Has the Steep Rise in Gasoline Price Changed the Consumption Style?

- Estimation of Price Elasticity and Evaluation of Impact -

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Summary

Based on price elasticity, this study examined how the rise in price affects demand of gasoline, which attracts attention of the public. We estimated two types of price elasticity: constant elasticity and variable elasticity.

With the estimations, we determined that the constant price elasticity of gasoline was 0.08 in the short term and 0.21 in the long term. Energy demand is usually considered inelastic against the price; the study supported this idea. For the variable price elasticity, the current short-term elasticity was around 0.06 and long-term elasticity was approximately 0.14. Having started to rise in 2004 again, price elasticity of gasoline is now rather inelastic. The rise in price is not considered to have caused consumers to save on gasoline, which might suggest that saving is limited, and consumers are tired of cutting back on the use of gasoline.

The carbon tax is being considered as a means for achieving the goals of the Kyoto Protocol; we concluded that it would not produce the significant effect of curbing gasoline consumption, meaning that the effect of reducing carbon dioxide emissions would only be 0.1% or so at most in the long term.

Introduction

The prices of crude oil and many other energy resources are rising. Remaining at high levels, energy prices along with the subprime lending crisis may slow the global economy. The prices of energy in Japan have also significantly risen: gasoline prices have exceeded 150 yen per litre, the highest-ever price. With the fact that the domestic demand for gasoline, which had been on the rise, started to decline, some people believe that the rise in gasoline prices is causing people to curb gasoline consumption.

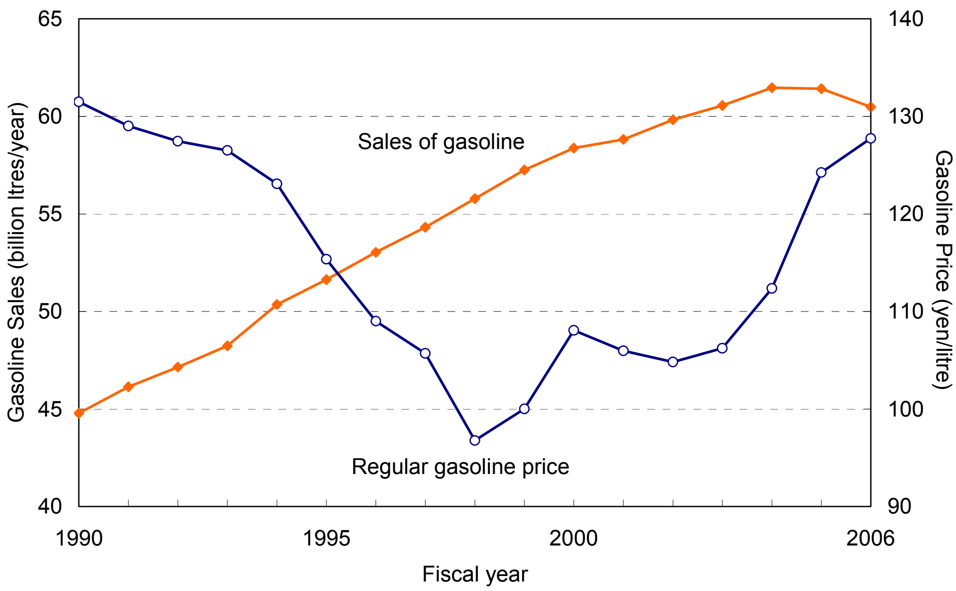
This study examines how the rise in price affects demand of gasoline, which attracts attention of the public, based on price elasticity. We estimated two types of price elasticity: traditional constant price elasticity and variable price elasticity by local regression. Using the constant price elasticity, we examined the extent to which the rise in gasoline prices suppresses demand.

In addition, using variable elasticity obtained through non-parametric regression that assumes no particular function form as the demand function, we examined how the rise in gasoline prices caused consumers to save on gasoline. Furthermore, based on the most recent price elasticity, we examined what effect the carbon tax would have on reducing carbon dioxide emissions.

1. Recent Relationship between Demand and the Price of Gasoline

The demand for gasoline has grown as automobiles have become more popular. Sales of gasoline doubled in the past 30 years: 60.55 billion litres of gasoline was sold in fiscal 2006. In recent years, however, there have been slowdowns in the growth of demand for gasoline because of a slowdown in the growth of the number of automobiles owned, decreased mileage per automobile ascribable to an increase in the number of owners with two or more cars and increased short-distance driving, and improved fuel efficiency. In F.Y. 2005, sales decreased (0.1% compared to the previous year) for the first time in 21 years, and again decreased 1.4% in F.Y. 2006 (see Figure 1). It is the first time in the postwar period that sales of gasoline decreased two years in a row

Figure 1: Gasoline Prices and Sales

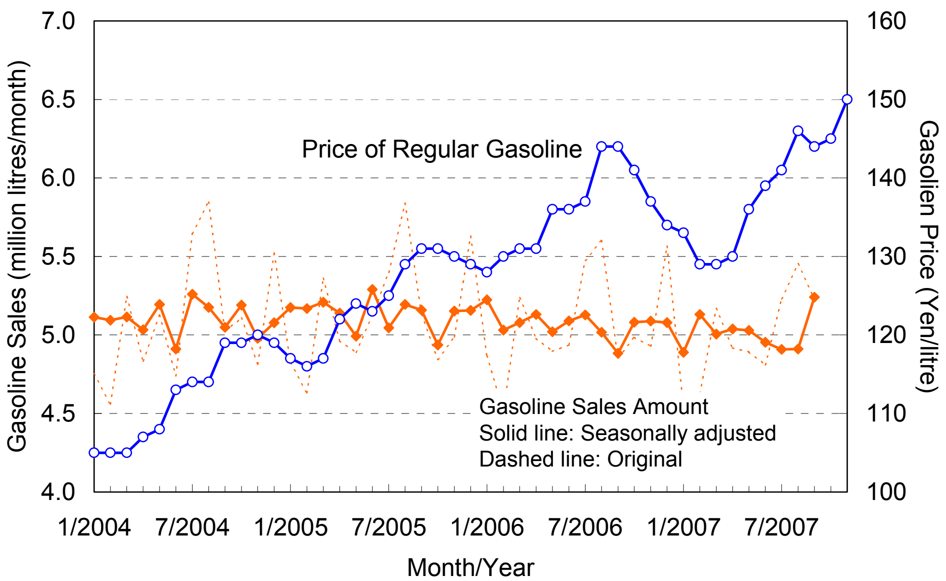


Source: Oil Information Center, *Resources / Energy Statistics* from the Ministry of Economy, Trade and Industry

Around 2004, at almost the same time frame and influenced by the rise in oil price and other factors, domestic gasoline prices also started to rise. The average retail price (including tax) of gasoline rose from 105 yen per litre in F.Y. 2002 to as high as 128 yen in F.Y. 2006, which is further rising in F.Y. 2007. Consequently, some people believe that the decrease in gasoline sales may have been caused by the rise in gasoline prices.

With the most recent situation (Figure 2), however, we cannot immediately determine that the rise in gasoline prices is reducing sales of gasoline. In the period from autumn 2006 to early 2007, where oil prices were adjusted, gasoline prices also fell, which did not increase sales. In spring 2007 and afterward, gasoline prices rose as much as 15 yen in only six months, reaching the record-high level; sales have been declining slightly, showing no signs that a sharp increase in prices would cause a significant decline in sales.

Figure 2: Gasoline Prices and Sales (most recent)



Source: Oil Information Center, *Resources / Energy Statistics* from the Ministry of Economy, Trade and Industry

The chart shows that sales sometimes decreased in months when gasoline prices rose, which returned to previous levels in the following months. A rise in gasoline prices may cause people to refrain from buying gasoline in that month. It is not always linked to continuous decreases in gasoline sales. Consequently, basic demand for gasoline is not largely affected by the price.

2. Analyzing Factors behind the Demand for Gasoline

This section presents a quantitative analysis based on a decomposition analysis to examine the factors that caused the decrease in the demand for gasoline.

As expression (1) shows, the demand for gasoline can be defined by the stock-based-theoretical (catalogue) fuel efficiency, running condition, mileage per unit, and number of units owned.

$$\text{Demand for gasoline}[L] = \frac{1}{\text{Theoretical fuel efficiency}[km/L]} \times \frac{1}{\text{Running condition}} \times \text{Mileage per unit}[km/unit] \times \text{Number of units owned}[unit] \quad (1)$$

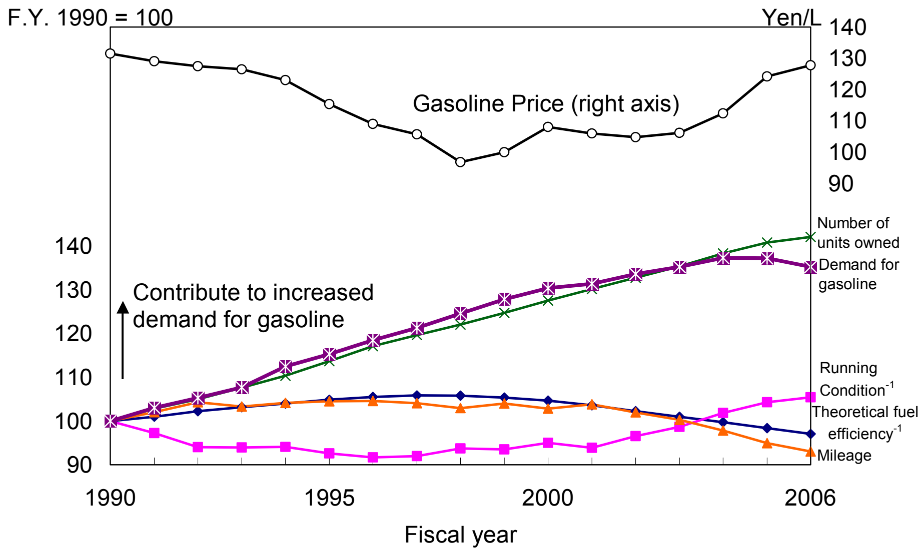
The running condition is the ratio of actual fuel efficiency to (divided by) theoretical fuel efficiency

$$\text{Running condition} = \frac{\text{Actual fuel efficiency}[km/L]}{\text{Theoretical fuel efficiency}[km/L]} \quad (2)$$

This indicates that actual fuel efficiency does not reach theoretical fuel efficiency due to traffic congestion and the use of car air-conditioners, which is known as the "70% theory."

Figure 3 shows the present and past demand for gasoline along with related factors.

Figure 3: Factors that Determine the Demand for Gasoline



Source: Oil Information Center; *Resources / Energy Statistics* from the Ministry of Economy, Trade and Industry; *Automobile Transportation Statistics* from the Ministry of Land, Infrastructure and Transport Japan; and *Handbook of Energy and Economic Statistics in Japan* from the Institute of Energy Economics, Japan

The number of units has consistently increased with the slowdown in growth. The running condition became worse in the 2000s. These two factors increased the demand for gasoline. On the other hand, theoretical fuel efficiency and mileage per unit peaked in the late 1990s, which then declined, decreasing the demand for gasoline. The notable point is that the improved theoretical fuel efficiency and decreased mileage per unit were not initiated by the current rise in gasoline prices but started at period of decreased gasoline prices when the Provisional Measures Law on the Importation of Specific Petroleum Refined Products was about to be abolished. It is said that the factors behind the improved theoretical fuel efficiency are the top runner program[1] and the goals achieved earlier by automobile manufacturers and that the factors behind the decreased mileage per unit are the increased number of units owned and increased short-distance drivers such as senior citizen and female.

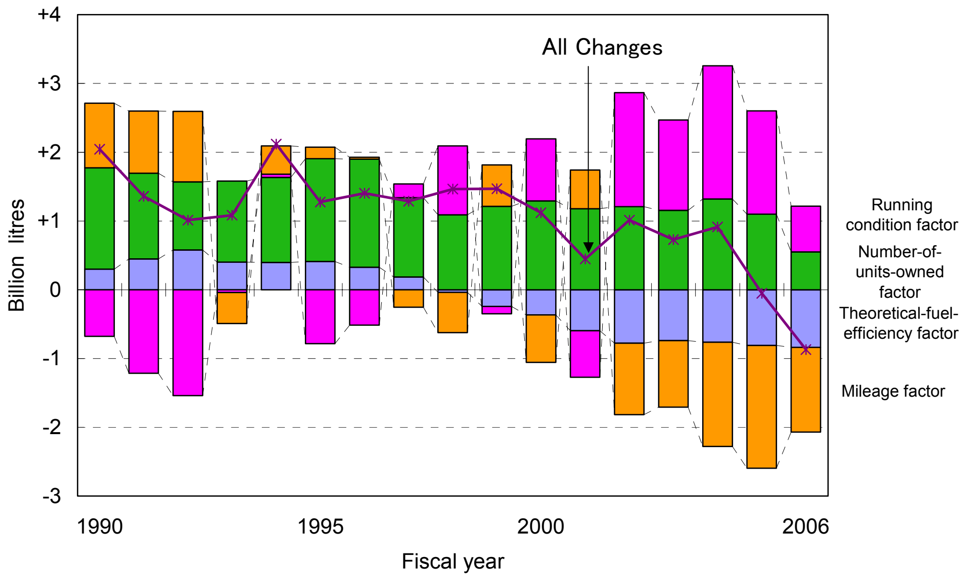
Then, based on expression (1), the factors are decomposed to determine to what extent each factor contributes to changes in demand for gasoline. By rewriting expression (1) to differentials as follows, changes in demand for gasoline can be broken down into the following factors: theoretical fuel efficiency, running condition, mileage per unit, and number of units owned.

$$\begin{aligned}\Delta\text{Demand for gasoline} \approx\ & \Delta\text{Fuel efficiency}^{-1} \times \text{Running condition}^{-1} \times \text{Mileage} \times \text{Number of units} \\ & + \text{Fuel efficiency}^{-1} \times \Delta\text{Running condition}^{-1} \times \text{Mileage} \times \text{Number of units} \\ & + \text{Fuel efficiency}^{-1} \times \text{Running condition}^{-1} \times \Delta\text{Mileage} \times \text{Number of units} \\ & + \text{Fuel efficiency}^{-1} \times \text{Running condition}^{-1} \times \text{Mileage} \times \Delta\text{Number of units} \\ =\ & \text{Theoretical fuel efficiency factor} + \text{Running condition factor} \\ & + \text{Mileage factor} + \text{Number of units owned factor}\end{aligned} \quad (3)$$

The decomposition analysis of expression (3) provides the results shown in Figure 4:

[1] The current fuel efficiency goal for F.Y. 2010 for (new) gasoline-driven passenger vehicles is 22.8% improvement compared with F.Y. 1995, and the next goal for F.Y. 2015 is 23.5% improvement compared with F.Y. 2004.

Figure 4: Decomposition Analysis of Demand for Gasoline



The chart above indicates that the most recent decrease in demand for gasoline is ascribable to the improved theoretical fuel efficiency and decreased mileage. In recent years, theoretical fuel efficiency is improving a little more than 1% each year, contributing to 700 to 800 million litres decreases each year. The mileage factor also significantly contributed to the decreased demand. In F.Y. 2006, however, the decrease in demand ascribable to this factor dwindled by about 600 million litres while the gasoline price rose 8 yen/litre. While the number of units owned and the running condition contribute to increased demand, the degree of contribution of these factors decreased in F.Y. 2006.

Saving on gasoline reportedly appears as the factors of mileage and running condition in the short term and as part of the factors of number of units owned and theoretical fuel efficiency in the medium- and long-term. The running condition factor, however, includes the effect of improving actual efficiency through decreased car air-conditioner use during a cool summer or reduced traffic congestion as well as saving such as eco driving. The number of units owned seems to be hitting a growth ceiling not only because of the rise in gasoline prices but also because of saturated possession, changes in the sense of vehicle value, returning to inner cities, and other factors.

Individual factors are affected by the social situation, income, prices, and other factors. Considering the nature and accuracy of the data, it is difficult to separate the area affected by prices. For this reason, the next section examines to what degree price affects demand using price elasticity by regarding the demand for gasoline as a whole.

3. Price Elasticity - Indicator of the Effect of Price on Demand

What effect does price have on demand for a given item? One of the most typical indicators that express the relationship between price and demand for a given item is the price elasticity. The price elasticity represents how much demand for an item changes in percentage when only the price changes by one percent. Since a rise in price normally decreases demand, the price elasticity is a negative value (for convenience, price elasticity are represented as absolute values in this study). For example, if demand for gasoline decreases 1% against a 10% rise in price (the other conditions remain unchanged), then the price elasticity is 1% / 10% = 0.1.

In actuality, it is unlikely that the price changes without changes in the other conditions; therefore, it is not possible to simply obtain price elasticity by following the definition. Normally, a demand function that includes the price as an independent variable is estimated. Then the price elasticity is obtained from estimated parameter and others.

Letting Demand E for the item is a function of Income Y and Price P, which are the most basic predetermined elements of the demand,

$$E = f(Y, P) \tag{4}$$

Then, Price Elasticity η is defined as follows because it represents the change ratio of Demand E when Price P has changed 1%.

$$\eta = \frac{\partial E / E}{\partial P / P} \tag{5}$$

As expressions (4) and (5) indicate, Price Elasticity η depends on the form of the demand function for the item. Here is a brief summary of how the demand function and price elasticity are related to each other.

With Demand Function f, the following both logarithmic function is most often used in estimating the elasticity:

$$\log E = \beta_0 + \beta_Y \log Y + \beta_P \log P \tag{6}$$

Given that this is used, Price Elasticity η is expressed as

$$\eta = \beta_P . \tag{7}$$

It is constant without depending on Demand E, Income Y, or Price P. On the other hand, linear function given that

$$E = \beta_0 + \beta_Y Y + \beta_P P , \tag{8}$$

the Price Elasticity η is

$$\eta = \frac{\beta_P P}{\beta_E E} . \tag{9}$$

It is proportional to Price P, inversely proportional to Demand E, and the variable.[2]

4. Estimation of Constant Price Elasticity

First, the most traditional constant price elasticity is estimated.[3] In other words, both logarithmic gasoline demand functions are considered. By adopting the amount of gasoline demand in the prior quarter as the independent variable, the short-term price elasticity that reflects the instant effect and the long-term price elasticity that reflects effects over an extended time period are estimated. As other independent variables, time trends that represent changes in trends, such as fuel efficiency and use, are added as well as income (real GDP) and price (real retail price of regular gasoline). Cooling degree-days, which represent the cooling load, are also adopted because the use of gasoline largely depends on the use of the car air-conditioner.

Namely, the function is expressed as

$$\log E = \beta_0 + \beta_Y \log Y + \beta_P \log P + \beta_T TIME + \beta_D CDD + \beta_{-1} \log E_{-1} \qquad (10)$$

where

E: Demand for gasoline, Y: real GDP, P: actual gasoline price,
$TIME$: time trend, CDD: cooling degree-days,
E_{-1}: demand for gasoline in the prior quarter.

Because the third quarter (July to September) was different from the other quarters, a dummy variable that represents the third quarter was adopted as an independent variable. The estimation period is from 1994 to the most recent period because of the GDP data limitation.

Here are the estimation results. Inside the parentheses are t values.

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[2] If a trans logarithmic function, a quadric approximation close to $\log Y = 0, \log P = 0$ of a given function pattern is used,

$$\log E = \beta_0 + \beta_Y \log Y + \beta_P \log P + \tfrac{1}{2}\beta_{YY}(\log Y)^2 + \beta_{YP} \log Y \log P + \tfrac{1}{2}\beta_{PP}(\log P)^2 .$$

Price Elasticity η is expressed as

$$\eta = \beta_P + \beta_{YP} \log Y + \beta_{PP} \log P .$$

It is proportional to the logarithms of Income Y and Price P, and the variable.

[3] The following data is used for estimation of price elasticity:

Demand for gasoline: Domestic sales amount, *Resources / Energy Statistics* from the Ministry of Economy, Trade and Industry, quarterly integrated with seasonal adjustments.
Real GDP (reference year 2000, seasonally adjusted): *National Accounts* from the Cabinet Office
Retail price (including tax) of regular gasoline: The Oil Information Center, the Institute of Energy Economics, Japan
General prices (used to deflate the gasoline price): GDP deflator (reference year 2000), *National Accounts* from the Cabinet Office
Cooling degree-days: *Handbook of Energy and Economic Statistics in Japan* from the Institute of Energy Economics, Japan

$$\log E = 3.72089 + 0.028755 * \log Y - \underline{0.080929} * \log P + 0.001764 * TIME$$
$$(2.08) \quad (0.28) \quad (-3.82) \quad (2.94)$$
$$+ 0.000143 * CDD - 0.050140 * DUMQ3 + \underline{0.606398} * \log E_{-1}$$
$$(3.41) \quad (-3.19) \quad (5.99)$$

Estimation period: 2nd quarter 1994 – 3rd quarter 2007, R^2: 0.978

Therefore, the constant price elasticity for gasoline are 0.08 for the short term and 0.08/(1 – 0.61) = 0.21 for the long term.[4]

Table 1: Constant Price Elasticity

Short-term elasticity	0.08
Long-term elasticity	0.21

In other words, when the real price rises 1%, the demand for gasoline in that period will decrease 0.08%. In the third quarter of 2007, the most recent period, the gasoline price rose 8.7 yen per litre compared with the previous term (10.1% in real price). Consequently, it is estimated that this effectively reduced demand for gasoline 0.8%.

The general idea is that the energy demand is not elastic[5] against the price because energy is a necessity and the demand is derived demand; no immediate substitution for gasoline exists. The result of this study supports this idea.

5. Estimation of Variable Price Elasticity

Constant price elasticity means that changes of the gasoline consumption pattern are always fixed against any change in price. However, a 10% change in price may have different effects between an increase from 80 yen/litre to 88 yen and an increase from 150 yen to 165 yen. Under the current situation where the gasoline price is at the highest level in history, some people argue that consumers are becoming more likely to practice economy. It would be important to know how a rise in price changes consumer behaviour in estimating trends in demand for gasoline and evaluating the effect of the introduction of the carbon tax, etc.

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[4] The average economic growth during the estimation period was only 1.3% per annum, which was not very suitable for calculating elasticity (the estimation tends to be more accurate when data during a period with a certain level of economic growth is included). The estimation for a period (F.Y. 1997–2003 during which time economy showed higher growth showed less elasticity: the short-term price elasticity of 0.015 and the long-term price elasticity of 0.115

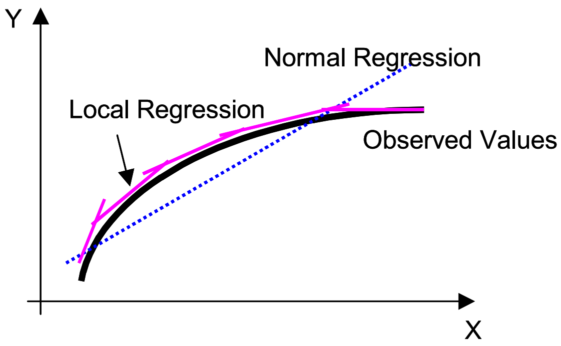
[5] In economics, if the price elasticity is greater than 1, then it is called elastic, and if it is smaller than 1, then it is called inelastic. In the first place, however, energy is inelastic against price. For this reason, 1 is not considered the threshold; if price elasticity is close to 0, then we call it inelastic in this study.

One approach to checking how the consumption pattern changes is estimation of the variable price elasticity. This approach looks at changes in consumption patterns through changes in the price elasticity against the price level.

For estimation of the variable elasticity, linear and trans logarithmic functions is used often as the demand function. The estimation through these functions, however, is based on the transcendental assumption that price elasticity change in proportion to the price level. It means that the argument starts with the precondition that a rise in price level makes consumers more likely to practice economy.

To lessen this assumption, this study uses local regression, one of the non-parametric regressions,[6] to estimate price elasticity. As Figure 5 shows, the concept of local regression divides the estimation target into appropriate segments to perform the regression in each segment.

Figure 5: Concept of Local Regression

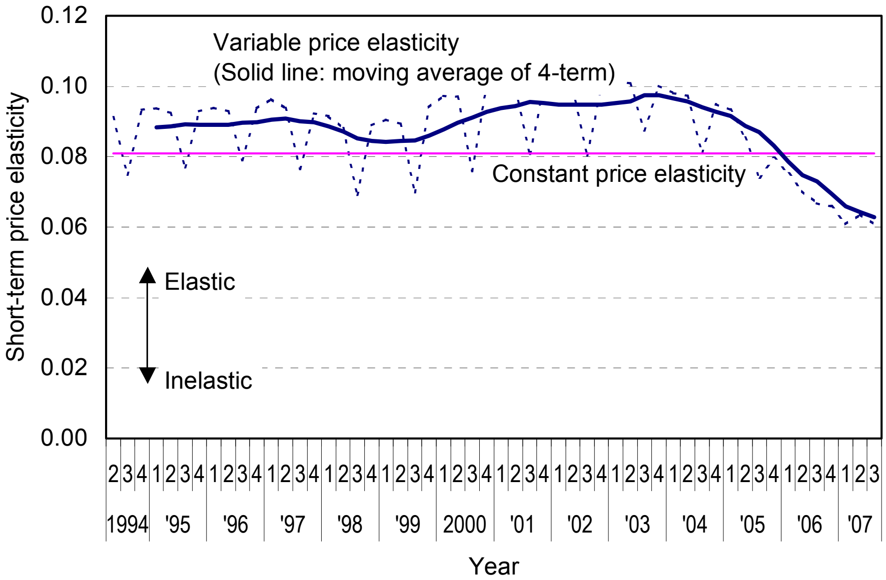


The price elasticity obtained through local regression is not subject to the constraint that it must be proportional to the price level; of course, they are variable. In addition, the use of local regression allows you to estimate the most recent price elasticity.

Figure 6 shows the short-term price elasticity obtained through the use of local regression in expression (10). Although the change width is only around 0.04, the price is inelastic with an average elasticity of 0.08, meaning that the change ratio is not small. The short-term price elasticity began to become elastic (economical) in the late 1990s, which peaked at around 0.10 in around 2003 and 2004, then became inelastic. The current short- and long-term price elasticity are around 0.06 and 0.14, respectively.

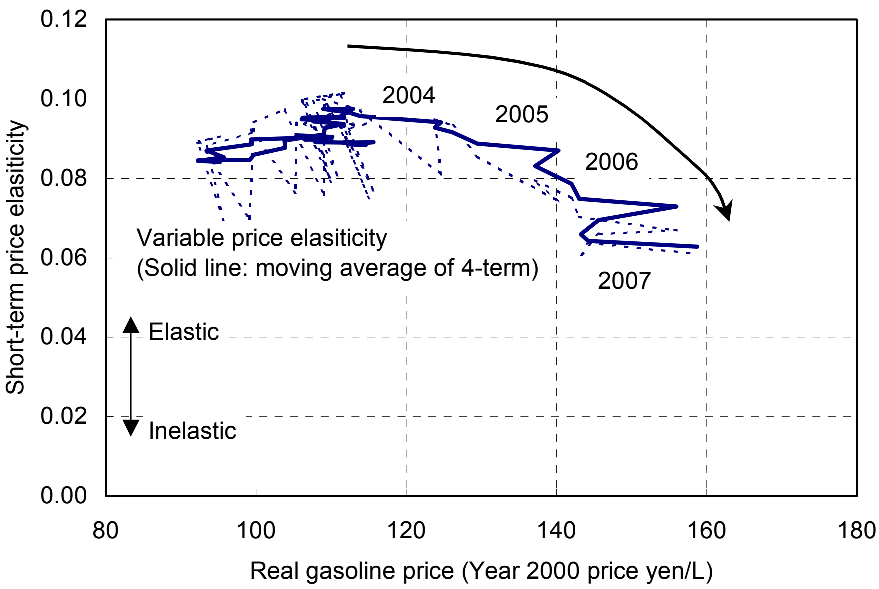
[6] Non-parametric regression does not mean that it uses no parameter. It does not perform parameterization. Normal (parametric) regression is designed to express the behaviour of the analysis target with a minimum number of regression coefficients (parameterization). On the other hand, non-parametric regression is designed to express the behaviours of the target without limiting the number of regression coefficients.

Figure 6: Short-term Price Elasticity



The horizontal axis on the chart represents real gasoline prices and the vertical axis, representing the short-term price elasticity (Figure 7), indicates that elasticity increases as the price level increases if it is less than around 120 yen. The figures in 2004 and afterward, however, indicate that elasticity does not increase but decreases with increases in the price level.

Figure 7: Gasoline Price and Short-term Price Elasticity



With the fact that energy is a necessity and gasoline cannot be easily substituted by another type of energy as a fuel for passenger cars, it may be considered that the consumers' saving on gasoline is limited and they are tired of doing so in four-years gasoline price rising. A rise in gasoline prices has some effect of suppressing demand. This effect is within the saving against prices, a behaviour that has been shown by consumers. It is not considered that the current rise in prices has caused consumers to practice further saving.

6. Effect of the Carbon Tax

This section estimates the effect of the carbon tax on suppression of demand for energy, i.e. reduction in carbon dioxide emissions, by using the most recent price elasticity.

As a means for suppressing energy-originated carbon dioxide emissions, the Ministry of the Environment, Tokyo Metropolitan Government, and other organizations are considering the introduction of carbon taxes. According to *Promotion of Tax Greening against Global Warming* (November 2006), *Specific Proposal on Carbon Tax* (October 2005), etc. from the Ministry of the Environment, the summary of the carbon tax being reviewed by the ministry is as follows:

Mechanism of the Carbon Tax

I. Taxation mechanism

(1) Home and offices

- Kerosene, gasoline, and LPG (upstream taxation)

(2) Factories, etc.

- Coal, heavy fuel oil, diesel oil, natural gas, jet fuel (report-based tax payment by large-volume emitters)

(3) Home, office, factories, etc.

- For electricity and town gas, the fossil fuels used by the power producers and gas companies are taxed.

Note: Gasoline, diesel oil, or jet fuel will not be taxed for the time being with consideration given to the rise in oil price, existing tax burdens, and other situations.

II. Tax revenue and rate

- Tax revenue: about 360 billion yen
- Tax rate: equivalent to 2,400 yen/carbon ton
  - For example, the tax rate for coal is 1.58 yen/kg on average.

* In terms of electricity, taxation on fuels for power generation is converted to 0.25 yen/kWh on average.

* The tax rate for gasoline after the system application is 1.52 yen/litre.

● Tax payment per household is about 2,000 yen per year (about 170 yen per month)

III. Abatement

● To ensure international competitiveness and promote and encourage endeavours to reduce emissions:

・ If a large-volume emitter has made efforts to reduce emissions, the tax is abated 80%.

・ Coal, coke, etc. for production of steel and others are not taxed.

・ The tax for kerosene is abated 50%.

・ Heavy fuel oil is taxed based on declaration by large-volume emitters. Oil used as a fuel for fishing boats is not taxed.

IV. Usage

● Funds for general use (the tax revenue is primarily used to take measures for forest sink; reduce the taxes for energy-saving home appliances and facilities for houses and buildings; and promote replacement purchases for efficient automobiles)

● Part of the tax revenue is transferred to local public organizations so that they can use it against global warming.

Effect and Impact of the Carbon Tax

● Reduction to be caused by the tax: about 43 million tons (3.5% reduction relative to year 1990)

● Affecting the economy: GDP reduction of 0.01% point annual

The carbon tax is expected to produce the following three major effects of suppressing demand for energy:

(1) Price effect caused by rises in energy prices

(2) Assistance for introduction of energy-saving equipment using the revenue tax as the fund and subsidies for measures against forests, HCFC, HFC, and others

(3) Announcement effect produced by introduction of the tax

The Central Environmental Council (2004) explains the announcement effect as follows:

The tax system is a major social concern. If introduction of a tax system for measures against global warming is widely recognized, and if everyone understands that the use of fossil fuels should be suppressed with the feeling that the tax is burdensome, then the announcement produces the effect of rapidly popularizing measures against global warming. For example, each time people buy gasoline, they feel the need to act against global warming. This is the effect of the announcement.

Each effect is evaluated as follows.

The price effect can be directly calculated from price elasticity. The carbon tax system of imposing 1.52 yen/litre taxes increases the gasoline price 1.1%. On the other hand, the current short- and long-term price elasticity are around 0.06 and 0.14, respectively; it is estimated that the suppression of demand for gasoline ascribable to the price effect is around 0.07% for the short term and only about 0.1% for the long term.

Subsidization to introduce energy-saving equipment is expected to produce a certain effect, which is merely based on the subsidies. The carbon tax should not inevitably be the source of funds for them. The carbon tax may be considered to have no specific subsidy effect.

While there is no definitive approach to calculating the effect of the announcement, it is possible to indirectly determine the degree of the effect. Recent daily news reports about rises in energy prices and increased burdens from energy costs call far greater attention to of the need for saving than the carbon tax that imposes a monthly tax of 170 yen (around $1.60) per household. As stated in the preceding section, however, rising prices do not cause consumers to be more likely to practice economy. In addition, according to the Cabinet Office (2007), the ratio of people who have an interest in the global environment has reached 92.3%, and 86.6% of people recognize that Japan produces increasingly more greenhouse gases compared with the year 1990. In other words, there is no possibility that the introduction of the carbon tax will dramatically stimulate interest in global warming. For these reasons, the announcement is not considered to be very effective.

As a result, the specific effect of the carbon tax suppressing demand is only expected to produce a meagre effect on prices.

In other words, this means that the carbon tax is as excellent as the cigarette tax as a fund source in that it does not decrease demand, ensuring the desired tax revenues.

Conclusion

We estimated that the constant price elasticity for gasoline is 0.08 for the short term or 0.21 for the long term. The general idea is that energy demand is inelastic against price. The results of this study support this idea. The current short- and long-term variable price elasticity are around 0.06 and 0.14, respectively. While the current rise in gasoline prices began in 2004, price elasticity is getting rather inelastic since that time. The rise in price has not caused consumers to be more likely to save, suggesting that saving is limited, and consumers are tired of saving on gasoline.

The carbon tax is being considered as a means of achieving the goals of the Kyoto Protocol. However, the tax is not expected to produce a significant effect on the suppression of gasoline consumption because any reduction in carbon dioxide emissions would only be 0.1 % or so at most in the long term.

Energy is a necessity, and no energy source can shortly substitute gasoline as a fuel for passenger automobiles. The price is an important signal in the market in general. However, it does not have a significant effect on the demand for gasoline in the short term in particular. In providing price-based policy guidance, mature consideration must be given to this fact.

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