AN ANALYSIS OF ROAD USER COST AND EXTERNAL COSTS OF MOTOR VEHICLES

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1. INTRODUCTION

In Japan, the aspects related to road user cost, such as abolishment of the provisional tax on gasoline and tolls on highways, are political issues. However, a discussion regarding the socially preferable level of road user cost has not been conducted thus far. In this paper, we first estimate the external cost of motor vehicles for different regions in Japan. On the basis of the results obtained from this estimation, we consider the mechanism of road user cost that corresponds with the level of external cost of motor vehicles. According to the Pigovian tax theory, road user costs must correspond with the marginal social cost of motor vehicles. In particular, we believe that the optimum level of road user cost is liable to vary from region to region because the external cost in each region varies considerably depending on traffic conditions. In this study, we estimate the external cost of motor vehicles in Japan according to prefecture and vehicle type, taking into account every region's traffic conditions; moreover, we reveal the features of regional external costs of motor vehicles.

The remainder of this paper is structured in the following manner. In section 2, we present an outline of automobile-related taxes. In section 3, we first discuss previous studies on external cost and then explain the method used by us for estimating external cost of motor vehicles. Thereafter, based on the equations obtained, we estimate the external costs of motor vehicles using a data set of 47 prefectures in Japan. Finally, based on our results, we consider road user cost in Japan.

2. OUTLINE OF AUTOMOBILE-RELATED TAXES

In Japan, automobile-related taxes are divided into taxes imposed on fuel and taxes imposed on vehicle ownership. Taxes imposed on fuel include gasoline tax, local road tax, light oil delivery tax, liquefied petroleum gas tax, crude oil tariff, and consumption tax. Gasoline tax is the tax imposed on gasoline; the current gasoline tax rate is 48.6 yen per litre (including provisional tax of 24.3 yen per litre). Local road tax is also imposed on gasoline; this tax was established in order to transfer funds to local governments for improving roads, and the current tax rate is 5.2 yen per litre of gasoline (including provisional tax). Light oil delivery tax is imposed on diesel fuel for diesel vehicles; the current tax rate is 32.1 yen per

litre of diesel fuel (including provisional tax). Liquefied petroleum gas tax is imposed on liquefied petroleum gas, which is used in taxis, and the current tax rate is 17.5 yen per kg of liquefied petroleum gas. Taxes imposed on vehicle ownership include automobile acquisition tax, automobile tax, compact automobile (keisharyo) tax, motor vehicle tonnage tax, and consumption tax. Automobile acquisition tax is imposed on car buyers; the current tax rate is 3~5% of the automobile price. Automobile and subcompact automobile taxes are imposed on vehicle owners, and are levied according to vehicle size. Motor vehicle tonnage tax is another tax imposed on vehicle owners according to vehicle weight. These taxes, along with crude oil tariff and consumption tax, are known as automobile-related taxes. From a historical perspective, these taxes were established in order to secure fiscal resources for road construction; thus, these taxes barely take into consideration the size of external costs of motor vehicles.

Table1 Types of automobile-related taxes

Type of tax		Outline
Tax on fuel		
	Gasoline tax	Gasoline：48.6yen/ℓ(including rovisional tax(24.3yen/ℓ))
	Local Road Tax	Gasoline：5.2yen/ℓ(including provisional tax(0.8yen/ℓ))
	Light oil delivery tax	Diesel fuel：32.1yen/ℓ(including provisional tax(15.0yen円/ℓ))
	Liquefied petroleum gas tax	Liquefied petroleum gas：17.5yen/kg
	Crude oil tariff	Tax on crude oil
	Consumption tax	5% of fuel price(tax on tax)
Tax on vehicles		
	Automobile acquisition tax	3～5% of car price
	Consumption tax	5% of total car price(tax on tax)
	Automobile tax	Determined by displacement
	Compact Automobile(keisharyo) tax	Determined by displacement
	Motor vehicle tonnage tax	Determined by tonnage

3. ESTIMATING EXTERNAL COSTS OF MOTOR VEHICLES

3.1 Previous studies on external costs of motor vehicles

In this section, we consider two separate categories of previous studies: those that use cities and those that use countries as aggregation units. As indicated in Table 1, in a majority of previous studies, the aggregation unit of external costs is country. For example, ECMT (1998) employed cross-sectional data sets of entire countries in Europe. The study investigates external costs for cars, trucks, and trains in 15 EU countries, including Switzerland and Norway. Road traffic accidents, noise, air pollution, climate change, road traffic congestion, and under-funded infrastructure are all considered external costs. UNITE (2003) and INFRAS/IWW (2005) also employed cross-sectional data sets of entire countries in Europe. UNITE (2003) is a study conducted by the European Commission (EC) for facilitating policy-making on the pricing and taxation of passenger and freight transportation modes. The study estimated operating and external costs of several transportation modes such as road, rail, air, and maritime transportation in 18 European countries. The external costs take into account road traffic congestion, air pollution, noise, climate change, and road traffic accidents, as well as other items including sight pollution and nuclear risks.

INFRAS/IWW (2005) is a study on the external costs of transport, drawn up in 1995, 1999, 2005, and 2007. The study estimates the external costs of cars, bikes, buses, trucks, trains, airplanes, and shipping in 17 European countries and considers road traffic accidents, noise, air pollution, climate change, destruction of the natural environment, and other items related to external costs. Koyama and Kishimoto (2001) is a pioneering study on the external costs of motor vehicles in Japan. This study estimates the external costs of motor vehicles in Japan by dividing motor vehicles into passenger cars, buses, small trucks, and trucks. Their list of external costs includes air pollution, climate change, noise, and road traffic accidents.

On the other hand, other studies estimate external costs using city as the aggregation unit. For example, Mayeres et al. (1996) estimate the external costs of transport in Brussels in 1995. Their study distinguishes among cars, buses, trams, subways, and trucks and considers the external costs of transport, road traffic congestion, air pollution, road traffic accidents, noise, and climate change. Gibbons and O'Mathony (2002) estimate the external costs of transport in Dublin in 2005. Their study distinguishes among passenger transportation by car, bus, or railways. The external costs considered are road traffic congestion, air pollution, road traffic accidents, and noise. Other studies include Jakob et al. (2006) for Oakland.

3.2 An outline of the estimation of external cost

When we estimate the external costs of automobiles, the manner in which evaluation figures of the estimation process and unit cost are determined is important. This study estimates the external costs of motor vehicles for 47 prefectures in Japan, based on Mizutani et al. (2009); they made the estimation process specific based on some previous studies conducted overseas as well as domestically. The estimation process is outlined below.
We estimate the external costs of motor vehicles by distinguishing the types of external costs. In this study, the total external costs of motor vehicles is the sum of the costs incurred due to road traffic accidents, air pollution, noise, climate change, and congestion. As is evident from the preceding paragraph, these cost items have been used by numerous previous studies. There are discussions that the congestion cost has already become an internal cost because a person using a motor vehicle to commute spends an excessive amount of time commuting due to congestion. However, numerous studies included the congestion cost as an external cost of motor vehicles; thus, in this study we also include congestion costs in the external costs of motor vehicles.

3.2.1 Key Variables for the Estimation of External Costs of Motor vehicles

For our study, a precise estimation of the average speed of motor vehicles and traffic volume in a region is important as these will be used as basic data. [1] The estimation process using annual road traffic volume and average speed is explained below.

Road Traffic Volume is derived in the following manner. First, we add the daily traffic volume on trunk roads for 47 prefectures using data from '2005 Road Transport Census

[1] In this study, a road is categorized into motorway and highway, which is according to the *2005 Road Transport Census (2005 Doro Kotsu Sensasu)*.

(2005 Doro Kotsu Sensasu)'; vehicles were categorized into cars, buses, small trucks, and trucks. Further, we calculate annual traffic volumes by multiplying the number of days in a year by daily traffic volumes. However, since we cannot use the traffic data pertaining to city roads, we calculate annual traffic volumes for city roads assuming that the traffic volume on city roads is the same as that on prefectural roads. [2]

Traffic Speed is derived in the following manner. First, the average traffic speed on the highway is estimated using a speed-flow model. This speed-flow model is estimated using data from '*2005 Doro Kotsu Sensas*', as given in equation (3.1). In this data, traffic volume per hour and traffic speed during peak traffic time is added. Further, we construct a model where the speed of motor vehicles on the highway was explained by traffic volume and the number of signals on the road.

$$V_{a,line} = \underset{(0.23)}{45.9} - \underset{(0.00051)}{0.0044}\, q_{a,line} - \underset{(0.12)}{5.9513}\, SIG_{a,line} \qquad (3.1)$$

$$adjR^2 = 0.32$$

$V_{a,line}$: Travel speed (km/h) per line in region a;

$q_{a,line}$: Traffic volume (vehicle/h) per line;

$SIG_{a,line}$: Number of signals per km of road survey sections.

a : Region;

$line$: Road section.

On the other hand, we assume that the average vehicle speed on the motorway is 80 km/h, which is legal, because most motorways are not congested.

3.2.2 Estimation Models of Individual External Cost

In this section, we explain the estimation process according to cost items.

According to Mizutani et al. (2009), the external cost of a road traffic accident is calculated by multiplying the unit cost of the damage by the total amount of damage caused by the road traffic accident. Such damage includes death, serious injury, and minor injury caused by the road traffic accident. The data pertaining to accident damage is obtained from *the Annual Report of Traffic Accidents (Kotsu Jiko Tokei Nenpo)*. The unit cost of a road traffic accident is obtained from the index of the Cabinet Office (2007). [3]

The external cost of air pollution is calculated by estimating the emission of PM_{10}, which is an air pollutant emitted by motor vehicles. First, we calculate the amount of PM_{10} emitted by motor vehicles in the 47 prefectures. The concentration of PM_{10} emitted by motor vehicles in the air is estimated on the basis of the amount of emission.[4] Further, we estimate

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[2] We analyze roads with a width of 5.5m or more.

[3] The unit cost of death caused by a road traffic accident is 229.032 million yen, serious injury is 84.81 million yen, and minor injury is 0.846 million yen.

[4] We use the dispersion model given by Mizutani et al. (2009) so that PM10 from the car may presume the influence given to the concentration in the region. The model is represented in the following manner.

$atm_{PM,a} = 0.03 + 0.0026 \ln(EMI_{PM,a})$

$atm_{PM,a}$:Annual average concentration of PM_{10} (mg/km^3) according to regions; ,

the adverse effects of these emissions on the health of residents. Finally, the adverse effect on the health of residents is calculated in monetary terms.[5]

The external cost of noise is calculated according to the method given by Mizutani et al. (2009). First, we estimate the noise level generated from the motor vehicles using the estimation model given in *Doro Toshi no Hyouka ni Kansuru Shishin Kento Iinkai* (1998). Next, we determine which section of the population is influenced by the noise caused by motor vehicles. Further, we estimate the external cost of noise by multiplying the unit cost of noise by the volume of damage caused by the noise.[6]

Next, the external cost of climate change is estimated by multiplying the unit cost of climate change by the amount of carbon dioxide (CO_2) emitted by motor vehicles.[7]

In order to calculate the external cost of congestion, we first estimate the amount of time lost by a motor vehicle user due to congestion, based on the average travel speed on the highway, which is estimated in the manner described in the preceding paragraph. We estimate the external cost of congestion by multiplying the value of time by the amount of time lost.[8] We define the amount of time lost as the additional travel time taken due to congestion as compared with the travel time taken when there is no congestion. Mizutani et al. (2009) assumed that legal speed is the travel speed when there is no congestion. Therefore, we determine the legal travel speed when there is no congestion at 40 km/h, and estimate the amount of time lost.

3.2.2 Results

In this study, we calculated the external costs of motor vehicles for 47 prefectures in Japan using regional data for the year 2005 and categorizing vehicles into cars, buses, light trucks, and trucks. We also calculated external costs by distinguishing among different kinds of external costs: road traffic accidents, air pollution, noise, climate change, and road traffic congestion.

In this section, we discuss the results of the estimated external costs of motor vehicles by examining the following aspects: (i) the magnitude of external costs in all of Japan, (ii) the relationship between external costs for 47 prefectures and population density, (iii) the marginal external cost by vehicle type.

First, Table 2 indicates the total external cost of motor vehicles and the percentage of GDP in Japan. The sum of external cost of motor vehicles in Japan is approximately 36 trillion yen. In terms of items of external cost, the external cost of road traffic congestion is the highest—42.4% of the total. This is followed by the external cost of air pollution and road traffic accidents. The magnitude of the external costs of motor vehicles is approximately

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$EMI_{PM,a}$:Annual amount of PM_{10} emitted by motor vehicles that run within a range of $1m^2$ in the region（$g/m^2/year$）.

[5] The index for the monetary calculation has been taken from Mizutani et al. (2009).

[6] The unit cost of noise is assumed to be 5,000 yen/dB, according to Mizutani et al. (2009).

[7] The unit cost of climatic change is assumed to be 14,000 yen/t-CO_2, according to Mizutani et al. (2009).

[8] The value of time is assumed to be 49.10 yen/vehicle/minutes for cars, 47.91 yen/vehicles/minutes for small trucks, 64.18 yen/vehicles/minutes for trucks, according to the Ministry of Land Infrastructure and Transport (2008).

7.2% of the GDP. This result is very similar to that of INFRAS/IWW (2004) (7.3%). The results obtained in ECMT (1998)—(4.2%)—did not include the external costs of road traffic congestion; however, our result will be similar to those of ECMT if we do not include the cost of road traffic congestion. The results obtained by Koyama and Kishimoto (2001) for Japan is an external cost of approximately 6.6% of GDP (median estimate), which is also similar to our result.

Table 2 Estimation Results of External Costs of Motor Vehicles

	Total	Accident	Air Pollution	Noise	Climate Change	Congestion
External Cost	36,205	7,408	9,654	883	2,894	15,366
	(100)	(20.5)	(26.7)	(2.4)	(8.0)	(42.4)

(note)
(1) Unit: billion yen

Second, Table 3 indicates marginal external cost by vehicle type. The external cost of a truck is 3~4 times higher than that of other vehicle types. In particular, trucks generate a high external cost of air pollution and noise. This study considers PM10, the emission levels of which are highest for trucks. The impact of PM10 from trucks proved to be dominant as compared to other external costs; the impact of road traffic congestion and road traffic accidents was dominant for cars.

Table 3 Marginal External Costs of Motor Vehicles

	Total	Accident	Air Pollution	Noise	Climate Change	Congestion
Car	31.35	8.76	1.03	2.15	2.32	17.10
Small Truck	41.77	8.76	8.16	2.61	2.79	19.44
Truck	131.54	8.76	71.70	11.57	12.31	27.21

(Note):
(1)Unit: yen/vehicle-km
(2)Marginal external cost is external cost divided by traffic volume (vehicle-km), thus marginal external cost is the same as the average external cost.

Third, Figure 1 illustrates the relationship between the external cost of motor vehicles for 47 prefectures and population density. The external cost is high in regions with higher population density, for example Tokyo, Osaka, and Kanagawa. We believe that regions with higher population density have a city structure that causes frequent road traffic congestion, pollution, and noise, which affects residents. In contrast, in the historic regions of Kyoto and Nara, the external cost is relatively lower. Kyoto and Nara appear to have zoning features that reduce the incidence of external cost of motor vehicles.

Further, we indicate the relationship between external cost of motor vehicles and population density among regions. Figure 1 indicates the relationship between the total marginal external cost of motor vehicles and population density among 47 prefectures. Marginal external cost of motor vehicles tended to increase in regions that are more populous. For example, the marginal external cost in populous regions such as Tokyo, Osaka, and Kanagawa is approximately three times higher than the national average.

Moreover, according to vehicle type, the marginal external cost of trucks is higher than that of other vehicle types.

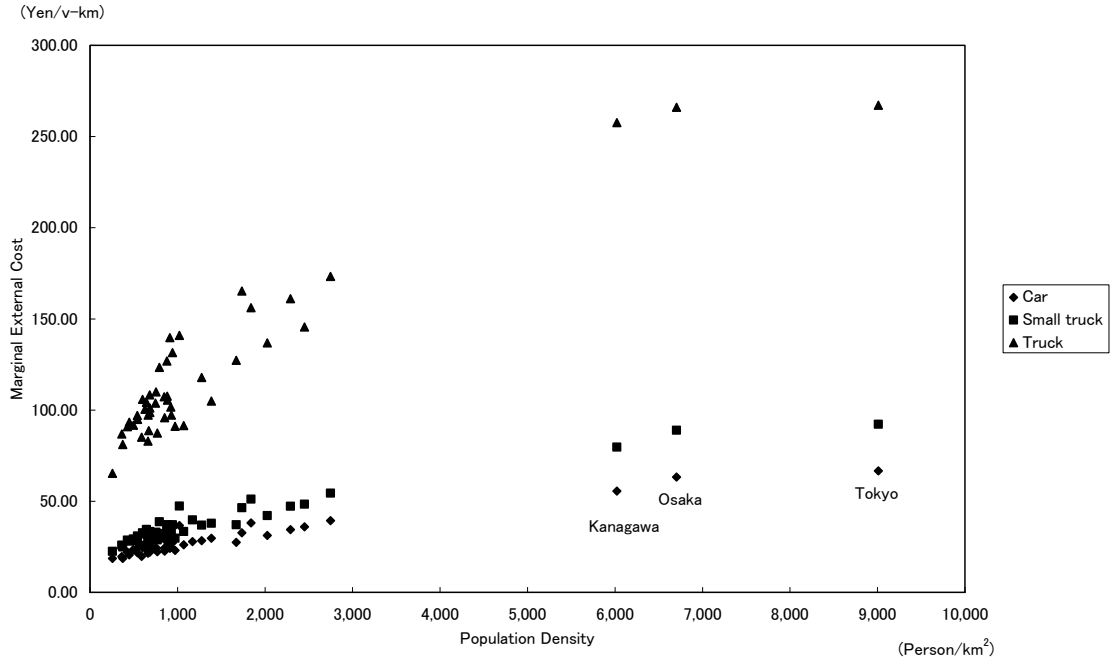

Figure 1 Relationship between marginal external cost and population density

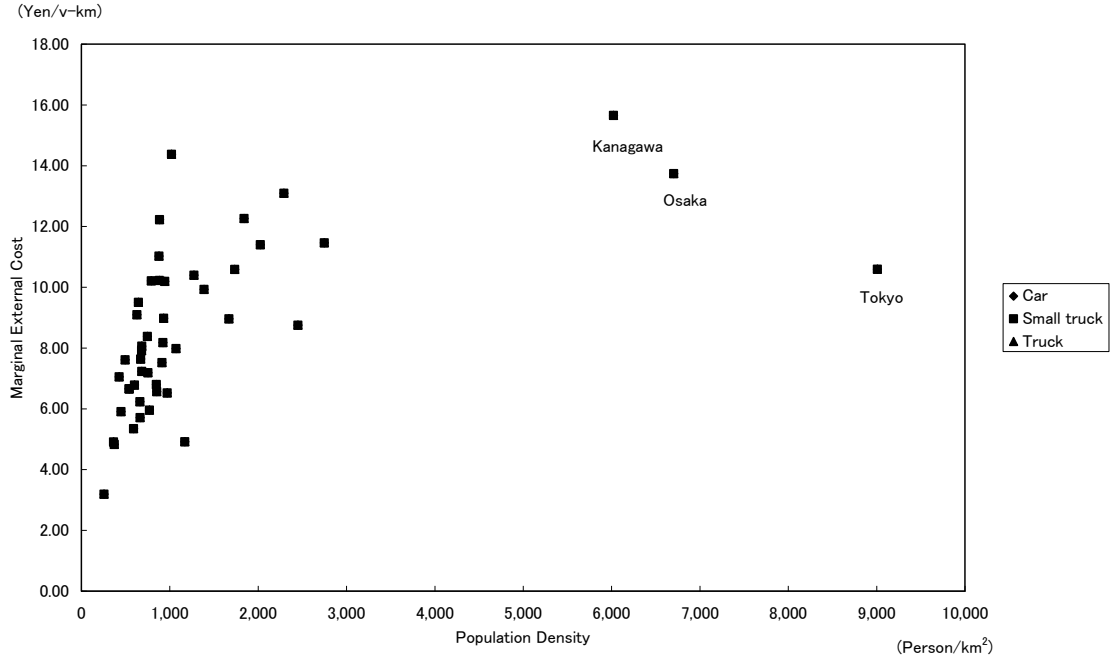

Figure 2 Relationship between marginal external cost of road traffic accidents and population density

Next, we show the relationship between marginal external costs by cost item and population density. Figure 2 illustrates the relation between marginal external cost of road traffic accidents and population density. When we estimated marginal external cost of road

traffic accidents, we were unable to consider the difference in accident risk according to vehicle type. Therefore, Figure 2 presents the relationship between marginal external cost of road traffic accidents of all vehicles and population density. Marginal external cost of road traffic accidents is not always high in populous regions.

Figure 3 illustrates the relationship between marginal external cost of air pollution and population density. Marginal external cost of air pollution is found to be high in populous regions. In particular, the marginal external cost of populous regions is approximately twice as large as the national average. With regard to vehicle type, the marginal external cost of trucks is higher than that of other vehicle types. This is because PM_{10}, which is usually generated by diesel-powered vehicles such as truck, was considered when we estimated the external cost of air pollution.

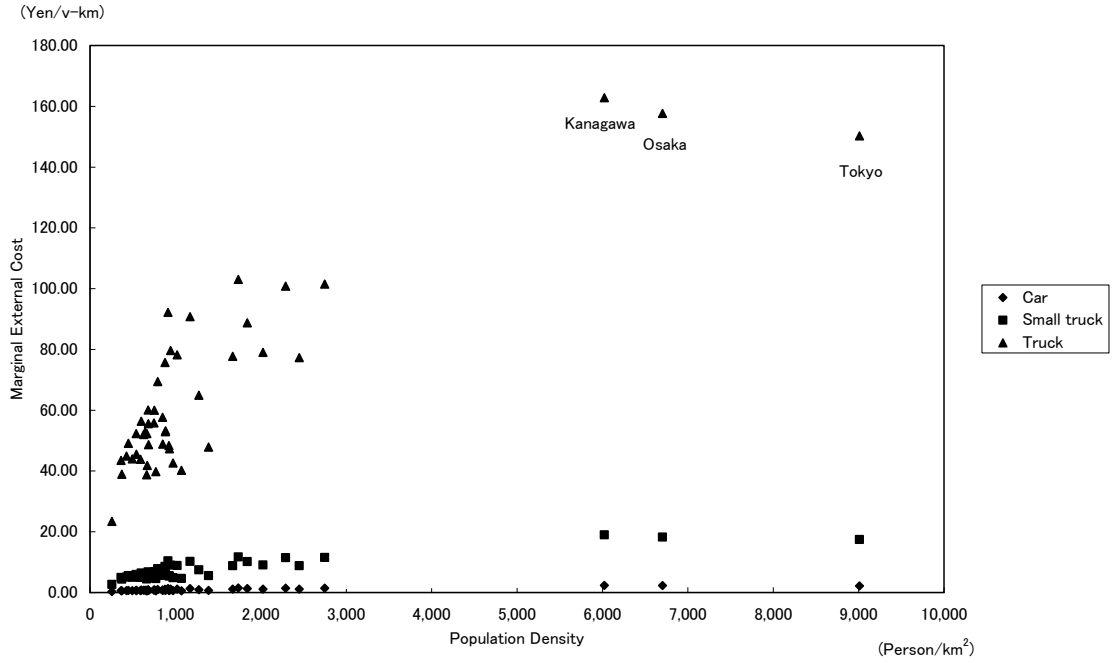

Figure 3 Relationship between marginal external cost of air pollution and population density

Figure 4 illustrates the relationship between marginal external cost of noise and population density. We assumed the noise levels of cars and small trucks to be the same, and it was one tenth of the noise levels of trucks. The marginal external cost of noise of motor vehicles is found to be high in populous regions. The reason for this is that a large number of residents have houses on the side of the road and are more influenced by the noise of motor vehicles in populous regions. Further, the marginal external cost of populous regions is approximately twice as high as the national average.

Figure 5 presents the relationship between marginal external cost of climate change and population density. Marginal external cost of climate change was not found to be closely related with population density. We calculate the amount of CO_2 emitted from motor vehicles by multiplying traffic volume by the emission factor of CO_2, which is determined by the travel speed of motor vehicles. Therefore, Figure 5 indicates a difference in the emission of CO_2 among regions

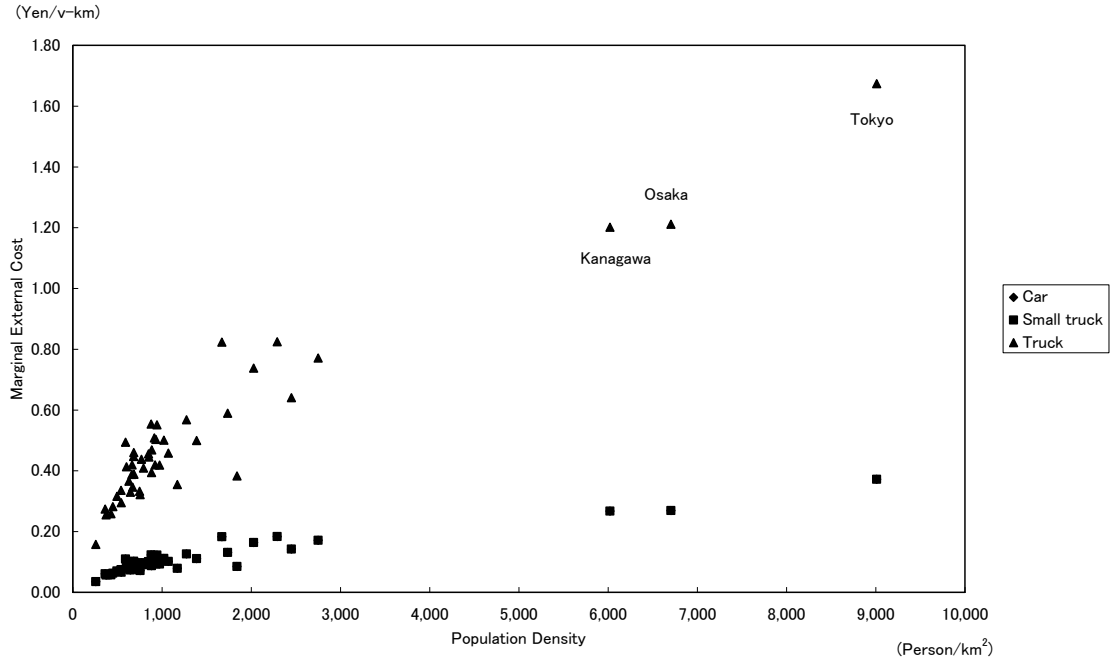

Figure 4 Relationship between marginal external cost of noise and population density

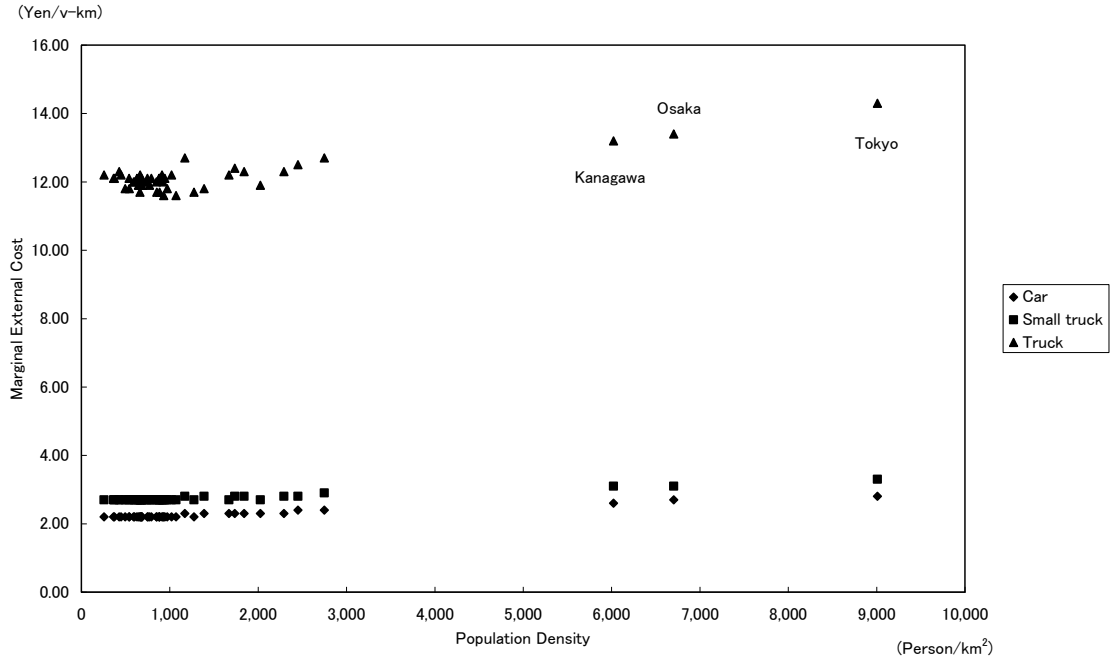

Figure 5 Relationship between marginal external cost of climate change and population density

Figure 6 illustrates the relationship between marginal external cost of road traffic congestion and population density. We calculate the amount of time lost due to congestion on the basis of the travel speed of motor vehicles; the external cost of congestion is evaluated in monetary terms. The travel speed of motor vehicles is lower in regions with a

greater population density and considerable amount of traffic. Figure 6 indicates that the marginal external cost of congestion increases with an increase in population density.

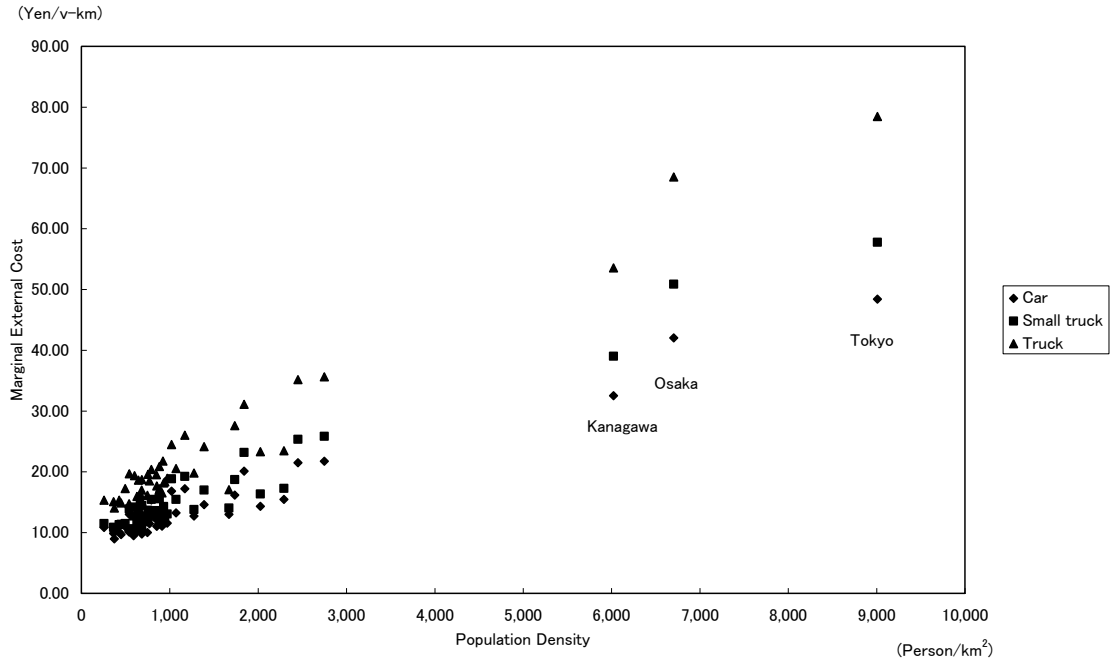

Figure 6 Relationship between marginal external cost of congestion and population density

4. CONSIDERATION OF ROAD USER COST

In this study, we consider road user cost from the perspective of the external costs of motor vehicles according to the Pigovian tax theory. In the preceding paragraphs, in order to clarify a feasible level of road user cost, we estimated marginal external cost of motor vehicles according to regions. We obtained the following features of marginal external cost of motor vehicles according to regions and vehicle type.

1. In Japan, marginal external cost from motor vehicles is 31.2 yen/km for cars, 41.8 yen/km for small trucks, and 131.5 yen/km for trucks. The marginal external cost of trucks is four times higher than that of cars and three times higher than that of small trucks.

2. With regard to regions, the marginal external cost of cars in Tokyo, where the population density is the largest, is 66.6 yen/km. On the other hand, the marginal external cost of cars in Hokkaido where the population density is the lowest is 18.6 yen/km. The results indicate that the marginal external cost is higher in regions with a higher population density.

3. With regard to cost items, marginal external cost of congestion, air pollution, and noise is higher in populous regions. On the other hand, the marginal external cost of road traffic accidents and climate change is not necessarily high in populous regions.

From these results, we consider the mechanism of feasible road user cost of motor vehicles that takes into account the marginal external cost according to regions, vehicle types, and cost items.

First, we discuss the relationship between external cost according to vehicle type and rates of automobile-related taxes. Table 4 presents the marginal external cost according to vehicle type and the rate of automobile-related taxes per vehicle on the road (per vehicle-km). In this table, the tax imposed on car buyers is excluded from automobile-related taxes. The rate of automobile-related taxes for cars is 31.4% of the external cost of the car while that for trucks is 8.7% of the external cost of trucks. The reason for this is that the tax for trucks is usually maintained at an artificially low level in Japan, even though trucks generate considerable external cost. This reason for this is that it is believed that trucks play a key role in the economic activity in Japan.

Table 4 Marginal external cost and the automobile-related taxes

Type of tax		Car	Small truck	Truck
Tax on fuel				
	Gasoline tax	5.17	5.91	
	Local Road Tax	0.55	0.63	
	Light oil delivery tax			8.75
	Liquefied petroleum gas tax	0.22	0.25	0.56
	Crude oil tariff	0.02	0.03	0.06
	Consumption tax	0.30	0.34	0.47
Tax on vehicle				
	Automobile acquisition tax			
	Consumption tax			
	Automobile tax	3.0	0.4	0.5
	Motor vehicle tonnage tax	1.4	0.7	1.1
Total tax revenue		10.6	8.2	11.5
Marginal external cost		31.4	41.8	131.5
Percentage of external cost		33.9%	19.7%	8.7%

(Note):
(1)Unit: yen/vehicle-km

In other words, currently, the external cost of motor vehicles is not appropriately borne by the user in Japan. In this case, when they move, people come to use motor vehicles. Residents bear the external cost of motor vehicles in the form of various damages. Thus, a taxation system that implements a mechanism through which the user bears the external cost of motor vehicles is necessary. In this study, we have ascertained road user cost by taking into consideration the marginal external cost of motor vehicles according to regions and vehicle types. Here, we consider the tax on vehicles, fuel tax, and road pricing as the instruments of road user cost.

First, the tax on vehicles is the tax that is imposed when a motor vehicle is purchased; the tax is imposed in proportion to the engine displacement and weight of the motor vehicle. Examples of such taxes in Japan are automobile acquisition and automobile

taxes. The fuel tax is the tax imposed on fuel when fuel is purchased for motor vehicles at a gas station.Examples of fuel taxes are gasoline and light oil delivery taxes. Road pricing is an instrument through which a charge is imposed on the use of a specific road. Through road pricing the external cost of motor vehicles is made internal for the user. For example, congestion charge is imposed on the user for the congestion in central London. Another example is the road pricing introduced for trucks by Kobe Line and Coastal line of the Hanshin Expressway in Japan in order to reduce the environmental impact of motor vehicle usage.

Now, these three instruments of road user cost are categorized according to the features of the instruments, the effect of external cost reduction, and problems related to different instruments based on the features of external costs of motor vehicles.

We have clarified in preceding paragraphs that the marginal external cost of motor vehicles differs greatly among different vehicle types and regions. Here, we examine whether the user can bear the external cost of motor vehicles through the three instruments of road user cost. Table 5 presents the results of this examination.

First, we compare the instruments according to the difference of external cost by vehicle types. The vehicle tax rate can be changed in proportion to the size of external cost according to vehicle types. However, the vehicle tax is not imposed on the amount a motor vehicle is used. In other words, the vehicle tax is imposed on the fixed costs of motor vehicles. Therefore, if car usage increases, the effect of making the external cost an internal one becomes limited because the road user cost decreases for each kilometre. Next, the fuel tax may be imposed according to whether the vehicle is powered by petrol or diesel. As is evident from preceding paragraphs, there is a large difference between the external cost of a car and small truck that use petrol and that of trucks that use diesel; this is due to the difference in the amount of air pollution, noise, etc. caused by the vehicles. The fuel tax is determined according to the size of this external cost. Moreover, a car with good fuel efficiency has a smaller environmental impact. This difference of fuel efficiency may be reflected in road user cost through fuel consumption. With regard to road pricing, the effect is different according to the system introduced. For example, when the system determines the tax according to vehicle type, a tax corresponding to external cost by vehicle types may be imposed.

Next, we compare the instruments according to the difference in external cost among regions. The difference in the external cost by regions cannot be taken into consideration when imposing vehicle tax. If the regional tax rate is determined according to external cost, the user will buy a car and run it in a region where the external cost is low. The difference in the external cost among regions cannot be taken into consideration when imposing fuel tax either. When a regional fuel tax rate is determined according to external cost, the user will use fuel in a region with a low fuel tax rate. Examples of such users are long-distance trucks. On the other hand, road pricing may be determined according to the external cost in the region because the charge is imposed on the use of roads. In addition, the charge may be determined according to the amount of congestion. Taking into consideration such a feature, the external cost of climatic change, the marginal external cost of which does not differ according to region, can make the user bear responsibility of the fuel tax. In this case, even if the tax rate is thoroughly determined in the entire country, there will barely be any unfairness in the imposition of road user cost among regions. On the other hand, the instrument that

makes other external costs internal and differs among regions, is road pricing; road pricing is determined according to the traffic situation in the region and may be effective.

For example, road pricing may be introduced in Japan in a portion of a region where problems such as congestion and air pollution are serious. However, currently, it is difficult to introduce road pricing in all of Japan. The reason for this is the problem of the constitutional cost of the system of road pricing and the problem of mutual agreement of the citizens with regard to the introduction of road pricing (Seki and Niwata (2007)). Therefore, it is important to discuss the manner in which the external cost of motor vehicles can be borne by users within the existing framework of automobile-related taxes. Moreover, there are numerous issues with regard to automobile-related taxes. For example, it is difficult to decide the most optimal vehicle tax rate. This tax is not imposed on the use of the car; therefore, it is not an instrument that can strictly internalize the external cost of a motor vehicle. However, this tax may be rather effective when there is a purpose such as popularizing environmentally friendly cars. Moreover, it is important that the fuel tax rate is determined according to external cost. As mentioned earlier, the level of taxation on diesel fuel is low in Japan. Therefore, we believe that it is necessary to make taxation according to vehicle type fair and just.

Table 5 Features of the instrument of road user cost

	Tax on Vehicle	Fuel Tax	Road Pricing
Internal effect			
By vehicle type	△	○	△
By regions	×	×	○
By time	×	×	○
Effect	・Substitution for eco-friendly cars	・Controlling use of cars ・Substitution for eco-friendly cars	・Controlling use of cars ・Changing routes
Issue	・Decision of tax rate	・Taxation on electric vehicles ・Correction of the unfair level of taxation for different vehicle types	・Introduction cost ・Mutual agreement among citizens

5. CONCLUSION

In this study, we estimated the external cost of motor vehicles in Japan, and considered the road user cost of motor vehicles. First, we found that the external cost of motor vehicles was 34.7 trillion yen in Japan. In particular, in regions with higher population density a large amount of external cost is generated. The results revealed that the external cost of trucks was larger than that for other vehicle types. Considering road user cost based on these results, it is found that the present automobile-related taxes cannot impose road user cost corresponding to the external cost of motor vehicles.

Further, the type of measure that may be effective for internalizing the external cost of motor vehicles, which differs according to regions and vehicle types, was also considered. The results revealed that road pricing is preferable as an instrument for internalizing the external cost of motor vehicles. However, there are numerous problems associated with road pricing. Therefore, instruments that enable the internalization of the external cost of motor vehicles must be discussed within the framework of automobile-related taxes in the future.
In recent years, vehicles with new technology, such as electric vehicles, have been gaining increasing popularity. External cost for such next-generation cars cannot be incurred within the framework of automobile-related taxes. Therefore, the questions that must be addressed in future research are as follows. How do electric vehicles generate external cost? How should the user bear the external cost?

REFERENCES

Beuthe, M., F. Degrandsart, J-F. Greerts and B. Jourquin (2002). External Costs of the Belgian Interurban Freight Traffic: A Network Analysis of Their Internalization. Transportation Research-D, 7D, 4, 285-301.

Cabinet Office (2007). Research Report on Economic Analysis of Damage and Loss Caused by Traffic Accidents (Kotsu Jiko no Higai Sonshitsu no Keizaiteki Bunseki ni Kansuru Chosa Kenkyu Hokokusho). Cabinet Office, Tokyo (in Japanese).

Danielis, D., and A. Chiabai (1998). Estimating the Cost of Air Pollution from Road Transport in Italy. Transportation Research, Part D, 3D, No.4, 249-258.

Deng, X. (2006). Economic Costs of Motor Vehicle Emissions in China: A Case Study. Transportation Research: Part-D, 11D, 216-226.

Doro Toshi no Hyoka ni Kansuru Shishin Kento Iinkai (1998). Guideline for the Evaluation of Road Investment: Draft (Doro Toshi no Hyoka ni Kansuru Shishin). Nihon Sogo Kenkyusyo, Tokyo (in Japanese).

ECMT (1998). Efficient Transport for Europe. OECD, Paris.

European Commission (2005). ExternE Externalities of Energy Methodology 2005 Update.

Eyre, N., E. Ozdemiroglu, D. Pearce, and P. Steele (1997). Fuel and Location Effects on the Damage Costs of Transport Emissions. Journal of Transport Economics and Policy, 31, 5-24.

Forkenbrock, D. J. (1999). External Cost of Intercity Truck Freight Transportation. Transportation Research: Part-A, 33A, 505-526.

Gibbons, E. and M. O'Mathony (2002). External Cost Internalization of Urban Transport: A Case Study of Dublin. Journal of Environmental Economics and Management, 64, 401-410.

INFRAS/IWW (2004). External Cost of Transport Update Study, UIC, Paris.

Jakob, A., J. L. Craig and G. Fisher (2006). Transport Cost Analysis: A Case Study of the Total Costs of Private and Public Transport in Auckland. Environmental Science and Policy, 9, 55-66.

Koyama, S. (2004). (Nippon ni Okeru Jidosha Kotsu Souon no Gaibu Hiyo no Suikei). Shodai Ronshu, 3, 4, 121-157 (in Japanese).

Koyama, S. and M. Kishimoto (2001). Approximate Figure of External Costs of Car transport in Japan (Nippon ni Okeru Jidosha Kotsu no Gaibu Hiyo no Gaisan). Transportation Policy Research (Unyu Seisaku Kenkyu), 14, 2, 19-30 (in Japanese).

Levinson, D. M., D. Gillen and A. Kanafani (1998). The Social Costs of Intercity Transportation: A Review and Comparison of Air and Highway. Transport Reviews, 18, 3, 215-240.

Mayeres, I., S. Ochelen and S. Proost (1996). The Marginal External Costs of Urban Transport. Transportation Research: Part-D, 1D, 1, 111-130.

McCubbin, D R. and M. A. Delucchi (1999). The Health Costs of Motor-Vehicle-Related Air Pollution. Journal of Transport Economics and Policy, 33, 3, 253-286.

Ministry of Land, Infrastructure and Transport (2003). Estimation Methods of the Unit Value of Time and the Unit Travel Costs (Jikan Kachi Gentani Oyobi Soko Keihi Gentani no Sansyutsu Hoho), the Road Bureau, the Ministry of Land, Infrastructure and Transport (in Japanese).

Persson, U. and K. Odegaarf (1995). External Cost Estimates of Road Traffic Accidents: An International Comparison. Journal of Transport Economics and Policy, 29, 3, 291-304.

Oshiro, N., M. Matsushita, Y. Namikawa and H. Onishi (2001). Fuel Consumption Rate and Coefficient for Emission of CO2 in the Case of Car Traveling (Jidosya Sokoji no Neryo Shohiritsu to Nisanka Tanso Haisyutsu Keisu). Civil Engineering Technology Reports (Doboku Gijutsu Shiryo), 43, 11, 50-55 (in Japanese).

Proof, S. and K. V. Dender (1998) “Variabilization of car taxes and externalities”, in Button, K J. and E T. Verhoef (1998) Road Pricing, Traffic Congestion and the Environment, Edward Elgar, pp.136-149.

Seki, T. and F. Niwata (2007) (Rodo・puraisingu riron to seisaku), keiso shobo, (in Japanese).

Small, K. A. and C. Kazimi (1995). On the Cost of Air Pollution from Motor Vehicles,” Journal of Transport Economics and Policy, 29, 7-32.

UNITE (2003). Unification of accounts and marginal costs for Transport Efficiency Final Report for Publication, Unite, UK.

WHO (World Health Organization) (1999). Health Cost due to Road Traffic-related Air Pollution: An Impact Assessment Project of Austria, France and Switzerland. Prepared for the WHO Ministerial Conference on Environment and Health, London, June, 1999, WHO.