japanese government. The effect, however, is disputable. There are two competing views on the effect on gasoline demand and carbon dioxide (CO_2) emissions, which is related to climate change. One is that this measure increases gasoline demand and CO_2 emissions and another is that this measure decreases them. The reason there are competing views is mainly from the difference in estimation of (1) newly induced traffic and/or shifted traffic from the other transportation modes, (2) shifted traffic from public roads to expressways, and (3) change in fuel efficiency on expressways by congestion and on public roads by less congestion.

If clarification of a step-by-step causality from the reduction in toll to change in gasoline demand is analyzed, the use of traffic demand model in expressways and public roads and energy demand model linking traffic with gasoline demand is suitable. Uncertainty (validity), however, of various assumptions in complex models actually leads to contradictory evaluation as a result.

Quantitative analysis of the effect on gasoline demand[1] and CO_2 emissions by the reduction in expressways toll is studies in this paper. By building a clear gasoline demand model based on actual data[2], the uncertainty of various assumptions in complex models and the less performance sometimes seen in theoretical models are avoided as much as possible. Using this model, the effect on gasoline demand and CO_2 emissions by the reduction in expressways toll is analysed quantitatively. Finally, by applying the obtained information, the effect on gasoline demand and CO_2 emissions by free expressways and by the repeal of the temporary tax on gasoline is estimated.

2. Reduction in toll of expressways

Starting with setting an upper limitation of toll of the Honshu-Shikoku Bridge Expressway and of the Aqua-Line Expressway on holidays at 1,000 yen on 20th March 2009, the toll of expressways is reduced until end of March 2011. As the upper limit of toll in rural areas on holidays is set at 1,000 yen, this reduction is often called as “1,000 yen expressways”.

[1] About 90 % of gasoline is consumed in passenger transportation sector.
[2] Supply side data, which provides wider coverage, is used. Then gasoline demand is observed through gasoline sales.

Table 1 Summary of the reduction of expressways toll

Holidays	**Rural: reduction by 50%, upper limit 1,000 yen** Expressways of NEXCOs and Honshu-Shikoku Bridge Expressway LDVs, mini-cars, motorcycles, etc. using ETC 0:00 - 24:00 on holidays Another 1,000 yen for Aqua-Line Another toll for Honshu-Shikoku Bridge Expressway with upper limit 1,000 yen
	Urban: reduction by 30% Expressways of NEXCOs LDVs, mini-cars, motorcycles, etc. using ETC 6:00 - 22:00 on holidays Reduction by 50% 0:00 - 6:00 and 22:00 - 24:00 on holidays
	Metropolitan Expressway and Hanshin Expressway Metropolitan Expressway on Sunday and public holidays (Tokyo routes: 500 yen, Kanagawa routes: 400 yen, Saitama routes: 300 yen) Hanshin Expressway on Holidays (Hanshin east routes: 500 yen, Hanshin west routes and Hanshin south routes: 350 yen) LDVs, mini-cars, motorcycles, etc. using ETC 0:00 - 24:00
Weekdays	**Rural: reduction by 30% - 50%** Expressways of NEXCOs All cars using ETC Reduction by 50%: 0:00 - 4:00, 6:00 - 9:00 and 17:00 - 20:00 Reduction by 30%: 4:00 - 6:00, 9:00 - 17:00 and 20:00 - 24:00
	Honshu-Shikoku Bridge Expressway: reduction by 30% - 50% All cars using ETC Reduction by 50%: 6:00 - 9:00 and 17:00 - 20:00 Reduction by 30%: 0:00 - 6:00, 9:00 - 17:00 and 20:00 - 24:00

Note: Including reduction before 1,000 yen expressways.

Source: Ministry of Land, Infrastructure, Transport and Tourism.

Although no significant effect of 1,000 yen expressways was observed in April as expressway traffic declined by 2.3% compared with April 2008 (possibly because of double charge at ramp-up period, etc.), expressway traffic after the toll reduction is more than the same months in the previous year for five months in a row (Figure 1).

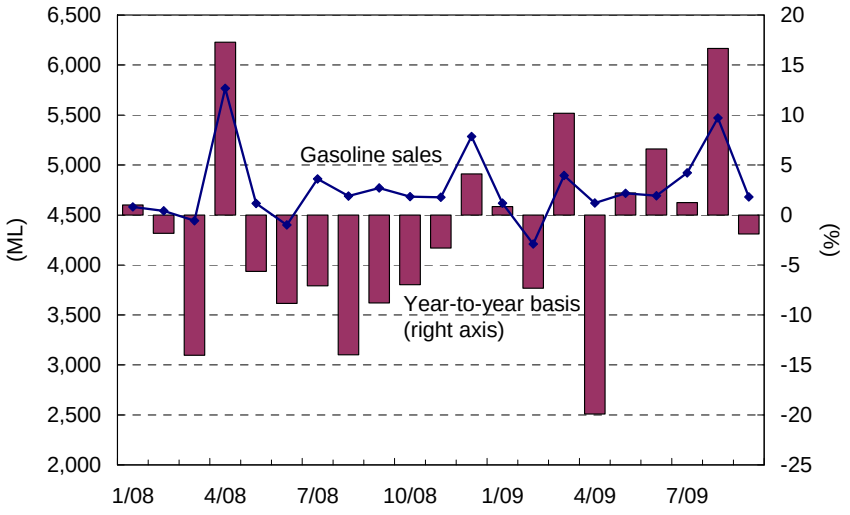
Figure 1 Traffic on expressways (original series)

Source: The Japan Expressway Holding and Debt Repayment Agency.

3. Trend of gasoline demand

When traffic increases, there is a concern that gasoline demand would also increase, which causes more CO_2 emissions. Gasoline demand compared with the same month of the previous year seemed to increase significantly after May like the expressway traffic (Figure 2).

Figure 2 Gasoline sales (original series)



Source: “Report of Mineral Resources and Petroleum Products Statistics”, Ministry of Economy, Trade and Industry

It may be a bit rough to judge the effect of the reduction in expressways toll only by the change and/or growth from the same month of the previous year. That is because various

incidents, which affected gasoline demand, happened after 2008:

(1) Current recession, which caused the reduction in expressways toll,

(2) Violent fluctuation of gasoline price led by surge and plummet of oil price (depression and promotion of the demand in medium- and long-term, restrained purchasing and impulsive purchasing in short-term), and

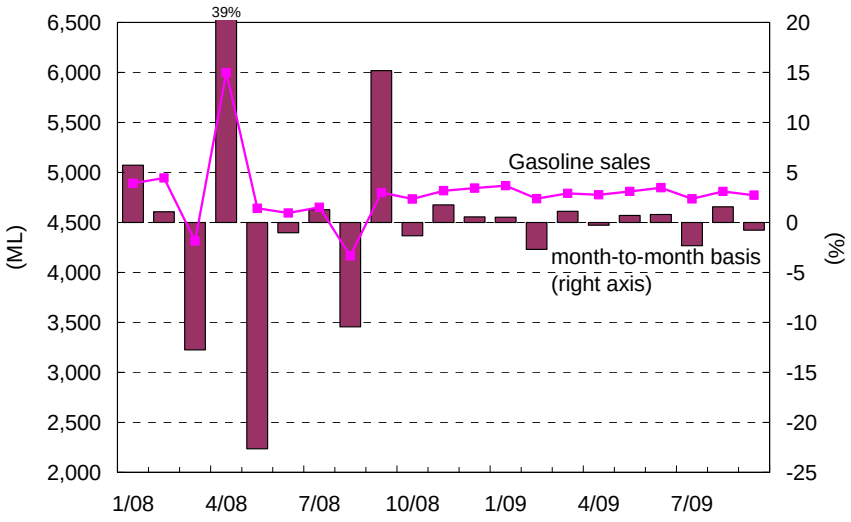
(3) Restrained purchasing and impulsive purchasing caused by the lapse and revival of the temporary tax on gasoline in spring of 2008.

It should be noted moreover that gasoline demand is under medium- and long-term downward pressure caused by improvement of vehicle fuel efficiency. Trend of gasoline demand can not be captured only by naive comparison from the same month of previous year without considering these incidents.

Therefore, comparison from the previous month using seasonally adjusted series (X12-ARIMA), is performed to evaluate the gasoline demand eliminating the effect caused by restrained purchasing and impulsive purchasing in (2) and (3). Observation of comparison from the previous month allows us evaluation of recent trend of gasoline demand without the effect of large fluctuation of gasoline demand in 2008.

The seasonally adjusted series shows that gasoline demand increases slightly or levels off rather than increases significantly (Figure 3).

Figure 3 Gasoline sales (seasonally adjusted)



Additionally trend cycle[3], or *TC*, obtained by seasonal adjustment allows us to grasp trend of

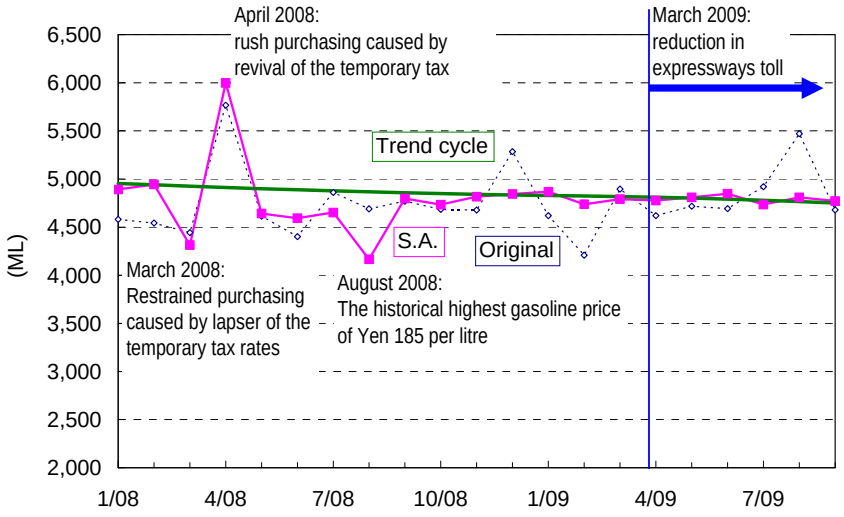
[3] Relationship among original series, seasonally adjusted series and each factor in multiplicative models is as follows:

Original series = (Trend cycle, *TC* × Irregular component, *I*) × Combined seasonal and trading day factors, *S*•*TD*

= Seasonally adjusted series, *TC*•*I* × *S*•*TD*.

gasoline demand more clearly (Figure 4).

Figure 4 Gasoline sales (original series, seasonally adjusted and trend cycle)



Although gasoline demand does not increase significantly, it does not mean that the reduction in expressways toll does not affect gasoline demand. That is because economic situation and gasoline price, which are major determinant of gasoline demand, has changed dramatically. Gasoline demand has been under downward pressure by both the recession after so-called "Lehman shock" in autumn 2008 and rising gasoline price after reaching the bottom in January 2009. It is supposed that gasoline demand could decline much more if the reduction in expressways toll were not enforced.

4. Building a gasoline demand model

Considering these situations, how the reduction in expressways toll affect gasoline demand is evaluated quantitatively by comparing actual data with estimated data under the assumption that the reduction of toll was not enforced. For this, gasoline demand is modelled based on following equation (monthly):

$$\ln q_t = \beta_0 + \beta_Y \ln y_t + \beta_P \ln p_t + \beta_T TIME + \beta_L \ln q_{t-12} + \beta_{07} DUMXX07 + \beta_{08} DUMXX08 + \beta_{09} DUMXX09 + u_t .$$

where

q_t : Gasoline demand of the month in ML, "Report of Mineral Resources and Petroleum Products Statistics", Ministry of Economy, Trade and Industry,

y_t : Consumption expenditures for two-or-more-person households of the month in Yen, "Family Income and Expenditure Survey", Ministry of Internal Affairs and Communications,

p_t: Gasoline price of the month in Yen per litre, Oil information Center, Institute of Energy Economics, Japan,

$TIME$: Time trend,

q_{t-12} : Gasoline demand in the same month of the previous year,

$DUMXX07$, $DUMXX08$, $DUMXX09$: Dummy variables representing peak months: July, August and September,

u_t : Error.

Expenditures for two-or-more-person households and gasoline price are deflated by consumer price index (2005-base, "Consumer Price Index", Ministry of Internal Affairs and Communications). Dummy variables for March 2008, April 2008 (representing the lapse and the revival of the temporary tax on gasoline) and August 2008 (representing the surge of gasoline price to the highest and restrained purchasing anticipating gasoline price decline after September) were added as exogenous variables. The estimation period was from F.Y. 2004 when oil price started to rise until March 2009, just before the reduction in expressways toll was enforced.

The estimation result is as follows: Numbers in parentheses are t values.

$$\begin{aligned}\ln q_t = & \underset{(0.33)}{0.315} + \underset{(4.03)}{0.383} \times \ln y_t - \underset{(-1.72)}{0.087} \times \ln p_t - \underset{(-1.65)}{0.00055} \times TIME + \underset{(3.73)}{0.448} \times \ln q_{t-12} \\ & + \underset{(2.86)}{0.052} \times DUMXX07 + \underset{(3.49)}{0.083} \times DUMXX08 + \underset{(2.40)}{0.041} \times DUMXX09 \\ & - \underset{(-3.23)}{0.109} \times DUM0803 + \underset{(4.87)}{0.163} \times DUM0804 - \underset{(-2.86)}{0.111} \times DUM0808.\end{aligned}$$

Coefficient of determination R^2: 0.84, F value: 25.6

Although the performance of the regression is not very good because of the monthly model, the result is enough for analysis with some level of tolerance. Meanwhile, income elasticity and price elasticity of gasoline demand delivered from the result are shown in Table 2.

Table 2 Elasticity of gasoline demand

	Income elasticity	Price elasticity[4]
Short-term elasticity	0.38	0.087
Long-term elasticity	0.69	0.16

This elasticity is broadly consistent with the one estimated using quarterly data (Yanagisawa, 2008).

[4] Shown in absolute value.

5. Estimation of the effect of the reduction in expressways toll

As the gasoline demand model developed in this study is based on data prior to the reduction in expressways toll, it suggests gasoline demand in which the reduction in toll was not enforced. With the gasoline demand model and actual data of consumption expenditures and gasoline price, etc. after spring 2009, the estimated value under the condition in which the reduction in toll was not enforced is available. Comparing the estimated value and actual gasoline demand allows us to evaluate the effect of the reduction in toll. The estimation period was after May 2009, excluding April 2009 when expressways traffic show also no significant effect.

From the result, the 1,000 yen expressways is estimated to make gasoline demand increase by about 1.3% (0.8 GL per year, or 1.8 Mt of CO_2 per year). The CO_2 emission is equivalent to about 0.1% of Japan's all energy-related CO_2 emissions in F.Y. 2007.

6. Estimation of the effect of free expressways and of the repeal of the temporary tax on gasoline

In this section, the effect of free expressways and of the repeal of the temporary tax on gasoline is estimated based on the obtained information.

(1) Effect of free expressways

If expressways become free of charge, gasoline demand is roughly estimated to increase by about 7.2% (4.1 GL per year, or 9.6 Mt of CO_2 per year)[5]. The CO_2 emission is equivalent to about 0.8% of Japan's all energy-related CO_2 emissions in F.Y. 2007.

(2) Effect of repeal of the temporary taxes on gasoline

Currently, the temporary taxes shown in Table 3 are imposed on gasoline:

Table 3 Temporary taxes

(Yen/L)

	Temporary tax	Principal tax	Difference
Gasoline tax	48.6	24.3	24.3
Local road tax	5.2	4.4	0.8
Total	53.8	28.7	25.1

[5] Based on the following rough estimate:

1.3% ÷ -23% × -100% ÷ 80% = 7.2%

where

the effect on gasoline demand of the current reduction in expressways toll: about 1.3% (above),

the current reduction in expressways toll: about -23% (estimated by Family Income and Expenditure Survey, etc.),

reduction in expressways toll of free expressways: -100%, and

current usage rate of ETC: about 80% (the Japan Expressway Holding and Debt Repayment Agency).

Although some guess that the temporary tax would be replaced with carbon tax (global warming tax), gasoline price will decline by 25.1 yen per litre if the temporary tax are repealed and the taxes are reduced to the principal taxes. This is equivalent to a reduction of 19% as the gasoline price in October 2009 is 129 yen per litre (Oil Information Center, the Institute of Energy Economics, Japan). This reduction in gasoline price is estimated to lead an increase in gasoline demand by about 3.1% (1.8 GL per year, or 4.1 Mt of CO_2 per year) based on the long-term price elasticity in Table 2. The CO_2 emission is equivalent to about 0.3% of Japan's all energy-related CO_2 emissions in F.Y. 2007.

(3) Effect of both free expressways and repeal of the temporary taxes

If both free expressways and repeal of temporary taxes are enforced, gasoline demand is estimated to increase by about 10.5% (6.0 GL per year, or 14 Mt of CO_2 per year) based on the above results. The CO_2 emission is equivalent to about 1.1% of Japan's all energy-related CO_2 emissions in F.Y. 2007.

Table 4 Impact on gasoline demand

	Current reduction in expressways toll	Free expressways	Repeal of the temporary tax	Total
Percentage change	+1.3%	+7.2%	+3.1%	+10.5%
Annualized (GL)	+0.8	+4.1	+1.8	+6.0
CO_2 emissions (Mt-CO_2)	+1.8	+9.6	+4.1	+14
Compared with total energy-related CO_2 emission in Japan in F.Y. 2007	[+0.1%]	[+0.8%]	[+0.3%]	[+1.1%]

Note: All numbers are approximate.

7. Estimation including other passenger modes

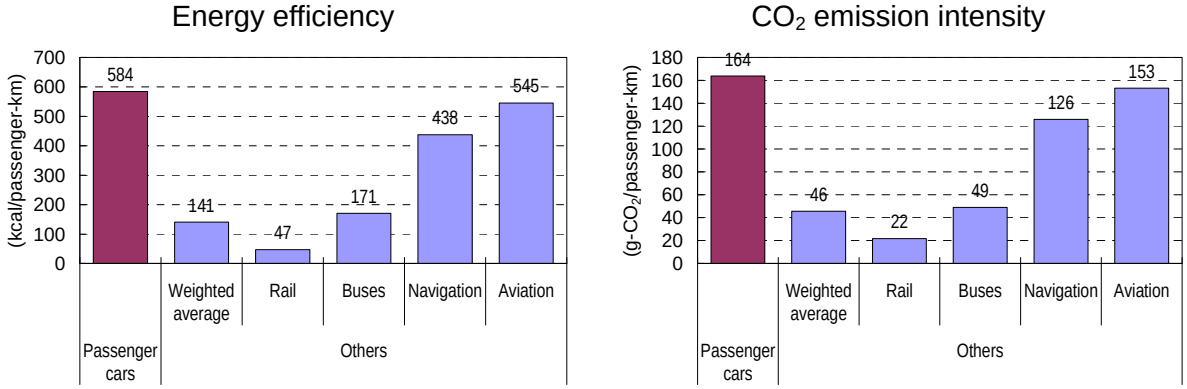
So far, the effect of the reduction in expressways toll, free expressways and repeal of the temporary taxes on gasoline demand has been estimated. In this section, the effect on the transport passenger sector[6] expanding the analysis area based on energy demand structure in F.Y. 2007[7] is analyzed. Results are dependent on estimation as to what extent non-passenger cars transportation modes are affected. It, however, is difficult to know how transportation demand by other modes is actually shifted to passenger cars due to data availability. In view of this, this paper shows both the upper and lower limit of the effect on transport passenger sector of these measures as a kind of evaluation.

The key is that the efficiency of passenger cars is substantially worse than other transport modes, especially rail and buses. In terms of both energy efficiency and CO_2 emission intensity,

[6] Gasoline accounts for about 80% of energy consumption of transport passenger sector.
[7] Therefore, some points may be different from the above sections.

passenger cars are worse than other transport mode by about four times (Figure 5). Therefore energy conservation and CO_2 abatement by shifting to more efficient mode from passenger cars (modal shift) is addressed.

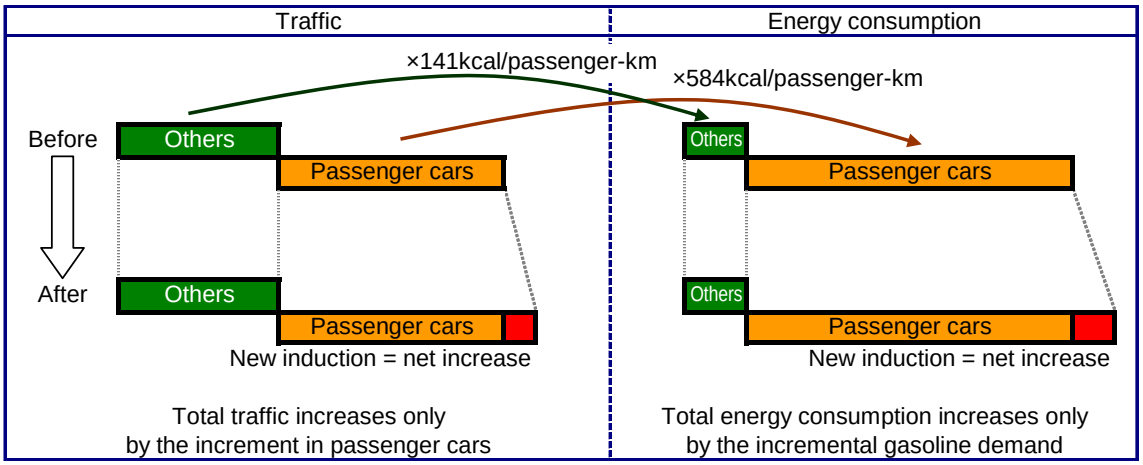
Figure 5 Energy efficiency and CO_2 emission intensity by mode (F.Y. 2007)



Source: Calculated from "Handbook of Energy & Economic Statistics in Japan", The Institute of Energy Economics, Japan, etc.

If all of the increase in traffic (gasoline demand) is newly induced by the reduction in expressways toll, free expressways and repeal of the temporary taxes; traffic, energy consumption and CO_2 emissions by other modes do not change at all. Total traffic increases only by increment of passenger cars and total energy consumption and CO_2 emissions increase only by equivalent to the incremental gasoline demand. These provide the upper limit of the effect.

Figure 6 In case of new induced demand (upper limit)

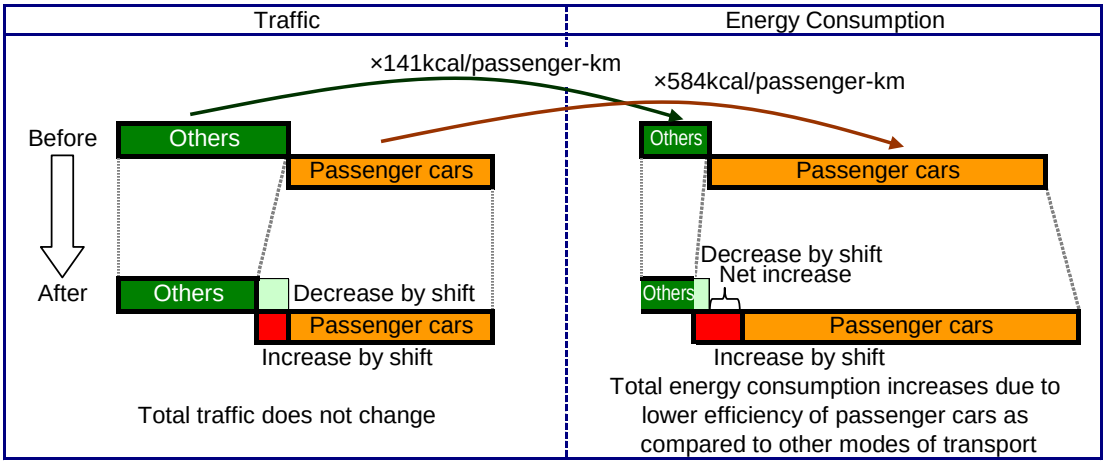


On the contrary, if all of the increase in traffic (gasoline demand) from these measures is due to the shift from other modes[8], traffic, energy consumption and CO_2 emissions by other modes

[8] The effect of the change in fuel efficiency is eliminated and it is assumed that increase of traffic by

decline due to the shift to passenger cars. Although total traffic does not change at all, total energy consumption and CO_2 emissions increase due to the reason that the efficiency of passenger cars is lower than the other modes. These provide the lower limit of the effect.

Figure 7 In case of modal shift (lower limit)



Based on these assumptions, the enforcement of both the free expressways and repeal of the temporary taxes lead to increase of energy consumption by transport passenger sector in the range of about between 3.9 Mtoe per year (the lower limit) and 5.1 Mtoe per year (the upper limit) (Table 5). CO_2 emissions are estimated to increase by about 10 Mt - 14 Mt (Table 6). This is equivalent to increase of about 0.9% - 1.2% of Japan's all energy-related CO_2 emissions in F.Y. 2007.

Table 5 Change of energy consumption

(Mtoe)

	Current reduction in expressways toll	Total		
		Free expressways	Repeal of the temporary tax	
Passenger cars	+0.7 (+1%)	+3.5 (+7%)	+1.5 (+3%)	+5.1 (+10%)
Other modes	-0.2~0 (-2~0%)	-0.8~0 (-10~0%)	-0.4~0 (-4~0%)	-1.2~0 (-14~0%)
Total transport passenger sector	+0.5~+0.7 (+1%)	+2.6~+3.5 (+5~+6%)	+1.1~+1.5 (+2~+3%)	+3.9~+5.1 (+7~+9%)

Note: All numbers are approximate based on energy demand structure in F.Y. 2007.

passenger cars is proportional to increase of gasoline demand for simplifying the analysis. Compared with lower efficiency of passenger cars than other modes by about four times, change of fuel efficiency in some degree may not be substantial. Then the reduction in expressways toll, free expressways and repeal of the temporary taxes are equivalent to modal shift of about 11 billions passenger-km, 60 billions passenger-km and 25 billions passenger-km, respectively.

Table 6 Change of CO_2 emissions

($Mt\text{-}CO_2$)

	Current reduction in expressways toll	Free expressways	Repeal of the temporary tax	Total
Passenger cars	+2 (+1%)	+10 (+7%)	+4 (+3%)	+14 (+10%)
Other modes	-1~0 (-2~0%)	-3~0 (-10~0%)	-1~0 (-4~0%)	-4~0 (-14~0%)
Total transport passenger sector	+1~+2 (+1%)	+7~+10 (+4~+6%)	+3~+4 (+2~+3%)	+10~+14 (+6~+9%)
Compared with total energy-related CO_2 emission in Japan in F.Y. 2007	[+0.1%]	[+0.6~+0.8%]	[+0.2~+0.3%]	[+0.9~+1.2%]

Note: All numbers are approximate based on energy demand structure in F.Y. 2007.

8. In closing

The current reduction in expressways toll may seem not to lead in significant increase of gasoline demand due to the recession. It, however, is estimated that the reduction in toll increases gasoline demand by about 1.3% (0.8 GL per year, or 1.8 Mt of CO_2 per year) actually.

If expressways become free of charge, gasoline demand is estimated to increase by about 7.2% (4.1 GL per year, or 9.6 Mt of CO_2 per year). If the temporary taxes on gasoline are repealed and the taxes are reduced to the principal taxes, gasoline demand is estimated to increase by about 3.1% (1.8 GL per year, or 4.1 Mt of CO_2 per year). If both of these two measures are enforced, gasoline demand is estimated to increase by about 10.5% (6.0 GL per year, or 14 Mt of CO_2 per year). In this case, CO_2 emissions by transport passenger sector are estimated to increase by about 10 Mt - 14 Mt depending on how much traffic will shift to passenger cars from other modes. This is equivalent to increase of about 0.9% - 1.2% of Japan's all energy-related CO_2 emissions in F.Y. 2007, or increase of about 0.8% - 1.1% of Japan's all greenhouse gases emission in the base year of Kyoto Protocol (1990).

This 14 Mt per year wipes out the abatement from the "Cool Biz" and "Warm Biz" programs in 16 years[9]. If we compensate this increase by nuclear power generation, about two more plants[10] are needed. If we compensate this increase by credit, procurement of credit of about 29 billion yen[11] is needed.

Launch of consistent policies toward reduction of greenhouse gases emissions is more important now as the very severe emission target, reduction by 25% of 1990, has been announced even being premised on the formulation of a fair and effective international framework by all major economies and agreement on their ambitious targets.

[9] 0.9 Mt per year (Advisory Council on Resources and Energy, 2008).
[10] CO_2 reduction by a 1.1 GW-class nuclear plant is 6.2 Mt per year (Suehiro, 2008).
[11] Based on current EU Allowance price of €15/t and exchange rate of €1 = Yen 135.

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