Spatiotemporal Changes of Traffic Demand Price Elasticities in Japan Throughout 2008: Bayesian Approach[1]

Makoto Chikaraishi
Ph.D. Candidate
Graduate School for International Development and Cooperation, Hiroshima University
1-5-1, Kagamiyama, Higashi-Hiroshima 739-8529, Japan
Tel/Fax: +81-82-424-6957; E-mail: chikaraishi@hiroshima-u.ac.jp

Akimasa Fujiwara
Professor
Graduate School for International Development and Cooperation, Hiroshima University
1-5-1, Kagamiyama, Higashi-Hiroshima 739-8529, Japan
Tel/Fax: +81-82-424-6921; E-mail: afujiw@hiroshima-u.ac.jp

Junyi Zhang
Associate Professor
Graduate School for International Development and Cooperation, Hiroshima University
1-5-1, Kagamiyama, Higashi-Hiroshima 739-8529, Japan
Tel/Fax: +81-82-424-6919; E-mail: zjy@hiroshima-u.ac.jp

Back Jin Lee
Associate Research Fellow
Korea Research Institute for Human Settlements,
224 Simin-ro, Dongan-gu, Anyang-si, Gyeonggi-do, 431-712, Korea
Tel: +82-31-380-0373; Fax: +82-31-380-0484; E-mail: bjlee@krihs.re.kr

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Please send any correspondence to Mr. Chikaraishi, Tel./fax: +81-824-24-6957;
e-mail: chikaraishi@hiroshima-u.ac.jp

ABSTRACT

This study attempts to examine spatiotemporal changes of traffic demand elasticities with respect to gasoline prices and economic conditions, focusing on the substantial fluctuations occurred through the whole year of 2008 in Japan. This is intended to acquire a better knowledge of the spatial and temporal (in)stability of the elasticities, and what possible reasons there are for the changes of the elasticities. To do this, a random coefficient model is first built to represent spatial heterogeneity in the elasticities, and estimated by using a hierarchical Bayesian method. Next, a sequential Bayesian updating method is further applied to examine monthly changes of the elasticities. The data used in the empirical analysis was a monthly traffic volume data collected on 53 expressway routes. The results showed that, while the monthly changes in the average elasticities over all routes were mainly observed before August 2008, the different directions of changes across routes were observed after September 2008 when gasoline price began to fall down. The results also indicated that responses to gasoline price changes might be dependent on the causes of price changes. Furthermore, on urban expressway routes, it was found that once a reduction in traffic demand is successfully attained due to a rising gasoline price, the traffic demand could not be fully recovered even after the actual prices fall again to the original level.

1. INTRODUCTION

In Japan, substantial fluctuations of gasoline price were observed through the whole year of 2008, similar to the situations in other countries. The price soared to 185 Yen per liter in August 2008, and then plunged to 106 yen in January 2009. Such remarkable gasoline price fluctuations have undeniable effects on various aspects of travel behavior in various places. In Japan, traffic volumes on Metropolitan expressways in August 2008 changed by -8.5%, compared to those in August 2007. Also in United States, travel on all roads in August 2008 changed by -5.6% compared to that in August 2007 (*1*). Such gasoline price fluctuations at local level are mainly caused by the relationships between supply and demand, e.g., increased global demand, limited supply and production capacity, and speculative buying and selling in future. On the other hand, these fluctuations might also be influenced by political decisions. Actually, in Japan, temporary tariff rate (25.1 yen per liter) was outdated in April 2008, and it was restored from May 2008. At the same time, it is expected that in recent years global economic recession has also had certain impacts on traffic demand. In fact, traffic volumes on Metropolitan expressways in Japan decreased compared to those in the same month a year ago, even after gasoline prices dramatically declined. Understanding the sensitivity of traffic demand to such gasoline price fluctuations has important implications for policies, such as environmental taxation for responding to climate change.

Focusing on the above-mentioned special situations occurred in 2008, this study attempts to examine spatiotemporal changes of traffic demand elasticities with respect to gasoline prices as well as economic condition through the whole year of 2008 in Japan.

In this context, a number of studies have confirmed that price elasticity is not stable over time (e.g., *2-4*), Interestingly, Dargay and Gately (*5*) pointed out the existence of asymmetric responses to upward and downward price fluctuations, and underscored that real fuel price would need to be raised substantially in order to successfully reduce fuel demand. They also found that once a reduction in demand is attained, it would not be fully recovered even if actual price falls again. Different from the study by Dargay and Gately, we examine the short-term (monthly) responses of traffic demand to fuel price, instead of the annual responses, because it is expected that such short-term responses might show a quite different fluctuation pattern from the annual responses. At the same time, it is expected that behavioral responses to changes in gasoline price may depend on the causes of price changes (e.g., a change of tax system, and the interplay of supply and demand) (*6*). Goodwin et al. (*7*) reported that at the early stage of congestion charging in London, price elasticity of traffic demand was higher than expected, i.e., the elasticity was different from that of fuel price. Therefore, it can be assumed that the outdated/restored temporary tariff rate (25.1 yen per liter) occurred in Japan has different impacts on traffic demand from other causes of gasoline price fluctuations. Furthermore, the above-mentioned observations may vary with spatial characteristics (e.g., quality of public transport systems and availability of alternative transport services). Generally speaking, it might be difficult for trip makers in rural areas to shift to other travel modes even in case of dramatic increase of gasoline price, compared to those in urban areas. Recognizing such regional differences is important for policy makers, for example, to determine a proper level of pricing scheme by reflecting actual situations at different areas/regions.

In this study, the spatiotemporal changes are measured by temporal changes at monthly level and spatial heterogeneities at route level. To capture the spatiotemporal changes of gasoline price elasticities of traffic demand, we first build a random coefficient model to represent spatial heterogeneity, by further taking into account the influence of economic conditions, which are also expected to strongly affect traffic demand. The model is estimated by using a hierarchical Bayesian method. From the model, we can obtain the price elasticities as well as the economic condition elasticities for each expressway route by reflecting the stochastic variations of elasticities across space. One can separately estimate the elasticities; however, such separate estimation might be highly unstable as mentioned in the next section. Next, we apply a sequential Bayesian updating method (*8*) to examine monthly changes of the elasticities for each expressway route. Such updating method allows us to draw the trajectory of spatiotemporal changes. The data used in this study were collected on 53 expressways in Japan, covering the whole year of 2008, when gasoline prices substantially varied.

The rest of paper is structured as follows. The next section describes how to apply the random coefficient approach to calculate the elasticities for each expressway route, the estimation method of the model, and the sequential Bayesian updating method. In Section 3, data used in this study are explained. After that, the developed model is estimated, and updating results are described and discussed. In final section, key conclusions and future tasks are summarized.

2. METHODOLOGY

2.1. Model Formulation

In this study, we calculate two types of elasticities: i.e., the gasoline price elasticity (e_p) and the economic condition elasticity (e_E). They can be expressed as follows:

$$e_P = \frac{\partial Q/Q}{\partial P/P} = \frac{\partial \ln(Q)}{\partial \ln(P)}, \quad e_E = \frac{\partial Q/Q}{\partial E/E} = \frac{\partial \ln(Q)}{\partial \ln(E)}, \tag{1}$$

where, P is gasoline price, E is economic condition index, and Q is traffic demand. Economic condition index represents a coincident composite index, which provides a quantitative measurement of economic strength. In this sense, the E indicates the “volume” of economic activities (the details will be mentioned in Section 3).

There are several ways to calculate the elasticities, such as a simple log-log model (i.e., a log-transformed Cobb-Douglas demand function), a partial adjustment model, and an error correlation model (details refer to existing literature (e.g., *2*, *7*, *9-10*)). Here, exploring the best model to calculate the elasticity is not the purpose of this study. Instead, we focus on how to represent regional (or route) differences of the elasticities. Therefore, we just employ the standard Cobb-Douglas demand function, which is one of the most frequently used models in existing literatures. A simple way to obtain the region-specific (or route-specific) elasticity is to conduct model estimations for each region separately. However, as pointed out by Maddala et al. (*11*), such separate estimation can give wrong signs and are highly unstable in context of energy demand at the state level of the USA. Although the estimated elasticities using pooling the data from different states can give right signs and are comparatively stable, they argued that these elasticities are not valid because the hypothesis of homogeneity of the elasticities is rejected. Accordingly, Maddala et al. (*11*) proposed to use shrinkage estimators as compromise estimates between unstable heterogeneous estimates and untenable homogeneous estimates. It was also confirmed that the shrinkage estimators generate much more reasonable values of elasticities than other estimators in the context of traffic demand (*8*). In line with these existing studies, this paper models traffic demand by using the random coefficient approach in order to address spatial (route) differences (i.e., heterogeneity) of the elasticities. Concretely speaking, to represent the traffic demand on expressways, the following log-transformed Cobb-Douglas demand function is applied.

$$\begin{aligned}\ln(Q_{imy}) = & (\mu_0 + \gamma_{i0}) + (\mu_1 + \gamma_{i1})\ln(Q_{im(y-1)}) + (\mu_2 + \gamma_{i2})\ln(P_{imy}) \\ & + (\mu_3 + \gamma_{i3})\ln(E_{imy}) + (\mu_4 + \gamma_{i4})T_{my} + \varepsilon_{imy}\end{aligned} \tag{2}$$

Here, Q_{imy} represents traffic volume on expressway route i during month m of year y and $Q_{im(y\text{-}1)}$ indicates the traffic volume in the same month of the previous year y-1. $Q_{im(y\text{-}1)}$ is introduced to accommodate the autoregressive nature of traffic demand mainly because of seasonality such as sightseeing season. For example, in Japan, people usually take several consecutive days off during May, August, and January. P_{imy} represents the pump price of regular gasoline related to route i. E_{imy} indicates the economic condition related to route i. Such route-specific economic condition could capture the impacts of the changes of industrial and/or commercial conditions along a route. This may be derived from the differences of spatial distributions of industries. For example, it is expected that a route along an area heavily depending on tourism industry is more easily affected by the economic condition, because people may first start to reduce their non-mandatory travel (however, because of the data limitation, in the empirical analysis we will adopt economic condition data at national level as a proxy indicator. The details will be explained in Section 3). The above mentioned two influential factors, i.e., gasoline price and economic condition index (i.e., income-related indicator), are well-known two important influential factors on travel demand (e.g., *2*, *10*). T_{my} is a variable to represent the temporal trend of traffic demand. ε_{imy} is an error term, assumed to be normally distributed with mean 0 and variance σ^2_0. μ_0, μ_1, μ_2, μ_3, and μ_4 are unknown parameters representing the average effects of corresponding explanatory variables across routes. γ_{i0}, γ_{i1}, γ_{i2}, γ_{i3}, and γ_{i4} are assumed as random variables, which express route-specific deviations from the average effects. These random variables γ_{i0}, γ_{i1}, γ_{i2}, γ_{i3}, and γ_{i4} are further assumed to follow the following multivariate normal distribution with means 0 and variance-covariance matrix Σ,

$$\Sigma = \begin{bmatrix} \sigma^2_{\gamma 0} & \sigma_{\gamma 01} & \sigma_{\gamma 02} & \sigma_{\gamma 03} & \sigma_{\gamma 04} \\ \sigma_{\gamma 01} & \sigma^2_{\gamma 1} & \sigma_{\gamma 12} & \sigma_{\gamma 13} & \sigma_{\gamma 14} \\ \sigma_{\gamma 02} & \sigma_{\gamma 12} & \sigma^2_{\gamma 2} & \sigma_{\gamma 23} & \sigma_{\gamma 24} \\ \sigma_{\gamma 03} & \sigma_{\gamma 13} & \sigma_{\gamma 23} & \sigma^2_{\gamma 3} & \sigma_{\gamma 34} \\ \sigma_{\gamma 04} & \sigma_{\gamma 14} & \sigma_{\gamma 24} & \sigma_{\gamma 34} & \sigma^2_{\gamma 4} \end{bmatrix}, \tag{3}$$

where, diagonal elements are variances of corresponding random variables, and non-diagonal elements are covariances.

Based on the above model specification, we can obtain the average and route-specific elasticities defined in eq. (1). Concretely speaking, μ_2 corresponds to the average price elasticity of traffic demand e_p, and μ_3 corresponds to the average elasticity of traffic demand with respect to economic condition index e_E. And, ($\mu_2+\gamma_{i2}$) and ($\mu_3+\gamma_{i3}$) are the route-specific price elasticity e_p and economic condition elasticity e_E, respectively.

2.2. Hierarchical Bayesian Estimation Method

There are several ways to estimate the above-defined random coefficient model, such as the restricted maximum likelihood method, the simulated maximum likelihood method, and the hierarchical Bayesian estimation based on Markov Chain Monte Carlo (MCMC) method (*12*). Existing studies showed that these methods are asymptotically equivalent (e.g., *13*, *14*). In this study we employ the hierarchical Bayesian estimation based on MCMC method. The main reason for this is the conceptual differences between maximum likelihood methods and Bayesian methods. In a Bayesian scheme, the estimated parameters are treated as distributions as a consequence of applying the Bayes' theorem (*12*, *15*), and therefore we can update the estimated parameters at a previous time point to those at a current time point through Bayesian updating scheme (details are given in the next subsection). Another reason is that γ_i can be directly obtained from the sampling procedure. Here, γ_i corresponds to shrinkage estimators shown in Maddala et al. (*11*) or Goldstein (*13*), and it is equivalent to BLUP (Best Linear Unbiased Prediction) from a statistical perspective.

The Bayesian estimation incorporates prior distribution assumptions and yields a chain, which is used for making point and interval estimates of parameters, based on successive sampling from posterior distributions conditional on other parameters. A set of the estimated parameters are treated as a probability distribution, which will be used to update the parameters at the next step. This will be explained later. The posterior distribution of eq. (2) can be written as follows:

$$\pi(\gamma_1,\ldots,\gamma_I,\mu,\Sigma,\sigma_0 \mid Q,x) \propto \prod_{i\in I}\prod_{my\in TT_i} f(Q_{imy},x_{imy} \mid \gamma_i,\mu,\sigma_0)\, p(\gamma_i \mid \Sigma)\, p(\mu)\, p(\Sigma)\, p(\sigma_0). \tag{4}$$

Here, μ = {μ_0, μ_1, μ_2, μ_3, μ_4} and γ_i = {γ_{i0}, γ_{i1}, γ_{i2}, γ_{i3}, γ_{i4}}. $\pi(\gamma_1,\ldots,\gamma_I,\mu,\Sigma,\sigma_0 \mid Q,x)$ is the joint posterior distribution of all parameters conditional on observed data (i.e., dependent variable Q and explanatory variables x). $f(Q_{imy},x_{imy} \mid \gamma_i,\mu,\sigma_0)$ represents the likelihood function of eq. (2) conditional on unknown parameters. $p(\mu)$, $p(\Sigma)$, and $p(\sigma_0)$ are prior distributions. We assume that $p(\mu)$~$N(\mu_0, V_\mu)$ [normal distributions], $p(\Sigma)$~$Wishart(c, \Sigma_0)^{-1}$ [an inverted Wishart distribution], $p(\sigma_0)$~$Gamma(a, b)^{-1}$ [an inverted Gamma distribution]. Here, μ_0, V_μ, c, Σ_0, a, and b are given parameters based on prior information. In this study, due to the lack of prior information, we will assume the non-informative prior distributions for all parameters. In addition to the above mentioned settings, γ_i is considered to be sampled from normal distributions with mean 0 and variance Σ. This additional procedure creates "hierarchical" sampling procedure. Then we can obtain the parameter γ_i for each route directly from the successive sampling.

The draws from the above-mentioned posterior distributions of all parameters are obtained from the following procedure:

Step 1: Set the initial values $\mu^{(0)}, \Sigma^{(0)}$ and $\sigma_0^{(0)}$;

Step 2: Repeat the following sampling tasks (t = 1, 2, …);

(a) Sampling $\mu^{(t)}$ from $\pi\left(\mu \mid \gamma_1^{(t\text{-}1)}, \ldots, \gamma_I^{(t\text{-}1)}, \Sigma^{(t\text{-}1)}, \sigma_0^{(t\text{-}1)}, Q, x\right)$

(b) Sampling $\gamma_i^{(t)}$ from $\pi\left(\gamma_i \mid \mu^{(t)}, \gamma_1^{(t)}, \ldots, \gamma_{i-1}^{(t)}, \gamma_{i+1}^{(t\text{-}1)} \ldots, \gamma_I^{(t\text{-}1)}, \Sigma^{(t\text{-}1)} \sigma_0^{(t\text{-}1)}, Q, x\right)$ for all i

(c) Sampling $\Sigma^{(t)}$ from $\pi\left(\Sigma \mid \mu^{(t)}, \gamma_1^{(t)}, \ldots, \gamma_I^{(t)}, \sigma_0^{(t\text{-}1)}, Q, x\right)$

(d) Sampling $\sigma_0^{2(t)}$ from $\pi\left(\sigma_0^2 \mid \mu^{(t)}, \gamma_1^{(t)}, \ldots, \gamma_I^{(t)}, \Sigma^{(t)}, Q, x\right)$

Step 3: Retain the above samples after some pre-given criteria are met;

where,
$$\pi\left(\mu \mid \gamma_1, \ldots, \gamma_I, \Sigma, \sigma_0, Q, x\right) \sim N\left(A^{-1}\left\{\sum_{i \in I} x_i^T \left(Q_i - x_i \gamma_i\right) + \sigma_0^2 V_\mu^{-1} \mu_0\right\}, \sigma_0^2 A^{-1}\right)$$
$$\pi\left(\gamma_i \mid \mu, \Sigma, \sigma_0, Q, x\right) \sim N\left(B^{-1}\left\{x_i^T \left(Q_i - x_i \mu\right)\right\}, \sigma_0^2 B^{-1}\right)$$
$$\pi\left(\Sigma \mid \mu, \gamma_1, \ldots, \gamma_I, \sigma_0, Q, x\right) \sim \mathit{Inverse\,Wishart}\left(I + c, \sum_{i \in I} \gamma_i^T \gamma_i + \Sigma_0\right)$$
$$\pi\left(\sigma_0^2 \mid \mu, \gamma_1, \ldots, \gamma_I, \Sigma, Q, x\right) \sim \mathit{Inverse\,Gamma}\left(N/2 + a, \sum_{i \in I} S_i / 2 + b\right)$$
$$S_i = \left(Q_i - x_i \mu - x_i \gamma_i\right)^T \left(Q_i - x_i \mu - x_i \gamma_i\right), \quad A = \sum_{i \in I} x_i^T x_i + \sigma_0^2 V_\mu^{-1}, \quad B = x_i^T x_i + \sigma_0^2 \Sigma^{-1}.$$

Here, the sampling procedure is conducted by using WinBUGS (Bayesian inference Using Gibbs Sampling (*16*)).

2.3. Sequential Bayesian Updating Method

Suppose that the elasticities at month m are already obtained from the posterior distribution of parameters, $\pi\left(\gamma_1, \ldots, \gamma_I, \mu, \Sigma, \sigma_0 \mid Q, x\right)$. In fact, the estimates (μ) are equivalent to BLUE (Best Linear Unbiased Estimator) and the estimates (γ_i) are equivalent to BLUP (Best Linear Unbiased Prediction) from the statistical perspective. Now, suppose that we have the data $Q_{i(m+1)y}$ and $x_{i(m+1)y}$ at month m+1. Since parameters at month m+1 might be different from those at month m due to temporal changes, these parameters at month m+1 might not be equivalent to the BLUE/BLUP. To take into account such temporal changes, this study employs a Bayesian updating method. The Bayesian updating method updates the parameters at month m+1 by combining information from the data at month m+1 expressed through the likelihood function $f\left(Q_{i(m+1)y}, x_{i(m+1)y} \mid \gamma_i, \mu, \sigma_0\right)$ with the estimated parameters at month m, $\pi\left(\gamma_1, \ldots, \gamma_I, \mu, \Sigma, \sigma_0 \mid Q, x\right)$. This process is described as follows:

$$\begin{aligned} &\pi\left(\gamma_1, \ldots, \gamma_I, \mu, \Sigma, \sigma_0 \mid Q, x, Q_{i(m+1)y}, x_{i(m+1)y}\right) \\ &\propto \prod_{i \in I} \prod_{my \in TT_i + 1} f\left(Q_{imy}, x_{imy} \mid \gamma_i, \mu, \sigma_0\right) p\left(\gamma_i \mid \Sigma\right) p(\mu) p(\Sigma) p\left(\sigma_0\right) \\ &\propto \prod_{i \in I} f\left(Q_{i(m+1)y}, x_{i(m+1)y} \mid \gamma_i, \mu, \sigma_0\right) \pi\left(\gamma_1, \ldots, \gamma_I, \mu, \Sigma, \sigma_0 \mid Q, x\right). \end{aligned} \tag{5}$$

3. DATA

In the empirical analysis, we use the monthly traffic volume data on 53 expressway routes from three data sources in Japan:

1) Data 1: 3 routes from Metropolitan Expressway Co., Ltd. (http://www.shutoko.jp/),
2) Data 2: 42 routes from East Nippon Expressway Co., Ltd. (http://www.e-nexco.co.jp/),
3) Date 3: 8 routes from West Nippon Expressway Co., Ltd.: the data come from a survey by its branch office of Chugoku region.

The periods of observed traffic volume data differ from source to source: Data 1 covers the period from April 2005 to January 2009; Data 2 from April 2006 to January 2009; and Data 3 from April 2004 to January 2009.

As shown in eq. (2), the pump price P_{imy} of regular gasoline is the price related to route *i*. However, the price is not specific to a route, but it might change across regions. Here, the pump price at prefecture level on a monthly basis is used. In other words, the price related to route *i* is the price at the prefecture that the route is located. If the route passes across two or more prefectures, then the average price in these prefectures will be used. Note that this is intended to acquire better approximation values of gasoline price for each route, and does not reflect where a driver purchases the gasoline. The price data were obtained from the website (http://oil-info.ieej.or.jp/) of Oil Information Center of the Institute of Energy Economics in Japan.

As for the economic condition index, its elasticity is similar to the income elasticity calculated by using GDP, but the economic condition index is available on a monthly basis while GDP is only on a quarterly basis. Although some prefectures have released their own economic condition indices, the definitions are quite different from prefecture to prefecture and the indices on a monthly basis are not available at many prefectures. Therefore, the data at national level on a monthly basis are used as a proxy indicator. The relevant data are available from the website (http://www.cao.go.jp/index-e.html) of Economic and Social Research Institute, Cabinet Office, Government of Japan. This economic condition index is a coincident composite index, which indicates the current state of the national economy.

Time series' variations of gasoline price and economic condition index are shown in Figure 1. As for gasoline prices, we can confirm substantial fluctuations in 2008. In April, the price was dramatically decreasing due to expiration of the temporary tariff rate (25.1 Yen per liter), which was restored in May. After that, the price soared to 185 Yen per liter in August, but it was rapidly decreasing again since then. As for the economic condition index, the values were relatively stable before 2008, but started to decrease after 2008 and the ranges of reductions became bigger especially from August 2008.

4. MODEL ESTIMATION AND UPDATING RESULTS

Before making discussions on the updating results of elasticities, we will first show the detailed estimation results with full data (i.e., the updating is completed till January 2009). And then, we will analyze spatiotemporal changes of elasticities based on the updating results.

4.1. Estimation Results

The sample size of full data for the model estimation is 1,394 month*route from 53 routes. For this estimation, the non-informative prior distributions are given for all parameters, and we carry out a total of 36,000,000 iterations in order to obtain 10,000 draws: the first 6,000,000 iterations are used to for burn-in to mitigate start-up effects and the remaining 30,000,000 iterations are used to generate the 10,000 draws, i.e., every 3,000 iterations are retained as one draw. The number of total iterations is relatively high than usual, but it makes the estimated elasticities for each of route remarkably stable even when we conduct the iterations using different initial values. In order to check the convergence of the processes of obtaining the draws, we employ Geweke diagnostic (*17*). We also check the trace plot and autocorrelation in the parameter chains. The Geweke diagnostic takes two non-overlapping parts of the draws (i.e., the first 10% and the last 50% of the 10,000 draws in this study) to compares the means of the two parts, aiming to see whether these two parts of the chain are from the same distribution, using a test statistic based on Z-score. The chain is judged to reach the convergence if the statistic is less than 1.96 at 95% significant level.

The estimation results are shown in Table 1. Geweke diagnostics in estimation results indicate that all parameters are well converged, and R^2 is 0.9994, indicating the traffic volumes on 53 expressways are well explained by introduced explanatory variables. The average elasticity with respect to gasoline price is -0.118 and that of economic condition index is 0.464. These elasticity values are quite understandable and consistent with the existing elasticity values (e.g., *2*, *10*) if we regard the economic condition index as an income indicator. It is also confirmed that the correlation between gasoline price and economic condition index are not statistically significant, indicating that these two influential factors have impacts on traffic demand independently. Variances of estimate parameters are statistically significant (except for gasoline price), implying that each route has different degree of response to explanatory variables. Although the variance corresponding to gasoline price is not statistically significant in January 2009, the temporal changes of the elasticities and those differences among routes are still our main interest because the high differences might be observed at different time points.

4.2. Updating Results

In our proposed method, all parameters, including variances and covariances, are sequentially updated. Thus, we can obtain the trajectories of all parameters. However, because of space limitations, we only show the updating results of elasticities with respect to gasoline price and economic condition index (Table 2 and Table 3), which are our main interests. Details of other updating results can be obtained directly from the first author upon request.

4.2.1. Changes of the Average Elasticities across Routes

The changes in the average elasticities are shown in Figure 2. As for the price elasticities, it is particularly worth noting that the different changes are observed between two periods of rapid decreases of gasoline prices: April 2008 and September 2008 to January 2009. In the former period, in which temporary tariff rate (25.1 yen per liter) was outdated, the average price elasticities are dramatically decreasing. This decrease continues till May 2008, and then recovers to the initial level (around January to March 2008), approximately. On the other hand, in the latter period, the average price elasticity values seem to be quite stable over time, even though the gasoline prices were continually and intensively decreasing. Consequently, it can be said that the changes in the price elasticities between the two periods do not have a consistent pattern. One reason for this might be due to the different causes of price changes. Concretely speaking, the price change in the former period was caused by the governmental policy decisions, while the latter price changes were mainly caused by market mechanisms (e.g., the relationship between supply and demand). These results seem to be consistent with the report by Goodwin et al. (*7*) about the differences of traffic reduction between the estimated values based on the price elasticity and the actual response to congestion charging in London. Although the types of "policy decision" are quite different between our case study and their case, the common findings are that the price elasticities due to the above policy decisions seem to be substantially different from those caused by usual price changes. This suggests that when making a policy decision (e.g., introducing environmental taxes), the expected response to price changes might be dependent on not only the tax level, but also the types of the taxes.

As for the changes in the average elasticities with respect to economic condition index, the values are relatively stable after August 2008 while temporary decreases are observed especially from March to May 2008. This might also be relevant to temporary tariff rate (25.1 yen per liter). Namely, in March, people already knew that such price reduction would occur from April 2008, and thus there is a possibility that the use of expressways did not rely on the state of economic conditions, but people might just postpone their travel plans until April (this inference could be applicable only to non-mandatory travel). Another possible reason is that, because March corresponds to the end of a fiscal year in Japan, it is expected that the share of business trips is higher than that in the other months. Such business trips might be less influenced by economic conditions. However, from the aggregate data used in this study, we could not make a sound conclusion for the changes of the elasticities with respect to economic condition index, and it should be further examined in future.

4.2.2. Changes of the Route-Specific Elasticities

The trajectories of the route-specific elasticities are shown in Figure 3. Note that a few invalid values (i.e., positive elasticities for gasoline price and negative elasticities for economic condition index) are observed. Such invalid elasticities are mainly observed on local routes, which are defined as those expressways that do not pass through Tokyo, Kanagawa or Saitama prefecture. One possible reason for the invalid values is that traffic volume on these routes is susceptible to some special event traffic demands.

As for the route-specific elasticities with respect to gasoline price, it is confirmed that the direction of changes in the elasticities are quite different across routes, but each route seems to have a specific tendency of changes. Especially, there are some sharp differences between local and urban routes. Concretely speaking, the elasticities of all the urban routes, which, in a narrow sense, refer to those passing through Tokyo, Kanagawa, and/or Saitama prefectures in this study, are smaller than the average value of all the routes in January 2008, but the values on all urban routes become bigger than the average value in January 2009. To further confirm when such changes occurred, next, we compare the correlations of the route-specific price elasticities between pairs of months (see Table 4). As a result, before September 2008, high correlations (minimum is 0.94 between January and August) are consistently observed, even though two notable price fluctuations (i.e., outdated/restored temporary tariff rate and soaring gasoline prices) were observed during this period. However, it seems that September 2008 is a turning point, where the correlations between pairs of months largely change. Before September 2008, the correlations between neighboring months are almost close to 1. In contrast, after September 2008, the correlations decrease to 0.87, which is the maximum from September to November 2008, when gasoline prices were dramatically decreasing; and more remarkably, negative correlations are observed between the period before August and the period after November.

The question here is "why such structural changes occur only after September 2008?". One reason is that, on urban routes, the soaring gasoline prices up to August 2008 may reach a threshold that is enough to successfully reduce traffic demand, which might not be fully recovered even after actual prices fell down again. This is consistent with the observation by Dargay and Gately (*5*). On local routes, however, the directions of changes vary from route to route, perhaps because the prices might not be higher enough to give rise to the similar structural changes on some local routes. Thus, the argument by Dargay and Gately (*5*) might be applicable to urban routes, but not to all the local routes.

Concerning the route-specific elasticities with respect to economic condition index, the abrupt changes in the structure of elasticity differences among routes are observed in September 2008, as shown in Figure 3. From Table 4, we can confirm that such changes mainly occur only from September to November, like the case of price elasticities. The directions of the changes seem to be somewhat different between local and urban routes, but it is not so clear. For this, differences of industrial and/or commercial functions along different routes might be relevant. For example, traffic demand in some local regions heavily relying on tourism or manufacture might be more sensitive to the changes of economic situations. At this moment, it is still difficult to make a sound conclusion without knowing the impacts of such potentially influential factors on traffic demand.

5. CONCLUSIONS

This study has explored the spatiotemporal changes in the gasoline price elasticities of traffic volume on expressways as well as the economic condition elasticities in Japan through the whole year of 2008, in which substantial gasoline price fluctuations and depressed global economic environments were observed. For this purpose, the elasticities were first obtained for each expressway route by using a random coefficient approach with spatial heterogeneity, and then the elasticities were sequentially updated based on a Bayesian updating scheme to reflect the temporal changes. In the empirical analysis, using the monthly traffic volume data on 53 expressway routes, the elasticities were sequentially updated from January 2008 to January 2009. The gasoline price elasticities showed a structural change before and after September 2008, when gasoline price was intensively decreasing, while the changes in the average elasticities over all the routes mainly occurred before August 2008. In addition, our results support the indication of Goodwin et al. (*7*) – the response to gasoline price changes is dependent on the causes of price changes –. This implies that when deciding a new policy, for example, introducing environmental taxes, policy makers should recognize that responses of traffic demand to a price change may be dependent not only on the price change itself, but also on the type of the policy. It is also found that on urban routes, once a reduction in traffic demand is successfully attained by a rising gasoline price, traffic demand cannot be fully recovered to the original level before the price change. However, such observation seems to be not applicable to some local routes, suggesting that the urbanized level might be strongly associated with the above-observed structural changes. From the policy perspective, these results seem to suggest that, in urban areas, a temporal policy intervention to substantially increase gasoline price could reduce the road traffic volumes even after the price falls again, if the policy could earn people's recognition as similar properties with market mechanisms (e.g., the relationship between supply and demand). In future, it might be worth exploring the people's recognitions for various types of policies.

At the same time, the elasticities with respect to economic condition index also showed substantial fluctuations: from March to May 2008 at the average level, and from September to November 2008 at the route-specific level. One possible reason for the observed different responses across routes is the differences of industrial and/or commercial functions along routes. However, since in this study only the economic condition index at the national level is available as a proxy indicator, it is difficult to say that we already reached a sound conclusion. Given the fact that spatial distributions of industries differ from area to area (or route to route), it might be worth clarifying what kinds of industries are much more affected by economic conditions, and consequently how much decrease in traffic demand for each area can be observed. Such analysis may be useful for policy makers, for example, who attempt to expand or newly introduce expressways with considering the temporal stabilities of travel demand on a certain area given the industrial and/or commercial functions along a route.

Additionally, due to the data availability, this study has only dealt with traffic volume as an indicator of traffic demand. It seems important to confirm whether the same findings could be derived when, for example, vehicle-kilometer and fuel consumption are employed. From the methodological perspective, since the passing of time might induce the devaluation of information, it is worth incorporating the devaluation of information into the updating processes of calculating the elasticities. And, because there are probably some other factors (e.g., type of vehicle, special events, and ETC (Electronic Toll Collection) toll discount measures in Japan) influencing traffic demand, exploring the effects of these factors could provide more useful insights into policy decisions. Needless to say, it is also interesting to conduct similar analysis focusing on ordinary roads.

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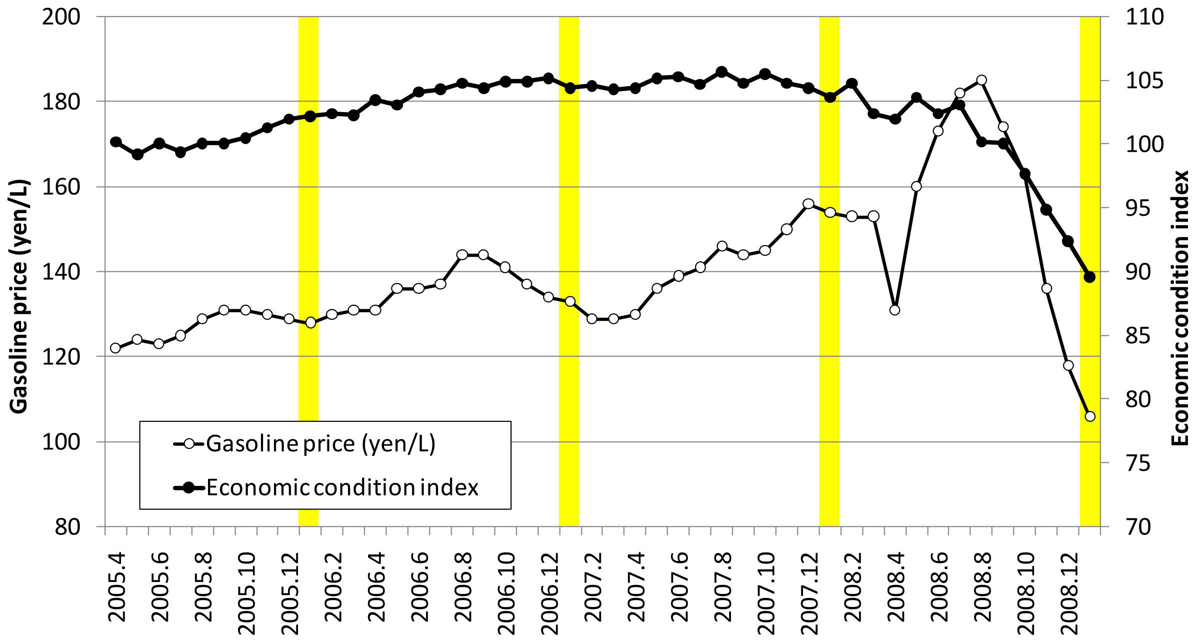

Notes) "Gasoline price" represents pump price of regular gasoline at national average. "Economic condition index" represents a coincident composite index. The composite index provides a quantitative measurement of economic strength. This is referred to as the index that indicates the "volume" of economic activities (Source: Cabinet Office, Government of Japan).

FIGURE 1 Time series' variations of gasoline price and economic condition index.

TABLE 1 Estimation Results with Full Data (up to January 2009)

Explanatory variables		Mean	S.E.	2.5%, 97.5% quantiles	Geweke
Constant	μ_0	0.413	(0.074)	0.267, 0.562	-0.431
Lagged dependent variable: $Q_{im(y-1)}$	μ_1	0.920	(0.019)	0.884, 0.957	0.390
Gasoline price: P_{imy}	μ_2	-0.118	(0.019)	-0.156, -0.080	1.041
Economic condition index: E_{my}	μ_3	0.464	(0.120)	0.226, 0.702	-0.438
Temporal trend: T_{my}	μ_4	1.94E-4	(0.001)	-0.001, 0.002	0.490
Residual	σ_0	0.002	(9.1E-05)	1.7E-3, 2.1E-3	0.050

Variance-covariance matrix Σ in eq. (3). (cells at the lower triangle part represents correlations)

0.097 (0.039)	-0.031 (0.010)	2.3E-03 (8.9E-03)	0.126 (0.052)	5.6E-04 (3.1E-04)
-0.938	0.011 (3.1E-03)	-2.2E-03 (2.6E-03)	-0.038 (0.016)	-2.4E-04 (9.8E-05)
0.115	-0.321	4.0E-03 (2.5E-03)	-0.015 (0.021)	4.0E-05 (9.9E-05)
0.616	-0.539	-0.361	0.430 (0.201)	1.6E-03 (1.1E-03)
0.391	-0.492	0.138	0.540	2.1E-05 (7.0E-06)

Number of samples (month*route)	1394
R^2	0.9994
LL[1)]	2481.78
pD[2)]	160.76
DIC[3)]	-4642.03

1) LL indicates logarithm likelihood with the posterior mean of each parameter. The LL value can be positive because the likelihood is defined based on density functions.
2) pD is a measure of model complexity for a Bayesian model. Details refer to Spiegelhalter et al. (*18*).
3) DIC stands for Deviance Information Criterion proposed by Spiegelhalter et al. (*18*), and it is defined as -2(LL-pD).

TABLE 2 Updating Results of Elasticities with Respect to Gasoline Price

Expressway [prefecture[1)]]	Jan08	Feb08	Mar08	Apr08	May08	Jun08	Jul08	Aug08	Sep08	Oct08	Nov08	Dec08	Jan09
Expressways through urban areas (here refer to Tokyo, Kanagawa, and Saitama in a narrow sense)													
Metropolitan Exp. routes in [Kanagawa]	-0.097	-0.050	-0.085	-0.045	-0.035	-0.097	-0.063	-0.090	-0.089	-0.110	-0.122	-0.122	-0.125
Metropolitan Exp. routes in [Saitama]	-0.089	-0.038	-0.070	-0.039	-0.030	-0.091	-0.060	-0.088	-0.123	-0.140	-0.159	-0.159	-0.174
Metropolitan Exp. routes in [Tokyo]	-0.095	-0.052	-0.087	-0.047	-0.036	-0.098	-0.064	-0.090	-0.094	-0.116	-0.130	-0.128	-0.132
Yokohama Yokosuka Road [Kanagawa]	-0.103	-0.046	-0.082	-0.044	-0.033	-0.096	-0.064	-0.092	-0.094	-0.112	-0.120	-0.117	-0.120
Yokohama Shindo [Kanagawa]	-0.099	-0.043	-0.079	-0.042	-0.032	-0.094	-0.062	-0.091	-0.092	-0.110	-0.119	-0.117	-0.120
Kan-Etsu Exp. [Niigata-(Kanto)]	-0.091	-0.036	-0.076	-0.042	-0.032	-0.094	-0.060	-0.089	-0.093	-0.114	-0.129	-0.130	-0.134
Keiyo Road [Tokyo-Chiba]	-0.099	-0.048	-0.084	-0.045	-0.035	-0.097	-0.064	-0.092	-0.094	-0.113	-0.124	-0.121	-0.123
Tohoku Exp. [(Tohoku)-(Kanto)]	-0.094	-0.039	-0.078	-0.041	-0.032	-0.094	-0.060	-0.089	-0.092	-0.111	-0.121	-0.120	-0.123
Joban Exp. [(Kanto)-(Tohoku)]	-0.093	-0.039	-0.076	-0.041	-0.032	-0.093	-0.061	-0.089	-0.092	-0.111	-0.122	-0.121	-0.125
Ken-O Exp. [(Kanto)]	-0.036	0.014	-0.023	-0.020	-0.014	-0.069	-0.034	-0.072	-0.107	-0.146	-0.193	-0.209	-0.213
Daisan Keihin Road [Tokyo-Kanagawa]	-0.096	-0.039	-0.075	-0.040	-0.031	-0.092	-0.060	-0.089	-0.091	-0.111	-0.122	-0.123	-0.128
Tokyo-Gaikan Exp. [Tokyo-Saitama-Chiba]	-0.092	-0.032	-0.070	-0.038	-0.029	-0.090	-0.057	-0.087	-0.090	-0.110	-0.123	-0.121	-0.126
Tokyo Bay Aqualine [Kanagawa-Chiba]	-0.084	-0.007	-0.052	-0.028	-0.020	-0.081	-0.058	-0.091	-0.103	-0.125	-0.136	-0.145	-0.145
Other expressways: through local areas													
Tokyo Bay Aqualine (accessway) [Chiba]	-0.106	-0.047	-0.089	-0.046	-0.035	-0.100	-0.075	-0.102	-0.126	-0.147	-0.162	-0.169	-0.157
Okayama Exp. [Okayama]	-0.095	-0.056	-0.090	-0.049	-0.039	-0.100	-0.068	-0.093	-0.101	-0.123	-0.133	-0.133	-0.135
Kamaishi Exp. [Iwate]	-0.099	-0.050	-0.089	-0.043	-0.039	-0.112	-0.078	-0.107	-0.118	-0.125	-0.119	-0.110	-0.117
Tateyama Exp. [Chiba]	-0.095	-0.034	-0.075	-0.041	-0.030	-0.093	-0.067	-0.095	-0.094	-0.117	-0.135	-0.138	-0.133
Kotoka Noshiro Road [Akita]	-0.154	-0.120	-0.130	-0.059	-0.047	-0.115	-0.086	-0.120	-0.170	-0.171	-0.152	-0.142	-0.131
Hiroshima-Iwakuni Road [Hiroshima]	-0.087	-0.058	-0.094	-0.050	-0.039	-0.101	-0.068	-0.092	-0.115	-0.136	-0.155	-0.157	-0.163
Hiroshima Exp. [Hiroshima]	-0.103	-0.053	-0.089	-0.048	-0.038	-0.100	-0.068	-0.095	-0.111	-0.135	-0.158	-0.168	-0.182
Sasson Exp. [Hokkaido]	-0.107	-0.063	-0.099	-0.052	-0.040	-0.103	-0.069	-0.096	-0.104	-0.119	-0.125	-0.125	-0.126
Yamagata Exp. [Miyagi-Yamagata]	-0.115	-0.061	-0.101	-0.053	-0.042	-0.107	-0.075	-0.100	-0.103	-0.115	-0.116	-0.108	-0.112
Sanyo Exp. [Okayama-Hiroshima-Yamagichi]	-0.092	-0.042	-0.080	-0.042	-0.033	-0.094	-0.059	-0.086	-0.083	-0.109	-0.121	-0.119	-0.120
Akita Gaikan Road [Akita]	-0.174	-0.158	-0.177	-0.090	-0.072	-0.144	-0.113	-0.128	-0.154	-0.155	-0.134	-0.123	-0.116
Akita Exp. [Akita-Iwate]	-0.121	-0.086	-0.113	-0.060	-0.047	-0.113	-0.081	-0.105	-0.123	-0.139	-0.145	-0.143	-0.139
Matsue Exp. [Shimane]	-0.751	-0.761	-0.719	-0.353	-0.288	-0.400	-0.365	-0.292	-0.316	-0.173	-0.009	0.045	0.034
Joshin-Etsu Exp. [Gunma-Nagano-Niigata]	-0.100	-0.045	-0.083	-0.043	-0.034	-0.095	-0.065	-0.093	-0.094	-0.110	-0.115	-0.114	-0.116

TABLE 2 (Cont'd) Updating Results of Elasticities with Respect to Gasoline Price

Expressway [prefecture[1)]]	Jan08	Feb08	Mar08	Apr08	May08	Jun08	Jul08	Aug08	Sep08	Oct08	Nov08	Dec08	Jan09
Other expressways: through local areas													
Shin-Kuko Exp. [Chiba]	-0.143	-0.106	-0.116	-0.062	-0.052	-0.124	-0.094	-0.117	-0.118	-0.126	-0.119	-0.111	-0.107
Fukagawa-Rumoi Exp. [Hokkaido]	-0.080	0.024	-0.016	-0.001	-0.001	-0.071	-0.057	-0.087	-0.104	-0.131	-0.155	-0.169	-0.184
Aomori Exp. [Aomori]	-0.145	-0.135	-0.161	-0.080	-0.063	-0.133	-0.104	-0.124	-0.143	-0.139	-0.124	-0.117	-0.119
Senen Road [Miyagi]	-0.108	-0.062	-0.096	-0.055	-0.045	-0.113	-0.084	-0.106	-0.111	-0.120	-0.113	-0.104	-0.102
Sendai-Tobu Road [Miyagi]	-0.105	-0.056	-0.084	-0.048	-0.038	-0.104	-0.073	-0.098	-0.107	-0.118	-0.120	-0.114	-0.114
Sendai-Hokubu Road [Miyagi]	-0.120	-0.076	-0.113	-0.080	-0.056	-0.130	-0.106	-0.124	-0.113	-0.118	-0.109	-0.099	-0.095
Chiba Togane Road [Chiba]	-0.103	-0.048	-0.083	-0.045	-0.034	-0.097	-0.067	-0.096	-0.095	-0.109	-0.115	-0.111	-0.112
Chugoku Exp. [(Chugoku)]	-0.107	-0.045	-0.082	-0.043	-0.034	-0.095	-0.061	-0.088	-0.078	-0.103	-0.111	-0.109	-0.115
Nagano Exp. [Nagano]	-0.110	-0.058	-0.085	-0.043	-0.033	-0.098	-0.071	-0.104	-0.103	-0.114	-0.116	-0.111	-0.113
Higashi-Kanto Exp. [Chiba-Ibarabi]	-0.100	-0.047	-0.083	-0.044	-0.034	-0.095	-0.063	-0.091	-0.096	-0.117	-0.132	-0.130	-0.133
Higashi Mito Road [Ibaragi]	-0.168	-0.131	-0.173	-0.083	-0.067	-0.142	-0.118	-0.130	-0.123	-0.116	-0.092	-0.073	-0.059
Tohoku-Chuo Exp. [Fukushima-Yamagata]	-0.126	-0.102	-0.107	-0.050	-0.038	-0.107	-0.079	-0.106	-0.114	-0.123	-0.122	-0.114	-0.117
Yuzawa-Yokote Road [Akita]	-0.102	-0.064	-0.094	-0.051	-0.038	-0.102	-0.073	-0.102	-0.116	-0.128	-0.136	-0.132	-0.130
Hokkaido Exp. [Hokkaido]	-0.097	-0.043	-0.081	-0.043	-0.033	-0.095	-0.060	-0.089	-0.095	-0.114	-0.124	-0.126	-0.131
Doto Exp. [Hokkaido]	-0.379	-0.400	-0.394	-0.182	-0.146	-0.235	-0.201	-0.178	-0.183	-0.148	-0.097	-0.083	-0.036
Hidaka Exp. [Hokkaido]	-0.074	0.021	-0.019	-0.031	-0.024	-0.089	-0.060	-0.093	-0.065	-0.088	-0.097	-0.095	-0.105
Nihonkai-Tohoku Exp. [Niigata-Yamagata-Akita]	-0.162	-0.142	-0.158	-0.077	-0.059	-0.124	-0.094	-0.114	-0.150	-0.152	-0.150	-0.145	-0.144
Hachinohe Exp. [Iwate-Aomori]	-0.108	-0.051	-0.077	-0.040	-0.030	-0.094	-0.067	-0.099	-0.093	-0.108	-0.109	-0.103	-0.110
Ban-Etsu Exp. [Fukushima-Niigata]	-0.111	-0.056	-0.092	-0.047	-0.036	-0.099	-0.070	-0.098	-0.106	-0.115	-0.115	-0.106	-0.114
Momoishi Road [Aomori]	-0.318	-0.355	-0.395	-0.187	-0.156	-0.249	-0.219	-0.196	-0.175	-0.131	-0.052	-0.013	0.002
Hamada Exp. [Shimane-Hiroshima]	-0.108	-0.083	-0.118	-0.065	-0.051	-0.116	-0.085	-0.108	-0.106	-0.126	-0.133	-0.136	-0.130
Futtsu-Tateyama Road [Chiba]	-0.049	-0.029	-0.086	-0.048	-0.037	-0.098	-0.070	-0.113	-0.195	-0.192	-0.186	-0.185	-0.183
Yonago Exp. [Tottori-Okayama]	-0.112	-0.061	-0.095	-0.051	-0.040	-0.102	-0.069	-0.093	-0.083	-0.107	-0.109	-0.106	-0.104
Yonezawa Nan-Yo Road [Yamagata]	-0.089	-0.057	-0.097	-0.058	-0.045	-0.118	-0.090	-0.117	-0.089	-0.098	-0.092	-0.082	-0.085
Kita-Kanto Exp. [Gunma-Tochigi-Ibaragi]	-0.111	-0.075	-0.145	-0.093	-0.084	-0.168	-0.142	-0.149	-0.104	-0.092	-0.057	-0.031	0.010
Hokuriku Exp. [Niigata-Toyama]	-0.117	-0.076	-0.110	-0.058	-0.046	-0.112	-0.084	-0.106	-0.109	-0.122	-0.125	-0.122	-0.115
Average (μ_2)	-0.127	-0.083	-0.116	-0.061	-0.048	-0.115	-0.084	-0.107	-0.114	-0.124	-0.123	-0.118	-0.118

1) If the number of prefectures passed through by the corresponding expressway is three or more, we only show the name of a wider region name in ( ).

TABLE 3 Updating Results of Elasticities with Respect to Economic Condition Index

Expressway [prefecture[1)]]	Jan08	Feb08	Mar08	Apr08	May08	Jun08	Jul08	Aug08	Sep08	Oct08	Nov08	Dec08	Jan09
Expressways through urban areas (here refer to Tokyo, Kanagawa, and Saitama in a narrow sense)													
Metropolitan Exp. routes in [Kanagawa]	0.527	0.606	0.098	0.183	0.138	0.387	0.399	0.694	0.538	0.210	0.246	0.281	0.315
Metropolitan Exp. routes in [Saitama]	0.575	0.654	0.148	0.214	0.173	0.415	0.418	0.730	1.610	1.276	0.902	0.678	0.614
Metropolitan Exp. routes in [Tokyo]	0.532	0.598	0.090	0.177	0.131	0.381	0.396	0.696	0.708	0.416	0.409	0.384	0.418
Yokohama Yokosuka Road [Kanagawa]	0.502	0.621	0.106	0.191	0.150	0.393	0.394	0.676	0.665	0.305	0.207	0.203	0.204
Yokohama Shindo [Kanagawa]	0.522	0.634	0.116	0.196	0.156	0.398	0.403	0.685	0.618	0.223	0.161	0.190	0.186
Kan-Etsu Exp. [Niigata-(Kanto)]	0.557	0.658	0.123	0.198	0.155	0.402	0.413	0.706	0.730	0.373	0.333	0.358	0.346
Keiyo Road [Tokyo-Chiba]	0.517	0.613	0.098	0.184	0.139	0.386	0.394	0.680	0.633	0.290	0.302	0.292	0.292
Tohoku Exp. [(Tohoku)-(Kanto)]	0.543	0.649	0.121	0.200	0.157	0.402	0.412	0.707	0.692	0.261	0.168	0.170	0.137
Joban Exp. [(Kanto)-(Tohoku)]	0.547	0.649	0.124	0.201	0.159	0.403	0.409	0.697	0.652	0.257	0.228	0.247	0.272
Ken-O Exp. [(Kanto)]	0.780	0.839	0.283	0.283	0.251	0.507	0.525	0.859	1.685	1.679	1.734	1.700	1.507
Daisan Keihin Road [Tokyo-Kanagawa]	0.536	0.650	0.129	0.205	0.166	0.409	0.416	0.704	0.657	0.273	0.202	0.236	0.238
Tokyo-Gaikan Exp. [Tokyo-Saitama-Chiba]	0.553	0.673	0.146	0.216	0.175	0.420	0.425	0.717	0.684	0.236	0.186	0.174	0.161
Tokyo Bay Aqualine [Kanagawa-Chiba]	0.572	0.762	0.192	0.251	0.219	0.454	0.417	0.680	1.078	0.834	0.640	0.820	0.797
Other expressways: through local areas													
Tokyo Bay Aqualine (accessway) [Chiba]	0.448	0.603	0.072	0.168	0.125	0.367	0.339	0.578	1.217	1.437	1.688	1.857	1.654
Okayama Exp. [Okayama]	0.540	0.584	0.083	0.167	0.119	0.373	0.378	0.665	0.871	0.663	0.521	0.497	0.444
Kamaishi Exp. [Iwate]	0.518	0.602	0.081	0.188	0.113	0.323	0.343	0.567	0.638	0.382	0.329	0.258	0.257
Tateyama Exp. [Chiba]	0.535	0.664	0.128	0.201	0.166	0.402	0.382	0.641	0.638	0.534	0.718	0.771	0.716
Kotoka Noshiro Road [Akita]	0.256	0.340	-0.042	0.120	0.071	0.309	0.306	0.459	1.377	1.709	1.868	1.802	1.552
Hiroshima-Iwakuni Road [Hiroshima]	0.564	0.575	0.070	0.160	0.114	0.368	0.379	0.676	1.402	1.215	1.046	0.955	0.918
Hiroshima Exp. [Hiroshima]	0.512	0.599	0.088	0.173	0.124	0.374	0.383	0.671	1.181	1.122	0.992	1.034	1.071
Sasson Exp. [Hokkaido]	0.484	0.556	0.053	0.153	0.113	0.357	0.378	0.646	0.716	0.388	0.296	0.356	0.188
Yamagata Exp. [Miyagi-Yamagata]	0.446	0.562	0.047	0.152	0.101	0.341	0.348	0.607	0.608	0.244	0.142	0.096	0.087
Sanyo Exp. [Okayama-Hiroshima-Yamagichi]	0.553	0.638	0.113	0.194	0.150	0.401	0.417	0.725	0.461	0.189	0.148	0.154	0.184
Akita Gaikan Road [Akita]	0.153	0.192	-0.192	-0.010	-0.075	0.175	0.184	0.369	0.880	1.210	1.298	1.230	1.074
Akita Exp. [Akita-Iwate]	0.408	0.465	0.007	0.120	0.068	0.313	0.320	0.566	0.963	1.021	1.077	1.022	0.862
Matsue Exp. [Shimane]	-2.496	-2.085	-1.863	-1.122	-1.286	-0.972	-0.912	-1.035	-0.683	-0.158	0.180	0.357	0.561
Joshin-Etsu Exp. [Gunma-Nagano-Niigata]	0.514	0.623	0.102	0.191	0.146	0.393	0.392	0.662	0.665	0.224	0.085	0.136	0.169

TABLE 3 (Cont'd) Updating Results of Elasticities with Respect to Economic Condition Index

Expressway [prefecture[1)]]	Jan08	Feb08	Mar08	Apr08	May08	Jun08	Jul08	Aug08	Sep08	Oct08	Nov08	Dec08	Jan09
Other expressways: through local areas													
Shin-Kuko Exp. [Chiba]	0.306	0.390	0.002	0.113	0.044	0.266	0.265	0.457	0.575	0.465	0.625	0.614	0.571
Fukagawa-Rumoi Exp. [Hokkaido]	0.640	0.905	0.323	0.379	0.341	0.520	0.445	0.761	1.381	0.969	0.584	0.576	0.223
Aomori Exp. [Aomori]	0.311	0.286	-0.136	0.035	-0.014	0.227	0.229	0.420	0.776	0.736	0.664	0.623	0.544
Senen Road [Miyagi]	0.479	0.560	0.062	0.141	0.081	0.314	0.309	0.554	0.581	0.349	0.227	0.204	0.178
Sendai-Tobu Road [Miyagi]	0.489	0.581	0.100	0.171	0.120	0.356	0.355	0.623	0.697	0.379	0.319	0.283	0.239
Sendai-Hokubu Road [Miyagi]	0.424	0.503	0.010	0.040	0.026	0.243	0.213	0.402	0.296	0.151	0.231	0.305	0.334
Chiba Togane Road [Chiba]	0.503	0.615	0.105	0.184	0.146	0.388	0.381	0.640	0.525	0.143	0.170	0.160	0.206
Chugoku Exp. [(Chugoku)]	0.495	0.627	0.108	0.194	0.148	0.397	0.411	0.709	0.196	-0.101	-0.123	-0.061	0.038
Nagano Exp. [Nagano]	0.471	0.576	0.100	0.194	0.152	0.384	0.366	0.573	0.619	0.293	0.153	0.163	0.130
Higashi-Kanto Exp. [Chiba-Ibarabi]	0.516	0.615	0.105	0.189	0.147	0.395	0.403	0.689	0.740	0.448	0.489	0.406	0.382
Higashi Mito Road [Ibaragi]	0.188	0.296	-0.179	0.020	-0.048	0.181	0.157	0.332	0.203	0.024	0.307	0.255	0.175
Tohoku-Chuo Exp. [Fukushima-Yamagata]	0.403	0.415	0.036	0.165	0.125	0.341	0.332	0.561	0.698	0.453	0.484	0.342	0.330
Yuzawa-Yokote Road [Akita]	0.488	0.545	0.060	0.154	0.114	0.362	0.359	0.597	0.869	0.647	0.838	0.777	0.638
Hokkaido Exp. [Hokkaido]	0.529	0.632	0.110	0.193	0.152	0.397	0.417	0.705	0.728	0.319	0.150	0.220	0.106
Doto Exp. [Hokkaido]	-0.816	-0.723	-0.862	-0.406	-0.499	-0.240	-0.207	-0.096	-0.191	0.480	1.510	1.942	2.051
Hidaka Exp. [Hokkaido]	0.641	0.876	0.298	0.248	0.206	0.425	0.417	0.660	0.204	-0.473	-0.853	-0.807	-0.796
Nihonkai-Tohoku Exp. [Niigata-Yamagata-Akita]	0.210	0.254	-0.132	0.044	-0.001	0.263	0.266	0.493	1.202	1.321	1.424	1.312	1.248
Hachinohe Exp. [Iwate-Aomori]	0.492	0.608	0.126	0.207	0.171	0.404	0.386	0.616	0.503	0.091	-0.165	-0.245	-0.292
Ban-Etsu Exp. [Fukushima-Niigata]	0.469	0.583	0.077	0.177	0.134	0.377	0.372	0.631	0.778	0.307	0.057	-0.080	-0.055
Momoishi Road [Aomori]	-0.496	-0.545	-0.853	-0.414	-0.539	-0.291	-0.273	-0.225	-0.533	-0.256	0.111	0.071	0.134
Hamada Exp. [Shimane-Hiroshima]	0.462	0.473	-0.010	0.095	0.039	0.293	0.299	0.538	0.508	0.609	0.728	0.874	0.897
Futtsu-Tateyama Road [Chiba]	0.667	0.649	0.067	0.142	0.102	0.366	0.369	0.526	2.183	2.597	2.534	2.343	1.940
Yonago Exp. [Tottori-Okayama]	0.466	0.568	0.069	0.162	0.113	0.366	0.373	0.659	0.258	-0.010	-0.059	0.047	0.108
Yonezawa Nan-Yo Road [Yamagata]	0.570	0.579	0.061	0.134	0.084	0.293	0.280	0.450	0.106	-0.336	-0.470	-0.444	-0.409
Kita-Kanto Exp. [Gunma-Tochigi-Ibaragi]	0.448	0.506	-0.097	-0.023	-0.147	0.060	0.042	0.165	-0.943	-1.002	-0.293	-0.056	-0.100
Hokuriku Exp. [Niigata-Toyama]	0.430	0.507	0.017	0.127	0.074	0.317	0.305	0.547	0.626	0.478	0.632	0.685	0.652
Average (μ_2)	0.387	0.479	0.001	0.116	0.065	0.307	0.308	0.548	0.669	0.489	0.496	0.504	0.464

1) If the number of prefectures passed through by the corresponding expressway is three or more, we only show the name of a wider region name in ( ).

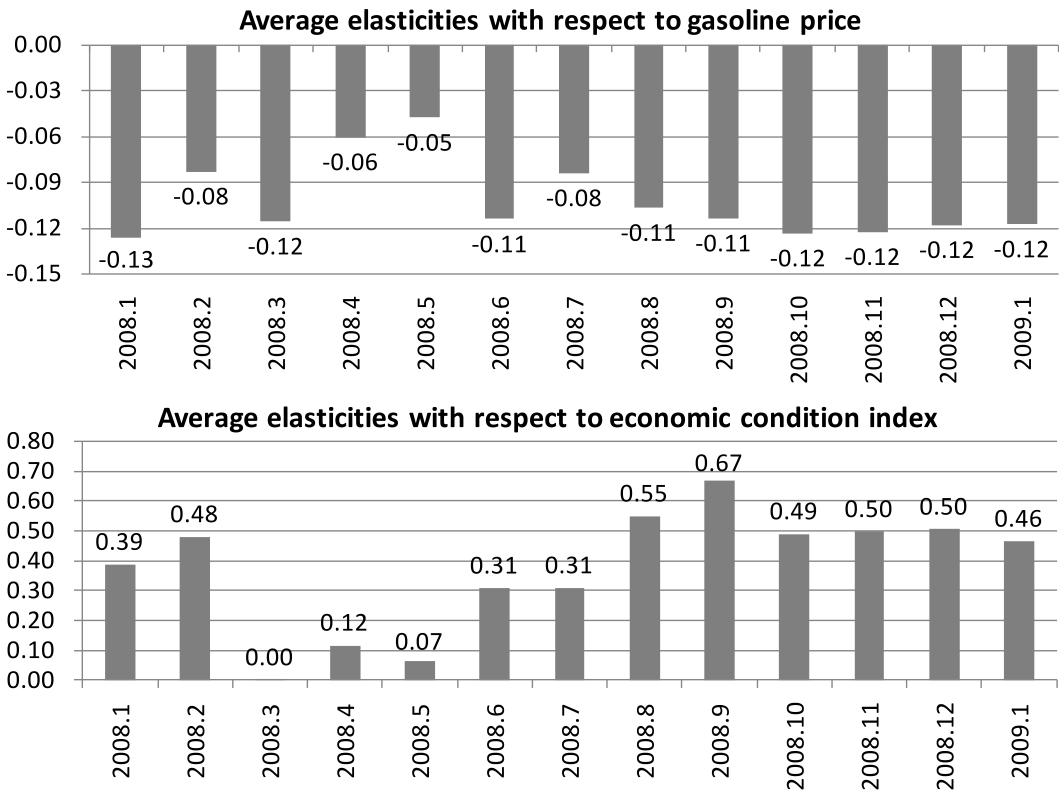

FIGURE 2 Changes in the average elasticities.

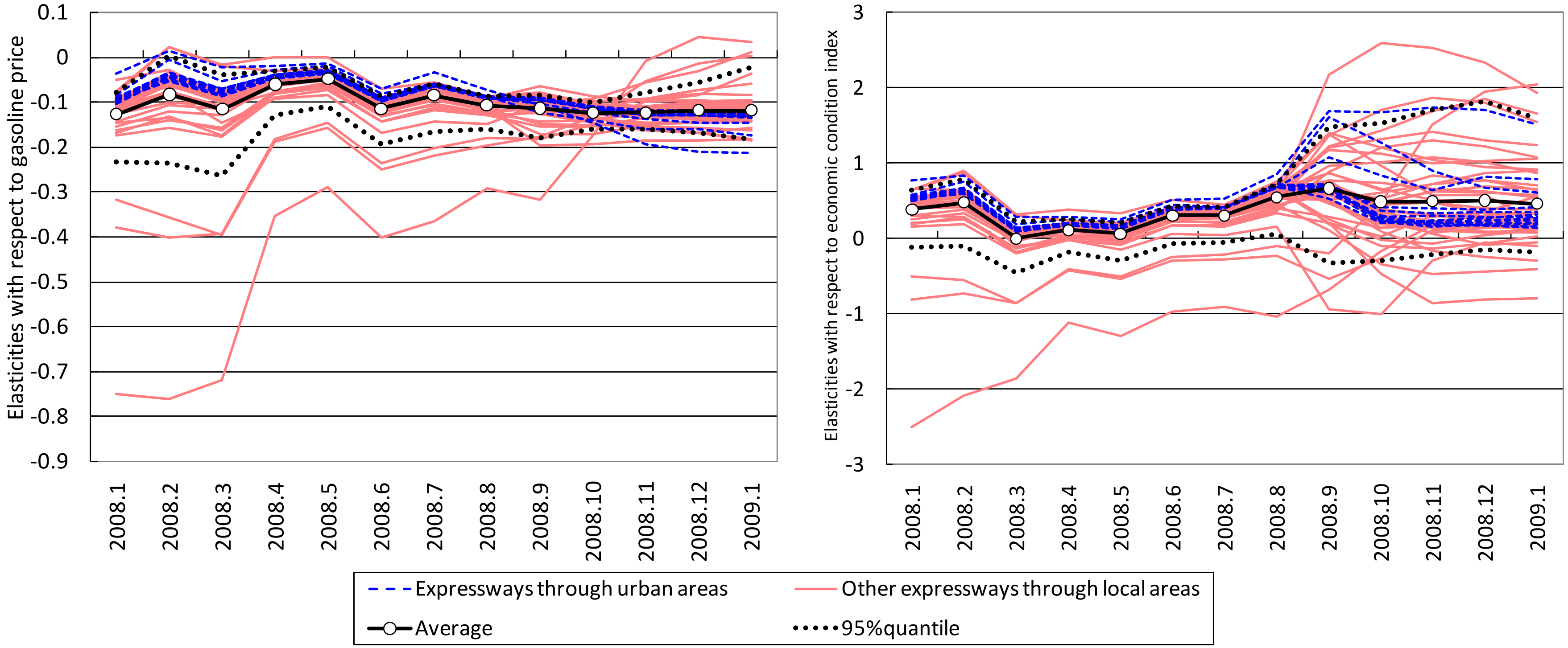

FIGURE 3 Trajectories of route-specific elasticities.

TABLE 4 Correlation Matrices of the Route-Specific Elasticities

		2008												2009
		1	2	3	4	5	6	7	8	9	10	11	12	1
2008	1	1.00	0.99	0.98	0.97	0.97	0.97	0.96	0.94	0.52	0.18	-0.03	-0.10	-0.18
	2	0.99	1.00	1.00	0.99	0.98	0.98	0.97	0.96	0.52	0.15	-0.08	-0.13	-0.22
	3	0.98	1.00	1.00	0.99	0.99	0.99	0.98	0.97	0.54	0.18	-0.06	-0.12	-0.21
	4	0.97	0.99	0.99	1.00	1.00	0.99	0.99	0.98	0.57	0.21	-0.03	-0.10	-0.18
	5	0.97	0.98	0.99	1.00	1.00	1.00	0.99	0.98	0.59	0.22	-0.02	-0.08	-0.17
	6	0.97	0.98	0.99	0.99	1.00	1.00	1.00	0.99	0.61	0.25	0.00	-0.06	-0.14
	7	0.96	0.97	0.98	0.99	0.99	1.00	1.00	0.99	0.62	0.26	0.01	-0.06	-0.13
	8	0.94	0.96	0.97	0.98	0.98	0.99	0.99	1.00	0.61	0.24	-0.01	-0.07	-0.14
	9	0.84	0.87	0.86	0.85	0.84	0.84	0.84	0.87	1.00	0.89	0.66	0.57	0.50
	10	0.40	0.45	0.43	0.40	0.39	0.38	0.38	0.42	0.80	1.00	0.92	0.87	0.81
	11	-0.67	-0.65	-0.67	-0.70	-0.71	-0.73	-0.73	-0.71	-0.30	0.32	1.00	0.98	0.96
	12	-0.73	-0.72	-0.74	-0.76	-0.78	-0.79	-0.79	-0.78	-0.41	0.20	0.99	1.00	0.99
2009	1	-0.70	-0.71	-0.74	-0.77	-0.78	-0.80	-0.80	-0.79	-0.42	0.16	0.95	0.97	1.00

Note) Cells at the lower triangle part represent the correlations of route-specific elasticities with respect to gasoline price between pairs of months. Cells at the upper triangle part represent those correlations with respect to economic condition index.