Inefficiency in Command-and-Control Approach toward Adoption of Low Emission Vehicles: Japanese Experience of Air Pollution from Diesel Trucks

Toshi H. Arimura*), Kazyuyuki Iwata**)

*) Department of Economics, Sophia University, Tokyo, Japan.
**) Graduate School of Economics, Sophia University, Tokyo, Japan.

ABSTRACT

This paper empirically examines the "vehicle type regulation," which prohibits the use of old and dirty vehicles, mainly diesel trucks, in Japanese metropolitan areas. The regulation was introduced, as a part of NO_x-PM Law, to mitigate air pollution problems in the area.

The regulation enforces early retirement of old vehicles. Thus, the compliance cost is estimated by computing the opportunity cost of the enforced retirement. Since the timing of enforced retirement differs depending on vehicle type and registration year, we estimated the cost of the compliance by type and year. Moreover, taking notice of the differential timing of retirement, we estimated the emission reduction and the marginal abatement costs for various types of vehicles.

The analysis suggests that the benefit of the emission reduction exceeds the cost incurred by the regulation. Therefore, the regulation is justified from the perspective cost-benefit ratio.

However, our study finds large deviation of marginal abatement costs among vehicle types and over time. Hence, there is a potential for cost savings by changing the timing of retirement enforcement. We conclude the paper by proposing economic instruments such as emission trading or tax for controlling NO_x and PM from diesel trucks.

JEL Classification: Q52, Q53, Q58

1. Introduction

To reduce air pollution in Japanese metropolitan area, a variety of environmental regulations have been placed on stationary sources, such as facilities, and mobile sources, such as automobiles. As a result, emission of sulfur dioxides has successfully been reduced. However, air pollution caused by nitrogen oxides (NO_x) did not improve through the 1980's. This is due to mainly increase in emissions from mobile sources. Then, Japanese governments introduced a new law to control the automobile emission, the "Automobile NO_x regulation law"[1] (June 1992). This law was targeted toward three metropolitan areas (Tokyo, Nagoya, Osaka areas), which became a "specified area".

Despite these efforts, concentration of NO_x in metropolitan areas still did not improve in the 1990s. In fact, environmental standard is satisfied at only about 60% of monitoring points along roads in the specified metropolitan area and for nitrogen oxides. The achievement of environmental standard for particle matters (PM) was even worse. The reason for the failure is due to heavy usage of diesel trucks.

Given these situations, "the Law concerning special measures for total emission reduction of Nitrogen Oxides and Particulate Matter from automobiles in specified areas" (revised June 2001) (hereafter referred as the "NO_x-PM law") was passed, which is a revised version of the "Automobile NO_x regulation law". This law is intended to improve the concentration of NO_x and PM within the specified areas of Tokyo, Nagoya and Osaka where atmosphere's air quality did not improve in 1990's.

In this paper, we will focus on "Motor-vehicle type regulation", one policy instrument within the "NO_x-PM Law". The "Motor-vehicle type regulation" basically bans use and registration of automobiles in the specified area above, unless automobiles satisfy the strict emission standard[2] defined in the NO_x-PM Law. Hence, this law practically enforces purchase of approved low emission vehicles in the specified area. Thus, this regulation provides an example of command-and-control approach toward diffusion of low emission vehicle. We will call the "NO_x-PM Law" as the "motor-vehicle type regulation" for simplicity.

This paper calculates the cost embodied by this regulation for each regulated area (Tokyo metropolitan area, Aichi-Mie Area, and Osaka-Hyogo Area). Then, we compare the cost with benefits to examine whether the policy is justified. Finally, we compute marginal abatement cost for various types of vehicles and discuss possibilities

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1 "The Law concerning special measures for total emission reduction of Nitrogen Oxides from automobiles in specified areas"

2 For instance, the emission standard of diesel trucks of weight from 1.7 tons to 2.5 tons under the new law is 0.63 g/km for NO_x and 0.06 g/km for PM.

in improvement of the vehicle type of regulation.

The contribution of this paper is to examine the cost effectiveness of air pollution policy on freight transportation in Japan. Most previous studies such as Goldberg (1998)) in U.S. or Fullerton *et al*. (2003) on air pollution problem from mobile sources examined policies on passenger vehicles. However, in Japan, trucks are known to be a major source of air pollution. Investigating the regulation on trucks, therefore, is an important step to design cost effective air pollution policies.

The next section shows impacts of the "motor-vehicle type regulation" on user and describes how to compute cost of the motor vehicle regulation. Then, emission reduction due to the regulation is estimated in Section 4. Cost efficiency of the motor vehicle regulation is discussed in Section 5. It is followed by concluding remarks in Section 6.

2. Compliance Methods and Cost of Compliance

This section defines cost computed in this paper by using information on compliance methods taken by users of vehicles subject the regulation.

Theoretically, we can consider several levels of cost of the "motor-vehicle type regulation" for entire economy. First, the additional cost for the truck transportation enterprises, users of trucks (the direct complying party) is an example. Second, if the cost of compliance increases the price of freight transportation, this will increase the cost for consumers of freight transportation, which reduces consumer surplus. Finally, if the price of freight increases, there might be substitution between truck vehicles and other transportation modes such as railways, air freight, or shipping. Thus, theoretically, "motor-vehicle type regulation" can incur the cost on the entire economy. However, the second and the third type of costs are not observed, or small if at all, since the price increase of freight transportation is small. Hence, this paper focuses on the first type of cost: direct cost for user of vehicles subject to the regulation.

<u>Cost of "Motor-Vehicle Type Regulation"</u>

In estimating the cost, we first calculate the cost of the regulation per vehicle type and multiply this cost to the number of vehicles subject to the regulation.

The compliance cost is the difference in the cost of having "motor-vehicle type regulation" and in the cost without the regulation. Therefore it is necessary to clarify the countermeasure of the user of the regulated automobile. Hereafter, we will consider the user and possessor of the automobile to be identical.

The "motor-vehicle type regulation" effects the behavior of possessing the automobile regulated because the regulation banes the usage of the regulated vehicle. In other words, the regulation forces the possessor of the regulated vehicle to take a different behavior. Thus, the cost for the possessor of the vehicle will be the difference in the cost without the regulation and with the regulation. This cost will be considered as the cost of "motor-vehicle type regulation". Therefore, we must clarify the compliance methods first.

Compliance Methods: Effects of the "Motor-Vehicle Type Regulation

The compliance cost of the "motor-vehicle type regulation" is the difference in the cost of having and not having the regulation. Thus, clarification of the compliance methods is needed in order to calculate the compliance cost.

To accurately investigate to the effects and the cost of the regulation, identification of which type of vehicle is regulated is needed. The main subjects of the regulation are trucks.[3] In general, trucks use light-oil as fuels. Thus the main targets of the regulation are diesel-vehicles.

Within the category "Trucks", the effects of the regulation and/or the compliance cost may differ between small trucks and standard trucks. In the following sub-section, we will investigate the effects of the regulation on the compliance methods for both small trucks and standard trucks, based on the survey committed by Japan Automobile Manufacturers Association.

Standard Trucks

How does the "Motor-vehicle type regulation" affect ownership of standard trucks? We will refer to the "Fiscal Year 2004: Truck Market Trend Surveys" [March 2005] published by Japan Automobile Manufacturers Association (JAMA) to grasp the effects of the regulation on standard trucks. Seventy-one percent of enterprises located in regulated areas (for simplicity at the prefecture level) replied that they were affected by the regulation.

The results of the survey on compliance methods in the specified area are shown in Table.1.[4] According to the survey, in the regulated areas, had 89% replies for 2) Change to new vehicles, implying that this type of countermeasure is dominant for facilities in regulated area. In the case of standard trucks, the change in fuel type is not an option. In other words, since the market does not supply gasoline-engine standard trucks, possessors of standard vehicles cannot change the type of fuel consumed by the engine

[3] Refer to the appendix for further explanation concerning regulated vehicles.
[4] The percentages are reported for entire regulated areas in parenthesis.

of the vehicle. In the case of small trucks, discussed below, the possessor has an option of converting the small truck from a diesel-engine vehicle to a gasoline-engine vehicle. As a consequence, the overwhelming countermeasure for the owners of standard trucks is to repurchase a new standard truck that complies with the regulation.

Small Trucks

Next, we will refer to the "Fiscal Year 2004: Small and mini truck market trend surveys" [March 2005] JAMA to investigate the effects of the regulation on small trucks.

The survey asked fourteen compliance methods. The results are shown in Table.2. [5] Similar to the standard trucks, the overwhelming compliance method for small trucks is repurchasing new trucks that comply with the regulation with responses of more than 80% of the enterprises. However, unlike standard truck owners, the owners of small trucks have the option to repurchase trucks that are gasoline-run. The switching of fuel sources is 38%, which is a second most frequently used method following repurchasing to a new diesel-engine vehicle.

From the two surveys discussed above, the most frequently used compliance method for owners of both small trucks and standard trucks is the repurchasing of new vehicles. Next, we will empirically investigate the effects and the costs of the "motor-vehicle type regulation", focusing on repurchasing new vehicles.

Cost of "Motor-Vehicle Type Regulation" per vehicle

The "Motor-vehicle type regulation" of the "NO_x-PM Law" was introduced in 2003, following the revision of the "NO_x-PM Law" in June 2001. As a result, vehicles that do not comply with the regulation were banned starting from 2003.

In the previous subsection, it was shown that the major compliance method was to repurchase trucks that comply with the regulation. The economic cost of replacement is defined as the difference between the cost incurred by the truck users with the regulation and the cost without the regulation. We will assume that the vehicle users do not change the pattern (mileages, frequency, etc.) of vehicle usage before and after the regulation. When the vehicle age reaches a certain age, the owners will naturally replace the old vehicle with a new vehicle. This behavior is not subject to change with or without regulations. Thus, the regulation only affects the timing of when to replace the vehicle (i.e. the regulation accelerates the rate of replacement).

The cost that is incurred by the acceleration of the replacement is calculated by

[5] In parenthesis, the figures indicate the percentages for the entire nation.

the following method. If a vehicle is banned by the "motor-vehicle type regulation" and the owner decides to replace it with a new vehicle, than the cost that arises is equal to the price of the new vehicle (1). However, the replaced vehicle would have been used for several years if the regulation was not enforced. Thus, if the regulation did not exist, the owner of the vehicle would have used the vehicle a few more years before replacement. These few usable years are estimated by the average life remaining at that point in time. Next, using the average life remaining, adjustment of the cost of purchasing a new vehicle without the regulation, valued at the time of introduction of the regulation is committed (2). The difference between cost (1) and (2), is the cost incurred by users due to the acceleration of replacement. Hence, the replacement cost, C^t_{rm}, of type m vehicle that is banned in year, t, is expressed as,

$$C^t_{rm} = P_m\left[1-\exp(-i\times Y_{rm})\right] \qquad (1)$$

where P_m is the purchasing price[6] of vehicle type m, r and i denotes the first registration year and interest rate, respectively. Most importantly, Y_{rm} denotes the years remaining at the introduction of regulation for type m vehicle registered at year r. That is, Y_{rm} represents the years that the owner could have used without the motor-vehicle regulation. In addition, the time variable, t, is standardized at 2004, $t = 0$, the year the regulation is introduced.

According to the survey in the previous section, some users of small diesel trucks replace the vehicles with gasoline trucks. In this case, the replacement cost is expressed as,

$$C_{rm} = P^G_{m_m}\left[1-\exp(-i\times Y_{rm})\right] \qquad (2)$$

where, P^G_m is the purchasing price of type m gasoline-engine vehicle.

This equation assumes that the timing of the replacement of the gasoline-engine vehicle is accelerated by the "motor-vehicle type regulation", even though the replacement to a gasoline vehicle was planned due to the general trend of strengthening environmental regulation. This assumption is plausible because the vehicle types of diesel-engine passenger car purchased are declining yearly.

In order to calculate the per vehicle compliance cost defined in (1) and (2), we

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6 We will assume that the purchasing price of the vehicles does not change over time.

must find Y_{rm}, years remaining when the regulation came into effect for the vehicle type. In this paper, as the estimate of Y_{rm}, we use the average life remaining of the vehicle at time when the regulation is enforced. Then, the following two items concerning each type of vehicle needs to clarify:

1) The year the vehicle becomes the subject of the regulation.
2) The average years remaining of the vehicle when the law is enforced.

For the computation of 2), we must use the average life remaining years of the vehicle before the regulation is enforced. If we use information on vehicles after the introduction of the regulation, we cannot assess the "pure" effect of the vehicle type regulation since the duration of vehicles has already changed due to the vehicle type regulation.

In the following, we will estimate cost and emission reduction of the regulation by vehicle type. For calculation of both total cost and emission, first, we calculate per vehicle cost (emission) for every vehicle type. Then, we multiply the number of vehicles for each type of vehicle with the corresponding per vehicle cost (emission) to obtain the total cost (emission) incurred by the regulation.

The year in which the vehicle becomes regulated (banned) (1), depends on the 1) first registration year, 2) type of vehicle (standard trucks vs. small trucks, trucks vs. passenger cars etc.), and 3) if the vehicle complies with the emission control regulation or not. Furthermore, the average life remaining is known to differ among vehicle types. Thus, by gathering information based on the smallest classification will increase the precision and accuracy of the estimated cost and emission.

On the other hand, in some variables, information is not necessarily available for certain type of vehicle. We approximate the missing information using information from the most similar vehicle type. Below, we will discuss the calculation method for equations (1) and (2).

<u>Identification of Vehicle Age When the Regulation in Enforced</u>

In this sub-section, we will determine the year in which the regulation bans the vehicle, by vehicle type and first registration year, to calculate the number of usage years reduced by the registration. Here, we will use standard trucks as an example of the process.

Then, when will vehicle usage be banned. In Table.3, the year of banning of the standard trucks that do not comply with the 2005 emission control regulation is presented.

Considering the fact that the motor-vehicle inspection certificate is valid for 2 years, a vehicle that was first registered in 1990 will be banned starting from October 1, 2004 to September 30, 2006. If we assume that the first registration is uniformly distributed, at the mean, these vehicles will be banned in 2005. Using the same methodology, the banned year is calculated for other first registration years.

Thus, the opportunity cost for replacement arises each year according to the banning of the vehicle based on the first registration year.

Using the process discussed above, the life remaining at 2004 according to the first registration year is shown in Table.4.

Calculation of the Average Life Remaining

As shown in equation (1), it is necessary to obtain the average life remaining of vehicles when there is no regulation to calculate compliance costs. In addition, the vehicle age for truck, compared to 1990 figures, is lengthening due to technical process and/or deregulation of automobile inspections (Oka *et al*.(2002)). Thus, usage of recent data in the calculation of life remaining is desired. On the other hand, vehicle ages maybe lowered due to replacement induced by the enforcement of the "NO_x-PM Law". Therefore, it is important to use the information before the regulation is enforced in calculating the average life remaining. Considering these reasons and the availability of data we use data for the year 2000. We calculate the average life remaining for each vehicle type following the method used in Oka *et al.*(2002). For simplicity, notation for vehicle types is omitted.

Firstly, the number of registered vehicles, $N(k)$ with vehicle age k, is obtained for standard trucks, small trucks, standard passenger cars, and small passenger cars, from the "Survey of Automobile Possession" Automobile Inspection and Registration Association (AIRA)[7] (in Japanese).

The disposal rate $d(k)$ is calculated as,

$$d(k) = (N(k) - N(k+1))/N(k).$$

Next, from this disposal rate, the survival rate $s(k)$ is calculated as,

[7] Hereafter referred to as AIRA data.

$$\begin{cases} s(0) = 1 \\ s(k) = s(k-1)[1 - d(k-1)]. \end{cases}$$

Following a previous study (Oka *et al.* (2002)), we assumed that all the vehicles are not used after 21 years. Using the survival rate, then, the average life remaining $L(T)$ for vehicle aged T is calculated by,

$$L(T) = \frac{\sum_{k=T}^{21} s(k)}{s(T)}.$$

Table.5 summarizes the calculation results of average life remaining is presented.

Vehicle prices

Vehicle prices are required in order to calculate compliance cost, as shown in Equation (1) and (2). Truck prices, by capacity load, are collected from “Japanese Truck Transportation Industry 2004” (Table.6). The price for other truck weights is obtained by regressing vehicle weight on price. In addition, the price estimated will also be used as the price for special-usage vehicles.

Prices concerning passenger cars are obtained from “Annual Report on New Vehicles Registered” Japan Automobile Dealers Association (JADA), for each model. Then, price by vehicle weight is determined by taking sample means of the collected data (Table.7).

For prices of other vehicles, we use the following substitution. Small truck price is used as a proxy for small four-wheeled trucks, small buses, and small special-usage vehicles, due to data availability. Further, standard truck price is used for trailers, standard special-usage vehicles, and standard buses, for the same reason.

Cost Per Vehicle Type

Given the procedure above, the compliance cost per vehicle by registration year is computed. The results are summarized in Table.8. It should be noted that, in each column (vehicle type), there are several kinds of vehicles that differ by weight. In the table, we use weighted averages.

Calculation of Total Cost

The total cost is calculated for every area (Tokyo metropolitan area, Osaka-Hyogo area, and Aichi-Mie area), each year by the following method. Let us denote the number of vehicles repurchased as N_{mj}^{t}, where m, j, and t represent vehicle type, municipality, and time, respectively. Recall that the cost that arises for type m vehicle first registered at year, r, is noted as C_{rm}^{t} (equation (2)). Therefore, the total cost that arises each year due to the regulation is $C_{rm}^{t} \times N_{mj}^{t}$. Since the total cost of "motor-vehicle type regulation" valued at 2004 prices is the aggregation of cost discounted present value for each year, total cost can be defined as,

$$TC = \sum_{r} \sum_{m} \sum_{j} \sum_{t=0} \frac{C_{rm}^{t} \times NR_{mj}^{t}}{(1+i)^{t}} .$$

Note that the number of repurchased vehicles NR_{mj}^{t} differs from the number of vehicles subject to the regulation. Compliance methods, previously discussed, show that "usage outside of regulated areas" and "disposal of vehicles" is also chosen by vehicle owners. Therefore, we must identify the percentage of repurchasing that occurs for vehicles subject to the regulation (JAMA (2005)). The subjects of this survey are business facilities. If the business facility possesses more than one vehicle, multiple compliance methods can be taken. Thus, business facilities possessing more than one vehicle has multiply replied. In reality, aggregation of the replied percentages of compliance methods by vehicle types yields 159% for standard trucks and 161% for small trucks.

In this paper, the following assumption is placed for every business facility that had multiple replies. The assumption is, businesses that have replied multiply have chosen the compliance method in same ratios. For example, if a business facility owns 20 vehicles and has chosen "usage outside of regulated areas" and "disposal of vehicles" as compliance methods, then compliance methods executed will be, 10 vehicles for "usage outside of regulated areas", whereas the remaining 10 vehicles will be "disposal of vehicles". In addition, further assumption is placed as; every business facility owns the same number of vehicles.

Using these assumptions, we can calculate the ratio of vehicle replacement by using the following method. First, determinate the percentage replied by aggregating the percentages for each compliance method. Next, aggregate the ratios of "replacing" and divide by the total percentage. By doing so, we obtain the ratio of "repurchasing".

Sixty-one percent[8] of standard trucks were identified as vehicles purchased (sum of "Replace with new vehicle" and "Replace with used vehicles"), using the method discussed above. Likewise, fifty-seven percent of small trucks were calculated as "replaced". We will use 57% for replacement rate of small four-wheeled trucks, small buses, and small special-usage vehicles, whereas the replacement rate of 61% for trailers, standard special-usage cars, and standard buses. Information concerning small and standard passenger cars is unavailable. However, usage of passenger cars in other unregulated areas is unrealistic, so the replacement rate is assumed to be 100%.

Identification of Regulated Vehicles

Discussed in the previous sub-sections, in calculating the compliance cost, determination of the number of vehicles subject to the "motor-vehicle type regulation" in regulated areas is a necessity. We abstract information concerning registered vehicles in March 2003 from the AIRA data.

As a result, 3,917,553 vehicles were identified. From the information abstracted, vehicles subject to the "motor-vehicle type regulation" were abstracted by category.

In the abstraction process, an explanation concerning missing data is needed. In the AIRA data set, many vehicles lacked information on emission adoption code. Approximately, 9% of the vehicles (350,000 vehicles) in the regulated areas lacked this information. For these vehicles, we estimated the number of vehicles subject to the regulation by exterminating the ratio of regulated vehicles to total vehicles, both with emission codes, by 1) first registration year, 2) registered location, 3) vehicle type, and 4) fuel type.

As a result, total vehicles subject to the regulation in small areas was approximately 2.6 million vehicles.

Special-usage vehicles with inspection certificate valid for one year are not subject to the regulation. However, the AIRA data does not distinguish the length of inspection validity. Therefore, we estimate the maximum and minimum number of special-usage vehicles in the case were all special-usage vehicles have 1) two year validity and 2) one year validity.

Diesel vehicles with inspection certificate valid for one year (taxies, rental vehicles, etc.) are subject to more stringent regulations compared to diesel vehicles with two year inspection validity. According to the "Monthly Statistical Report on Motor

[8] Here, we will use the price of new vehicles for used vehicles because information for used vehicle prices are unavailable.

Vehicle Transport", light-fuel consumption for business-usage passenger cars was 4,391kL, whereas home-usage passenger cars was 489,514kL (March 2004). Thus, we assume that the ratio of diesel vehicles with one year validity to vehicles with two year validity is $4{,}391/489{,}514$.

Total Cost

Based on the equation discussed previously, we calculate the cost, total cost of repurchasing vehicles, using a discount rate of 3%.
Calculation results shows that the total cost was 926 billion yen, in regulated areas. The cost by vehicle type and by prefecture is shown in Table.9.

Discussion on Cost Estimates

Several points need to be addressed concerning the estimated compliance cost. Firstly, the maintenance cost is disregarded in the calculation. If the maintenance cost rises as the vehicle ages, replacement of old vehicles will reduce maintenance costs. In this case, the estimated cost will also be an overestimation. Furthermore, it has been shown that, for passenger cars, maintenance cost is an important factor in choosing vehicles (Myojo *et al*.(2005)). In this analysis, data for both vehicle age and maintenance cost were unavailable. Thus, we discarded this factor.

Secondly, businesses possessing numerous vehicles may reduce the utilization rate of old vehicles and increase the utilization rate of new vehicles (Nomura (2002)). If the utilization rate changes, the cost is also overestimated. This item was also not included in the analysis.

Thirdly, the total cost disregards the purchasing of used vehicles because the price of used vehicles is unavailable. In this analysis, we assumed that all users replace the old vehicle with new vehicles. However, they could purchase used approved vehicles. From this perspective, the estimates may be overestimated.

Fourth problem is the cessation of business. The method used in this paper discards the possibility that when cessation of businesses occurs, then they do not repurchase vehicles after they dispose the old vehicles. It has been reported that a few businesses have disposed vehicles due to the recession. However, in the analysis, this type of information is unavailable.

3. Emission Reduction

Emission Volume Calculation Equation

Emission reduction is calculated, similar to the compliance cost, by three areas (Tokyo Metropolitan Area, Osaka-Hyogo Area, and Aichi-Mie Area). Further, the emission will be estimated using the following equation as a base by vehicle type and regulation year.

Emission Volume = Emission Intensity $\times$ Mileage $\times$ Number of Vehicles

Using this equation, we will calculate the emission from registered vehicles before and after the enforcement of the regulation. Emission coefficient for type m vehicle that are emission regulation adapted vehicles in year r is noted as e_{rm}. For vehicles that are adapted to the 2005 emission regulation is noted as e_{0m}. Within vehicle type m, the number of vehicles NE_{rmj}^{t} [9] denotes vehicles that adopt the emission regulation in year r and registered in municipality j in year t. Furthermore, mileage for municipality j is denoted as D_{mj}.

Emission before the "motor-vehicle type regulation", E is,

$$E = \sum_r \sum_m \sum_j e_{rm} \times NE_{mrj} \times D_{mj} \qquad (3).$$

Next, the estimation of emission after the enforcement of the regulation is conducted. Let I_{mj}^{t} be the dummy variable for vehicle type m in municipality j in year t showing if the vehicle is subject to the regulation or not. Using this notation, emission E^t for year t, after the enforcement of the regulation is calculated as,

$$E^t = \sum_r \sum_m \sum_j \left(I_{mj}^{t} e_{om} + \left(1 - I_{mj}^{t}\right) e_{rm} \right) \times NE_{rmj}^{t} \times D_{mj} \qquad (4).$$

Thus, the emission reduced, ER^t in year, t is calculated as,

$$ER^t = E^t - E \qquad (5).$$

Calculation of Emission: Data

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[9] The classification of vehicle types is more detailed for the "motor-vehicle type regulation" than the emission adoptive vehicle. Thus, NE_{rmj}^{t} needs to be identified.

Mileage information for each area is collected from the "Monthly Statistical Report on Motor-vehicle Transportation" under the following categories.

Every vehicle registered in each prefecture is not subject to the regulation. For example, in Tokyo, not every area is subject to the regulation. Thus, the mileage in regulated areas within Tokyo is calculated from the following equation.

Mileage in Regulated Areas (Tokyo) = Mileage (Tokyo) × (Registered Vehicles in Regulated Areas (Tokyo) / Registered Vehicles (Tokyo))

In the same manner, mileage is calculated for Kanagawa, Aichi, Osaka, and Hyogo. For Chiba and Saitama Prefectures, per vehicle average mileage is calculated for the entire Kanto Area, by vehicle type.

We obtain the emission coefficient information from Suri-Keikau Inc.(2005) by fuel type, vehicle type, regulation adoption year, emission intensity by speed for both NOx and PM.

Emission Reduction

Using equation (3), (4), and (5), the emission reduction of air pollutants for each prefecture is calculated. First, we use equation (3) to calculate the emission of air pollution particles. Further, the average speed of automobiles is approximately 20km in Tokyo. Thus, in the calculation, the intensity for average speed of 20km will be used. Results of the calculation are shown for NO_x and PM in Table.10.A and Table.10.B, respectively. This emission volume is the emission from vehicles subject to regulation.

Next, the emission after reduction is calculated by using reduction volume assuming that the regulation is implemented completely, equation (4), for both NO_x and PM. The total reduction for NO_x was 19,932 tons whereas PM was 3,334 tons. Thus, the vehicle type regulation is successful in reducing NO_x as well as PM dramatically. The reduction volume results are shown in Table.11A and B for NO_x and PM, respectively, by prefecture and by vehicle type.

As discussed in the cost analysis, owners of trucks may dispose vehicles due to the enforcement of the regulation. In this case, due to the recession, freight transportation may disappear or transportation methods maybe changed (changed to railways or shipping). If freight transportation disappears, emission is reduced, because railways and shipping have smaller emission intensities, compared to automobiles.[10]

[10] However, within the locations subject to the "NO_x-PM Law", it is difficult to consider that the transportation method shifts to railways and shipping in the Metropolitan area. Thus the shifting

Therefore, in either case, the emission level is smaller than assumed in this paper. However, in this paper, we determined the emission volume from mileage. Thus, the mileage reduced from disposing of vehicles is considered to some degree, so the bias in the estimation is expected to be marginal.

4. Discussion on Cost-Effectiveness

Cost versus Benefit

This section discusses cost–effectiveness of the vehicle type regulation. We start from comparing cost to benefit derived from the regulation.

The benefit of the regulation is the reduction of social cost due to the emission reduction. Koyama and Kishimoto (2001) provide social cost of standard truck in Japan. We focus on standard truck since the truck has been accused of air pollution in Japan. In their estimates, the social cost of air pollution to standard trucks ranges from 35.7 to 83.7 yen per NO_x gram (A). According to Suri-Keikaku (2005), the emission intensities of diesel trucks at the speed of 20 km per hour range from 0.585 to 1.034 NO_x gram per km (B). For the time being, let us assume that all the social cost of air pollution is due to NO_x. Then, we can obtain the social cost of NO_x by dividing the social cost of air pollution per km (A) by the emission intensities (B). Then, the social benefit of NO_x reduction is estimated to be from 34.5 to 143.1 yen per NO_x gram.

In order to find cost per emission reduction due to regulation, one must find out 'pure' effects of the regulation. According to Table.11, the NO_x emission is reduced by 4,188 ton from 2004 to 2012. However, this is not the amount of 'pure' reduction of NO_x emission. The reduction takes place over time from 2004 to 2014. Table.5 shows that the duration of standard truck usage is reduced by about 4 years. Hence, the pure reduction of NO_x emission is roughly 16,700 tons (=4188 times 4).

Now, we compute the cost per NO_x gram. Table.9 shows that the compliance cost for standard trucks is 34,32 hundred million (343.2 billion yen) yen. By dividing this cost by the emission reduction (16,700), we conclude that the estimate of cost is 20.5 yen per gram. The benefit is estimated to be 34.5 yen per NO_x gram at minimum. Hence, the cost is smaller than the estimates of the benefit.

Next, we conduct the same estimates for PM. Now, let us assume that all air pollution are due to PM. Using the social cost from Koyama and Kishimoto and emission intensities from Suri-Keikaku (2005) , the benefit of PM reduction is estimated to be from 295.0 to 1230.9 per gram. We can also compute the cost per PM with the

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effect is considered to be marginal.

procedure described above. The cost is estimated to be 98.7 yen per PM gram. Again, the benefit is greater than the cost. The comparison of cost and benefits are summarized in Table.12.

Thus, for both hypothetical situations, we find the benefits exceed the cost for standard trucks. This suggests that the vehicle type regulation is justified in terms of cost-benefit ratio. However, we must bear in mind that estimates of benefit of emission reduction always entail uncertainty.

Inefficiency of Command-and-Control Approach: Room for Improvement?

Now, we turn into the cost-effectiveness of the regulation given the emission reduction target. The discussion above suggests that social benefit of the vehicle type regulation exceeds its cost though there is some ambiguity regarding benefits. However, it does not imply that regulation achieved the emission target at the minimum cost.

We will show that there is room for improvement. That is, we can achieve the same emission level at lower cost. Using the information above, we can compute marginal abatement cost (MAC) by vehicle type as follows:

$$MAC_{rm}^{t} = \frac{C_{rm}^{t}}{(e_{rm} - e_{0m})x_{m}}$$

where x_m denotes mileage per year for vehicle type m. In this equation, the denominator represents the reduction of emission per year when a type m vehicle is replaced with an approved vehicle. The numerator represents the cost due to the replacement with the approved vehicle. Thus, the figure computed in this equation captures the marginal abatement cost (MAC) for vehicle type m. The estimates of MAC based on this equation are shown in Table.13.A and 13.B for NO_x and PM, respectively. One can observe quite a divergence in MAC among vehicle types each year.

Using MAC in Table.13.A and 13.B, we computed the ratio of maximum MAC to minimum MAC of NO_x and PM for each year. The results are shown in Table.14. Starting with NO_x, it is revealed that, in the same year, maximum MAC of NO_x can be more than ten times larger than the minimum MAC. For example, MAC for small special use vehicle is 7.8 yen per NO_x gram while MAC for standard passenger car is 82.2 NO_x grams per year. This is evidence that the enforcement of motor vehicle has some inefficiency to achieve the emission target defined by the NO_x -PM law.

For instance, in 2004, MAC for small special use vehicle is 94.6 yen per gram while MAC for standard passenger car is 675.8 gram per year. Thus, MAC for the former is 7 times larger than the later vehicle type.

This divergence in MAC both for NO_x and PM is clear evidence that the vehicle type regulation is not cost effective. If a regulation achieves an emission reduction target at the minimum cost, marginal abatement costs are expected to be equal or similar among polluters. However, as shown in Table.14., we find quite divergence, which proves that the regulator could have reduced the same amount of emission at lower costs. From the perspective of cost, there is room for improvement in policies on emission from vehicles.

How could the government achieve the same emission target with lower costs for the economy then? We conducted a simple simulation as follows. In 2006, MAC of NO_x for small special-use vehicle is 17.4 yen per gram and smallest among all the vehicle type (Table.13.A). In 2006, MAC of standard passenger vehicle is 92.0 yen per gram and greatest. If the regulator accelerates the retirement of the small passenger vehicle from 2005 to 2006, MAC the vehicle increases, but still is smaller than the MAC of standard passenger vehicle. To the contrary, if the regulator postpones the retirement from 2005 to 2006, MAC of the small passenger car becomes smaller, but still is greater than MAC of the small passenger car.

This exchange in retirement timing can achieve the same emission level in 2005 and 2006, just at a lower cost for the economy. In this way, the regulator can find a better way to achieve the same emission target. If the regulator have had introduced economic instruments of emission tax or emission trading instead of the vehicle type regulation, cost for the economy could have been smaller.

5. Concluding Remarks

This paper empirically investigated vehicle type regulation implemented in the Japanese metropolitan areas as an example of command-and-control approach for the diffusion of low emission vehicles. We examined the cost and the benefit of the regulation. It is suggested that the benefit exceeds the cost of the regulation. However, we found large deviations of marginal abatement costs among vehicle types, for both NO_x and PM. In the worst case, the deviation can be as much as 10 times. Although the air quality is expected to improve dramatically, there is room for improvement in regulation from the viewpoint of costs.

A simple simulation shows that the regulator can reduce cost for the economy by changing the timing of retirement enforcement for each vehicle type without changing the emission reduction. Economic instrument such as emission trading is one way to realize the least cost regulation. But, then, how much compliance cost can we save by introducing emission trading? This requires further analysis.

We must mention one caution on the vehicle type regulation. While the regulation successfully reduces the emission of NO_x and PM, emission of carbon dioxide did not decrease and in some cases increased, especially for larger size trucks due to the technological trade off between NO_x /PM reduction and CO_2 reduction. This is also an area of future work.

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Table.1. Compliance Methods: Standard Trucks

1)	Transfer the usage area to non-specified area	12%
2)	Replace with new approved vehicles	89%
3)	Replace with used approved vehicles	8%
4)	Dispose regulated vehicles and reduce the number in possession	35%
5)	Change to leasing rather than buying trucks	13%
6)	Change to renting cars rather than possessing them	0%

Table.2. Compliance Methods: Small Trucks

1)	Replace with approved diesel-engine vehicles	45%
2)	Replace with approved gasoline-engine vehicles	38%
3)	Replace with LPG vehicles	1%
4)	Replace with CNG vehicles	2%
5)	Replace with Hybrid vehicles	2%
6)	Replace with used approved vehicles	8%
7)	Use lease vehicles	11%
8)	Install NOx reduction devices	12%
9)	Install PM reduction devices	14%
10)	Dispose not complied vehicles after the postponement period is over	18%
11)	Reduce the number of vehicles possessed	8%
12)	Change the registration location to non-specified area	2%
13)	Consider cessation or change businesses due to difficulty of compliance	0%
14)	Cosign transportation business to other enterprises	2%

Table.3. Banned Year: Standard Trucks

Banned Year	First registration year
2004	1989
2005	1990,1991,1992,1993
2006	1994,1995
2007	1996,1997,1998
2008	1999
2009	2000
2010	2001
2011	2002

Table.4. Terminal Year at 2004

First Registration Year	Vehicle Age	Standard Trucks	Small 4-Wheeled Trucks Small 3-Wheeled Trucks	Standard Bus	Small Bus, Standard Special-Use Vehicle, Small Special- Use Vehicle, Trailer	Standard Passenger Car, Small 4-Wheeled Passenger Car*	Standard Passenger Car, Small 4-Wheeled Passenger Car*
						Safety Inspection: one year	Safety Inspection: two years
2001	3	7	6	10	8	7	7
2000	4	6	5	9	7	6	6
1999	5	5	4	8	6	5	5
1998	6	4	3	7	5	4	4
1997	7	3	2	6	4	3	3
1996	8	2	2	5	3	2	2
1995	9	2	2	4	2	1	2
1994	10	2	1	3	2	1	2
1993	11	1	1	2	2	1	1
1992	12	1	1	2	1	1	1
1991	13	1	1	2	1	1	1
1990	14	1	0	1	1	1	1
1989	15	0	0	1	1	1	0
1988	16	0	0	1	0	1	0
1987	17	0	0	1	0	1	0
1986	18	0	0	0	0	1	0
1985	19	0	0	0	0	1	0
1984	20	0	0	0	0	1	0
1983	21	0	0	0	0	1	0

Unit: year

*** Includes Small 3-Wheeled Passenger Car**

Table.5. Life Remaining

First Registration Year	Car Age	Standard Truck	Small 4-Wheel Truck	Standard Bus	Small Bus	Standard Special-Use Vehicle Trailer	Small Special-Use Vehicle	Standard Passenger Car	Small 4-Wheel Passenger Car	Standard Passenger Car	Small 4-Wheel Passenger Car	Small 3-Wheel Passenger Car
								Safety Inspection: one year		Safety Inspection: two years		
2002	2	5.45	2.96	4.19	0.96	4.45	0.96	4.19	1.73	4.19	1.73	1.73
2001	3	5.52	3.05	4.29	1.05	4.52	1.05	4.29	1.82	4.29	1.82	1.82
2000	4	5.63	3.26	4.50	1.26	4.63	1.26	4.50	2.04	4.50	2.04	2.04
1999	5	5.74	3.59	4.52	1.59	4.74	1.59	4.52	2.11	4.52	2.11	2.11
1998	6	5.94	4.16	4.77	2.16	4.94	2.16	4.77	2.45	4.77	2.45	2.45
1997	7	6.12	4.64	4.86	2.64	5.12	2.64	4.86	2.61	4.86	2.61	2.61
1996	8	6.38	4.21	5.22	3.21	5.38	3.21	5.22	3.07	5.22	3.07	3.07
1995	9	5.70	3.93	5.42	3.93	5.70	3.93	4.42	2.36	5.42	3.36	3.36
1994	10	5.13	4.57	4.94	3.57	5.13	3.57	3.94	2.10	4.94	3.10	3.10
1993	11	5.61	4.25	4.25	3.25	4.61	3.25	4.25	2.55	4.25	2.55	2.55
1992	12	5.12	3.97	4.05	3.97	5.12	3.97	4.05	2.59	4.05	2.59	2.59
1991	13	4.69	3.72	3.63	3.72	4.69	3.72	3.63	2.17	3.63	2.17	2.17
1990	14	4.28	4.47	3.66	3.47	4.28	3.47	3.66	2.40	3.66	2.40	2.40
1989	15	4.84	4.21	3.24	3.21	3.84	3.21	4.24	3.07	3.24	2.07	2.07
1988	16	4.35	3.90	3.16	3.90	4.35	3.90	4.16	3.27	3.16	2.27	2.27
1987	17	3.83	3.54	2.75	3.54	3.83	3.54	3.75	2.98	2.75	1.98	1.98
1986	18	3.25	3.09	2.38	3.09	3.25	3.09	3.38	2.85	2.38	1.85	1.85
1985	19	2.61	2.54	1.69	2.54	2.61	2.54	2.69	2.41	1.69	1.41	1.41
1984	20	1.87	1.84	0.89	1.84	1.87	1.84	1.89	1.79	0.89	0.79	0.79
1983	21	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00

Unit: year

Table.6. Truck Prices by Capacity Load

	Capacity Load		
	2ton	4ton	11ton
Price (Thousand Yen)	3,700	5,400	12,000

Table.7. Passenger Car Prices by Gross Vehicle Weight

Vehicle Type	Gross Vehicle Weight (kg)	Price
Small 4-Wheeled Passenger Car	501 - 1000	135.1
Small 4-Wheeled Passenger Car	1001 - 1500	202.9
Small 4-Wheeled Passenger Car	1501 - 2000	241.9
Small 4-Wheeled Passenger Car	2001 - 2500	241.9
Small 4-Wheeled Passenger Car	2501 - 3000	241.9
Standard Passenger Car	501 - 1000	281.3
Standard Passenger Car	1001 - 1500	281.3
Standard Passenger Car	1501 - 2000	428.0
Standard Passenger Car	2001 - 2500	428.0
Standard Passenger Car	2501 - 3000	428.0
Standard Passenger Car	3001 - 3500	428.0
Standard Passenger Car	3501 - 4000	428.0
Standard Passenger Car	4001 - 4500	428.0
Standard Passenger Car	4501 - 5000	428.0

Unit: ten thousand yen

Table.8. Cost per Vehicle

First Registration Year	Trailer	Small 4-Wheel Truck	Small 4-Wheel Passenger Car	Small Bus	Small Special-Use Vehicle	Standard Truck	Standard Bus	Standard Passenger Car	Standard Special-Use Vehicle	Total
1984		18.2	5.2	23.8	17.9	35.8	51.1	11.1	30.1	26.4
1985		25.6	9.5	33.0	25.9	46.5	67.8	20.7	43.6	33.9
1986	150.9	31.0	12.4	42.4	31.6	58.1	87.0	28.7	54.6	40.1
1987	176.1	35.1	13.4	48.9	34.7	70.1	73.5	33.0	63.8	45.8
1988	193.9	38.5	15.3	53.2	37.1	81.8	86.3	37.7	71.2	50.1
1989	171.5	41.0	14.1	42.8	29.6	89.4	99.1	38.6	59.9	50.4
1990	189.9	43.5	16.2	45.9	31.4	81.2	107.4	43.3	66.6	50.3
1991	162.6	35.4	14.7	48.9	33.0	89.4	91.2	42.9	75.3	49.1
1992	176.6	37.4	17.4	51.9	35.2	94.8	100.4	47.5	79.4	49.6
1993		39.3	17.1	40.3	28.1	102.8	112.2	49.8	63.6	50.8
1994	218.6	41.8	20.5	44.7	31.2	97.1	98.0	57.1	68.6	56.1
1995	238.9	35.7	22.1	48.5	34.7	111.1	82.7	62.3	73.3	60.1
1996		40.3	19.7	38.7	28.5	114.2	72.1	58.5	70.1	62.2
1997		44.0	16.3	31.3	22.6	106.9	64.7	53.1	70.7	61.3
1998		38.1	14.7	25.1	18.5	98.1	60.3	50.7	65.7	56.3
1999		31.5	12.3	17.2	13.0	100.7	56.8	46.8	63.7	50.1
2000		27.0	11.4	10.4	10.2	124.2	58.4	45.2	62.3	40.1
2001		24.7	9.9	7.9	8.2	45.5	50.5	42.0	34.5	26.8
2002		23.5	9.0	7.1	7.5	44.1		39.9	33.4	25.5
Total	204.5	36.4	17.2	37.0	24.0	96.8	83.3	53.0	66.7	52.8

Unit: ten thousand yen

Table.9 Cost by Vehicle Type and by Prefecture

		Prefecture								Total
		Aichi	**Saitama**	**Mie**	**Kanagawa**	**Chiba**	**Osaka**	**Tokyo**	**Hyogo**	
Vehicle Type	**Trailer**	8.7	0.0	0.0	0.0	1.3	23.4	0.0	0.0	33.5
	Small 4-Wheeled Truck	403.1	217.0	40.1	248.9	129.0	309.9	368.7	139.0	1855.8
	Small 4-Wheeled Passenger Car	155.6	82.7	14.8	88.8	57.8	141.5	99.1	66.4	706.8
	Small Bus	7.7	6.5	0.9	5.6	3.6	5.6	7.4	2.9	40.0
	Small Special- Use Vehicle	8.1	4.9	0.9	6.2	3.3	6.8	9.9	3.0	43.2
	Standard Truck	690.4	443.9	75.3	474.5	266.8	597.2	613.7	270.3	3432.1
	Standard Bus	20.1	11.6	2.3	25.9	11.9	21.7	35.1	11.8	140.5
	Standard Passenger Car	418.3	234.4	42.2	269.7	161.1	325.7	284.3	183.4	1919.3
	Standard Special- Use Vehicle	194.3	131.4	23.9	175.3	102.6	166.4	212.6	84.7	1091.2
Total		1906.4	1132.4	200.5	1294.9	737.5	1598.3	1630.9	761.6	9262.4

Unit: One hundred million yen

Table.10.A　Emission by Vehicle Type and by Prefecture: NOx

		Prefecture								Total
		Aichi	Saitama	Mie	Kanagawa	Chiba	Osaka	Tokyo	Hyogo	
Vehicle Type	Trailer	14.5	0.0	0.0	0.1	1.8	34.6	0.0	0.0	51.0
	Small 4-Wheeled Truck	2881.1	1392.2	279.9	1502.7	844.8	2574.8	2186.6	1410.5	13072.5
	Small 4-Wheeled Passenger Car	636.6	270.7	60.3	287.2	190.9	502.1	393.4	332.7	2674.0
	Small Bus	32.8	37.3	3.8	35.8	20.3	41.6	56.5	15.2	243.4
	Small Special- Use Vehicle	95.9	59.9	10.2	70.6	40.3	96.0	108.7	48.8	530.4
	Standard Truck	1919.0	1018.7	198.7	1007.8	586.1	1700.4	1337.3	696.2	8464.1
	Standard Bus	34.6	27.6	4.1	56.9	27.2	63.3	94.3	24.9	333.0
	Standard Passenger Car	521.0	239.9	53.5	267.4	165.2	359.4	352.9	284.4	2243.7
	Standard Special- Use Vehicle	887.2	486.8	81.4	603.9	349.9	679.0	720.9	306.7	4115.8
Total		7022.6	3533.0	691.9	3832.6	2226.5	6051.3	5250.6	3119.4	31727.8

Unit: ton

Table.10. B Emission by Vehicle Type and by Prefecture: PM

		Prefecture								Total
		Aichi	**Saitama**	**Mie**	**Kanagawa**	**Chiba**	**Osaka**	**Tokyo**	**Hyogo**	
Vehicle Type	**Small 4-Wheeled Truck**	264.3	127.8	27.1	140.3	76.8	252.9	190.4	139.2	1218.7
	Small 4-Wheeled Passenger Car	119.0	48.5	10.9	52.2	34.0	96.8	71.7	61.9	494.9
	Small Bus	3.8	4.2	0.5	3.7	2.4	4.5	5.9	1.7	26.6
	Small Special- Use Vehicle	9.2	5.3	1.1	6.4	3.5	9.2	9.4	4.7	48.8
	Standard Truck	211.2	108.8	22.5	105.2	63.2	177.3	141.9	74.0	904.0
	Standard Bus	3.9	3.1	0.5	6.2	3.2	6.8	10.3	2.6	36.7
	Standard Passenger Car	124.3	54.7	12.6	62.6	37.6	85.1	80.4	66.9	524.1
	Standard Special- Use Vehicle	77.3	41.4	8.2	48.7	32.3	62.2	59.6	29.5	359.2
Total		813.0	393.8	83.2	425.5	252.7	694.8	569.5	380.3	3612.8

Unit: ton

Table.11.A Emission Reduction by Vehicle Type and by Prefecture: NOx

		Prefecture								Total
		Aichi	Saitama	Mie	Kanagawa	Chiba	Osaka	Tokyo	Hyogo	
Vehicle Type	Trailer	14.3	0.0	0.0	0.1	1.8	34.3	0.0	0.0	50.6
	Small 4-Wheeled Truck	1850.9	869.1	180.0	897.8	527.4	1521.3	1369.5	863.7	8079.7
	Small 4-Wheeled Passenger Car	502.4	214.2	47.8	227.0	151.2	395.3	310.7	262.9	2111.5
	Small Bus	17.2	19.7	2.0	19.7	10.5	20.8	31.4	7.7	128.9
	Small Special-Use Vehicle	63.3	41.3	6.5	46.6	27.7	59.3	71.4	29.9	346.1
	Standard Truck	963.2	501.4	99.4	493.9	291.2	823.3	674.9	341.3	4188.7
	Standard Bus	16.8	13.4	2.0	27.2	13.4	30.3	45.2	11.8	160.2
	Standard Passenger Car	419.7	195.5	43.3	216.4	134.7	290.3	287.5	230.2	1817.7
	Standard Special-Use Vehicle	557.6	304.5	45.3	382.2	212.8	392.4	463.8	170.2	2528.9
Total		4405.5	2159.1	426.4	2310.8	1370.6	3567.4	3254.6	1917.7	19412.3

Unit: ton

Table.11.B Emission Reduction by Vehicle Type and by Prefecture: PM

		Prefecture								Total
		Aichi	Saitama	Mie	Kanagawa	Chiba	Osaka	Tokyo	Hyogo	
Vehicle Type	Small 4-Wheeled Truck	250.5	122.3	25.8	134.3	73.5	241.0	182.1	132.4	1161.9
	Small 4-Wheeled Passenger Car	98.0	39.6	8.9	42.8	27.7	80.1	58.7	50.9	406.7
	Small Bus	3.7	4.0	0.4	3.6	2.3	4.3	5.7	1.6	25.6
	Small Special- Use Vehicle	8.7	5.1	1.0	6.1	3.3	8.8	8.9	4.5	46.2
	Standard Truck	203.4	104.6	21.7	100.9	60.7	170.0	136.5	71.0	868.9
	Standard Bus	3.8	3.0	0.5	6.0	3.1	6.5	9.9	2.5	35.2
	Standard Passenger Car	107.0	47.1	10.8	53.9	32.3	73.3	69.2	57.6	451.2
	Standard Special- Use Vehicle	73.9	39.6	7.9	46.5	30.8	59.5	57.1	28.2	343.6
Total		748.9	365.2	76.9	394.1	233.8	643.5	528.1	348.7	3339.3

Unit: ton

Table.12. Cost and Benefit by NOx and by PM

		NOx	PM
Benefit	Upper Bound	143.1	1230.9
	Lower Bound	34.5	295.0
Cost		20.5	98.7

Unit: yen per gram

Table.13.A Marginal Abatement Cost: NOx

		Vehicle Type									Average
		Trailer	Small 4-Wheeled Truck	Small 4-Wheeled Passenger Car	Small Bus	Small Special-Use Vehicle	Standard Truck	Standard Bus	Standard Passenger Car	Standard Special-Use Vehicle	
Cost Occurrence Year	2004	52.6	16.8	40.7	19.2	7.8	37.7	47.0	82.2	20.9	22.8
	2005	63.9	25.5	33.5	44.4	14.8	85.1	85.8	92.0	46.3	49.5
	2006	75.4	29.3	42.6	45.4	17.4	105.4	126.1	130.5	48.0	59.3
	2007		29.2	36.7	42.0	19.0	105.7	122.9	122.0	53.0	67.4
	2008		24.3	35.9	34.3	14.8	99.3	105.3	131.1	56.9	60.6
	2009		20.6	39.1	27.9	13.4	103.6	89.8	182.5	58.3	58.4
	2010		19.7	51.0	18.4	10.1	123.8	83.1	259.2	59.1	51.2
	2011		19.7	45.6	8.2	8.9	43.9	78.8	249.5	56.0	40.9
	2012			43.3	7.1	7.5	45.0	76.0	244.9	28.9	51.7
	2013				6.4	7.4		76.9		40.4	36.2
	2014							71.7			71.7
Average		69.3	24.3	35.1	33.1	13.5	87.4	97.0	112.9	46.7	50.9

Unit: yen per gram

Table.13.B Marginal Abatement Cost: PM

		Vehicle Type								Average
		Small 4-Wheeled Truck	Small 4-Wheeled Passenger Car	Small Bus	Small Special-Use Vehicle	Standard Truck	Standard Bus	Standard Passenger Car	Standard Special-Use Vehicle	
Cost Occurrence Year	2004	137.6	251.4	103.8	94.6	164.8	184.1	675.8	137.2	148.4
	2005	189.0	208.1	182.3	137.4	352.3	318.6	441.0	298.7	287.9
	2006	161.1	159.4	195.0	125.2	521.2	510.0	472.2	416.6	321.2
	2007	161.8	136.0	228.2	95.3	616.3	498.0	441.2	435.4	357.0
	2008	192.1	127.2	188.4	75.8	586.4	460.2	450.8	382.8	357.8
	2009	206.4	114.6	158.3	72.1	628.5	536.4	485.9	375.1	366.5
	2010	194.4	113.6	123.4	69.7	845.5	495.7	526.9	413.6	348.2
	2011	190.9	100.8	81.2	83.7	346.7	474.8	505.8	492.9	285.1
	2012		95.1	69.4	69.0	356.2	464.2	498.2	271.0	304.4
	2013			62.9	64.9		511.6		402.9	315.7
	2014						421.4			421.4
Average		169.3	182.1	166.5	100.9	421.1	441.3	454.6	343.6	295.8

Unit: yen per gram

Table.14. Deviation from Marginal Abatement Cost: NOx and PM:
Ratio of Maximmum MAC to Minimum MAC

		NOx	PM
Cost Occurance Year	2004	10.5	7.1
	2005	6.2	3.2
	2006	7.3	4.2
	2007	6.5	6.5
	2008	8.8	7.7
	2009	13.7	8.7
	2010	25.7	12.1
	2011	27.9	6.0
	2012	32.5	7.2
	2013	10.3	7.9