Effect Analysis of Transport Sector Energy Consumption in Japan Based on the Method of Decomposition Analysis

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Abstract: Decomposition analysis is a method that analyzes the effects of factors which lead to the growth of energy consumption. This paper introduces the vector variables to the method of decomposition analysis in order to show the change of energy consumption in the transport sector in recent years in Japan. It is found that the travel demand of passengers has increased successfully every year and has crucially and steadily affected the transport energy consumption. GDP is another factor that caused great energy consumption during Japan's high economic growth period while it is also effective to reduce energy intensity and the average travel distance. According to the result, corresponding policy such as encouraging environmental vehicles is proposed.

Keywords: decomposition analysis, vector variable, transportation mode, energy intensity

1. INTRODUCTION

Japan has made a great economic achievement after the World War II, and the consumption of energy increased steadily meanwhile. However, the Japanese economy was severely shocked by the oil crises in the 1970s and slowed down. Because of the crises, more and more

attentions were paid to energy conservation by various researchers, and as a result, there was obvious improvement of energy efficiency in Japan a few years after the second oil crises. Nowadays, driven by the severe fluctuation of energy prices, researchers began to pay new attention to the problem of the energy consumption reduction. Therefore, it is meaningful to analyze the factors which affect energy consumption in order to reduce it, and it is significant especially in Japan with little energy of its own. Furthermore, the reduction of energy consumption leads to the reduction of carbon dioxide emissions in generally speaking, so it is also considered to be an indispensable way to fight against global warming.

As is known to all, the transport sector is responsible for a certain part of the total energy consumption. It accounted for 16.4% of the total energy consumption in the year 1973 at the first oil crises, and grew up steadily to reach 23.7% in 2005. The absolute amount of the energy consumption in the transport sector becomes 2.1 times of 22 years ago, according to Energy in Japan (2008) written by the Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry of Japan. The definite energy consumption of the transport sector in Japan is shown in Figure 1.



Figure 1 The energy consumption in the transport sector in Japan

The reasons for the increase of energy consumption in the transport sector are sophisticated and hard to distinguish completely. As traffic demand sharply increases, the amount of turnovers in both passenger transportation sector and freight transportation sector increased steadily. The breakdown of each means of transportation has been varying all the time as well. Besides, the variation of energy intensity plays an important role, too. Among all the factors that possibly affect the energy consumption in the transport sector, ones which give positive and negative effect remain a problem. Moreover, the proportion these factors actually account separately need to be studied at the same time. In this case, quantitative research is necessary for the analyzing the factors and corresponding policy-making.

This paper mainly identifies the factors behind the changes of energy consumptions in the transport sector during the recent decades in Japan and how much effect each factor has. For this purpose, we improve the method of decomposition analysis to make it suitable for this paper. The details of this method will be explained in the next section, while the result of the decomposition together with the analysis and policy suggestions will be given in the last section.

2. METHODOLOGY

The amount of energy consumption in the transport sector is affected by many factors such as the energy intensity of vehicles, travel distance and so on. Therefore, there is a certain relationship between the change of energy consumption and the changes of these factors in mathematics range. That is to say, the amount of change of each factor decides the amount of total change. Decomposition analysis mainly focuses on the decomposition of the change in total amount and distributes the change into the effects of its factors under certain rules. Accordingly, in decomposition analysis, changes in an energy-related aggregate indicator of interest are decomposed and distributed among a number of pre-defined factors (Ang,B.W. *et al.* 2003). In this paper, we decompose the energy consumption changes in the transport sector in Japan into some factors. The result will show the contribution by the each factor to the energy consumption. Based on the result, the policy-makers can find out the key factors and emphasize on the key factors' improvement, so the balance between the energy conservation and the economic development can be grasped.

Index decomposition methodology was used to study the impact of changes in product mix on industrial energy demand at first and now it is widely used not only in industrial fields but also in the environmental fields in general. It is first developed not long after the 1970s world oil crises and has continued to be studied until today with more and more papers presented every year (Ang,B.W. *et al.* 2000). It mainly deals with the issues whose total amount can be expressed by the factors multiplied together. Based on the number of studies reported, index decomposition analysis is now widely accepted as an analytical tool for policymaking on national energy and environmental issues (Ang,B.W. 2004). With the development of the method, a lot of mathematics skills are applied to the calculation of the decomposition. Scanning over the studies done by various researchers in recent years, we could find that the most widely used decomposition methods are apparently the Laspeyres method and the Divisia method, which are able to give decomposition results easily and reasonably. But the

trouble these two initial methods may bring in is that a factor left unexplained always exists, and this unexplained factor could be beyond imagination and lead to improper results. Consequently, two other methods were developed separately to achieve perfect decomposition. Refined Laspeyres index method and Logarithmic mean Divisia index method do not left any factors unexplained. At present, most of the decomposition studies are based on these improved methods. In this section, we show the results of decomposing a three-factor case, for the sake of simplicity, by the two methods discussed by Ang,B.W. *et al.*(2003). Under the principle of these methods, the decomposition with more factors can be done in the similar way.

Assume that V is the aggregate of interest and it is determined by three independent factors x_1 , x_2 , x_3 , where V= $x_1 x_2 x_3$. Consider the problem studied temporally and discretely, we assume the absolute change in V from year 0 to T, ΔV , will be decomposed to give effects associated with factors x_1 , x_2 , x_3 , We have

$$V^{0} = x_{1}^{0} x_{2}^{0} x_{3}^{0}, V^{T} = x_{1}^{T} x_{2}^{T} x_{3}^{T},$$

$$\Delta V = V^{T} - V^{0} = x_{1}^{T} x_{2}^{T} x_{3}^{T} - x_{1}^{0} x_{2}^{0} x_{3}^{0}$$

The purpose of this decomposition is to evaluate the effects imposed on V by each factor. That is to have $\Delta V_{x_1} \Delta V_{x_2} \Delta V_{x_3}$, calculated to separately show the changes of V caused by factors x_1 , x_2 , x_3 respectively.

Note that $\Delta x_1 = x_1^T - x_1^0$, $\Delta x_2 = x_2^T - x_2^0$, $\Delta x_3 = x_3^T - x_3^0$, therefore $\Delta V = (\Delta x_1 + x_1^0)^* (\Delta x_2 + x_2^0)^* (\Delta x_3 + x_3^0) - x_1^0 x_2^0 x_3^0 = \Delta x_1 \Delta x_2 \Delta x_3 + \Delta x_1 \Delta x_2 x_3^0 + \Delta x_1 x_2^0 \Delta x_3 + x_1^0 \Delta x_2 \Delta x_3 + \Delta x_1 x_2^0 x_3^0 + x_1^0 \Delta x_2 x_3^0 + x_1^0 x_2^0 \Delta x_3$

According to the rule of the Refined Laspeyres index method, the expression which has only one factor changed is obviously considers the effect is caused by the changed factor alone. The expression which has two factors changed will be divided into two averagely and distributes each effect to the changed factors, and in the same manner, the expression" $\Delta x_1 \Delta x_2 \Delta x_3$ " is to be divided into three parts and distributes each effect to the three factors.

The decomposition result of this three-factor case is as follows:

$$\begin{split} \Delta V_{x_1} &= \Delta x_1 x_2^0 x_3^0 + \frac{1}{2} \Delta x_1 \Delta x_2 x_3^0 + \frac{1}{2} \Delta x_1 x_2^0 \Delta x_3 + \frac{1}{3} \Delta x_1 \Delta x_2 \Delta x_3 \\ \Delta V_{x_2} &= x_1^0 \Delta x_2 x_3^0 + \frac{1}{2} \Delta x_1 \Delta x_2 x_3^0 + \frac{1}{2} x_1^0 \Delta x_2 \Delta x_3 + \frac{1}{3} \Delta x_1 \Delta x_2 \Delta x_3 \\ \Delta V_{x_3} &= x_1^0 x_2^0 \Delta x_3 + \frac{1}{2} x_1^0 \Delta x_2 \Delta x_3 + \frac{1}{2} \Delta x_1 x_2^0 \Delta x_3 + \frac{1}{3} \Delta x_1 \Delta x_2 \Delta x_3 \end{split}$$

The Logarithmic mean Divisia index method also gives perfect decomposition as the refined Laspeyres index method. Here is the decomposition result of the refined Laspeyres index method.

$$\Delta V_{x_1} = \ln \frac{x_1^T}{x_1^0} * L(V^T, V^0)$$
$$\Delta V_{x_2} = \ln \frac{x_2^T}{x_2^0} * L(V^T, V^0)$$
$$\Delta V_{x_3} = \ln \frac{x_3^T}{x_3^0} * L(V^T, V^0)$$

In the expressions above, $L(V^T, V^0) = \frac{V^T - V^0}{\ln V^T - \ln V^0}$ is the mean weight function defined as the logarithmic average of two positive numbers.

Moreover, the results of the decomposition can be achieved in two ways: the multiplicative decomposition and the additive decomposition. In the multiplicative decomposition, the change in an aggregate given as a ratio is decomposed, while in the additive decomposition, the change in an aggregate is decomposed in absolute changes (Ang,B.W. *et al.* 2003). These two ways have almost the same meaning basically, except that the additive decomposition can calculate the ratio of each factor occupied in the gross.

Now we come back to the issue this paper is discussing. Generally speaking, the energy consumption in transport sector is mainly related to the turnover of transportation, the energy intensity of transportation, the economic growth, the breakdown of each transportation mode etc., and Japan is no exception. The factors chosen for the energy consumption decomposition should fulfill the following conditions:

- 1. The factors should be meaningful for the analysis and policy-making;
- 2. All the factors have to be available for calculation;
- 3. The energy consumption can be expressed by all the factors multiplied together.

First, we start with the multiply equation: $E = O^*e$

In this equation, E is the energy consumption in the transport sector; O is the turnover of transportation (per capita kilometer in passenger transportation and per ton kilometer in freight transportation); e is the energy intensity in transport sector (energy consumption per turnover). It is noted, by Lakshmanan,T.R. *et al.*(1997), that the passenger and the freight transportation always show different characteristics and then we decide to do decomposition analysis in passenger transportation and freight transportation separately. In passenger transportation, turnover O is decomposed into the number of passengers and average travel distance of each passenger; in freight transportation, turnover O is decomposed into the number of passengers and average travel distance of each passenger; in freight transportation, turnover O is decomposed into the number of passengers and average travel distance of each passenger; in freight transportation, turnover O is decomposed into the number of passengers and average travel distance of each passenger; in freight transportation, turnover O is decomposed into the number of passengers and average travel distance of each passenger; in freight transportation, turnover O is decomposed into the number of passengers and average travel distance of each passenger; in freight transportation, turnover O is decomposed into the number of passengers and passenger into the number of passengers and passengers and passenger into

domestic product and transportation intensity of gross domestic product. The data of all the factors for both the passenger and the freight transportation are sufficient enough for calculation.

After that, we try to decompose the energy intensity e: normally, the factors are always described as figures to be analyzed and calculated. However, the transport sector is made up from many kinds of transportation vehicles such as trains, cars, airplanes and so on. The different vehicles have their own unique energy intensity so they cannot be integrated. To deal with this specialty, this paper introduces vector variables into the field of factors. The vector variable factors appear in the shape of row vector 1*n and column vector n*1 to represent every means of transportation to be studied. We decompose the energy intensity e into a 1*n vector variable **e** and an n*1 vector variable **w** for a collection of all the transport means. The meaning of **w** is the breakdown of turnover each transport sector accounts. The result that **e** multiplies **w** comes to the comprehensive energy intensity e. Lakshmanan,T.R. *et al.*(1997) also used the vector variables for index decomposition methodology, however, they contributed all the expressions that include more than one factor change to the factor effect of interaction among other factors, which may lead to excessive unexplained factors and so is not considered as a perfect decomposition. In contrast, this paper intends to decompose every expression to the end to thoroughly analyze the effect of each factor.

In this way, the decomposing equation is as follows:

Passenger transportation: $E_P = \mathbf{e} \mathbf{w} \mathbf{C} \mathbf{L}$

Freight transportation: $E_F = e w G T$

In the equation above, E_P is the total energy consumed in the passenger transport sector, and E_F is the total energy consumed in the freight transport sector. **e** is a vector made up of energy intensity elements with the dimension 1*n, where *n* is the number of modes in the transport sector, and **w** is a vector made up of mode share elements with the dimension n*1, where *n* is the number of modes in the transport sector. C stands for the number of passengers and L stands for the average distance each passenger travels. G stands for the gross domestic product in Japan, which is considered to directly affect the turnover of the freight transportation, and T stands for transportation intensity of the gross domestic product, which measures the synergetic effects of all the factors that are influencing the demand for freight transportation. The result of the all the factors multiplied together leads to the energy consumption indeed. Therefore, the changes of the energy consumption in the transport sector can be deduced from the factors explained above as follows:

The mode energy intensity effect ΔE_e , reflects the effect of the change in the energy intensity of each transportation mode. (ΔE_{eP} , ΔE_{eF} represent the effect in passenger

transportation and freight transportation respectively)

The mode share effect ΔE_w , reflects the effect of the change in the breakdown of each transportation mode ($\Delta E_{wP} \Delta E_{wF}$ represent the effect in passenger transportation and freight transportation respectively)

The travel demand effect ΔE_{C} , reflects the effect of the change in the passengers' demand for travel.

The travel distance effect ΔE_L , reflects the effect of the change in the average distance of travel by each passenger.

The GDP effect ΔE_G , reflects the effect of the change in the GDP in Japan brings in.

The transportation intensity of GDP effect ΔE_T , reflects the effect of the change in the transportation intensity of GDP in Japan.

Therefore, the changes of the energy consumption in the passenger transportation and the freight transportation are decomposed into the factors stated above:

$$\Delta E_{P} = \Delta E_{eP} + \Delta E_{wP} + \Delta E_{C} + \Delta E_{L},$$

$$\Delta E_{F} = \Delta E_{eF} + \Delta E_{wF} + \Delta E_{G} + \Delta E_{T},$$

The introduction of the vector variable makes it impossible to decompose the changes in the multiplicative decomposition, and the Logarithmic mean Divisia index method cannot be used as well, just because vector cannot be divided by another vector with the same dimension although the Logarithmic mean Divisia index method is robust and gives perfect decomposition very easily. In this case, we have no other choice than to use the refined Laspeyres method to decompose the changes in the additive decomposition. Note the precondition that vector variables also satisfy the condition: $(e+\Delta e) * (w+\Delta w) = e*w+e*\Delta w+\Delta e *w+\Delta e *\Delta w$. In this case, to treat the vectors as normal figures in calculation and the refined Laspeyres method is suitable for the decomposition with vector factors all the same.

Here we lay out the universal solution to the Refined Laspeyres index method according to Shapely.L,(1953):

From the year 0 to the year T, the effect of each factor is calculated through the equation summarized below:

$$\Delta E_{x} = \sum_{s=1}^{4} \frac{(s-1)! (4-s)!}{4!} \sum_{\substack{S:x \in S \\ |S|=s}} [E(S) - E(S-x)]$$

Here S is a set made up with some of the four factors and x is the one element in the set S. E(S) is a function where the factor included in S uses the data in year T, while for all the other factors use the data in year 0.|S| stands for the number of elements set S includes. S - x stands for the set S without its element x.

3. DATA AND RESULT

The data used in this paper is from Statistics of EDMC Energy and Economy (2009) by The Energy Data and Modeling Center in Japan, and The statistics Data of Transportation (2009) by the Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry of Japan. Besides, the Japan Statistical Yearbook provides the data of GDP. As for the vector variables, according to the data provided, the dimension of the vector is set to four, indicating the transportation means of road transport, railway transport, ship transport and air transport for both the passenger transportation and the freight transportation.

With the original data supplied for every year recently, we could find that the data figures have been level and continuous without obvious fluctuations. So it is feasible to pick up any groups of data from these years for analysis and there is no need to worry about essentially revising the results due to some special data in the database. For the moment, we use ten years as one period and inspect three periods from the year 1975 to 2005, with which we trace back to the years of the oil crisis and until recent years. Therefore, we pick up the data of the years 1975, 1985, 1995 and 2005 to do a three-period decomposition analysis.

From the data selected, we can get some intuitive image and the trends of data can be described as follows: The turnover breakdown of car and airplane are increasing gradually both in the passenger and the freight transportation sector all the periods. On the other hand, the turnover breakdown of railway and ship are decreasing as the time going on both in the passenger and the freight transportation sector. The GDP and the number of passengers are also increasing year by year, and at the same time, the average travel distance is vibrated and the GDP intensity keeps going down. Despite the report of the improving fuel efficiency in vehicles year by year, the energy intensity does not show decreasing trend in all means of transportation across the period, which is more or less beyond the ordinary opinion of people. The energy intensity of airplane is decreasing all the time but the other three transport means do not have any clear trend of the change in energy intensity. In particular, the energy intensity of car and ship in passenger transportation become much higher in the year 2005 than that in the year 1995. Maybe the popularization of high-emission vehicles consumes much energy in spite of the enhancing of the fuel efficiency can explain this fact.

The decomposition result based on the refined Laspeyres method is shown by the effect of every factor and every period studied as shown in Table 1. The percentages each factor occupies are also shown for convenience to read and analyze.

	1975-1985		1985-1995		1995-2005	
	Amount	Percentage	Amount	Percentage	Amount	Percentage
Effect of mode energy intensity(ΔE_{eP})	1488	11.8	-6475	-23.3	3046	74.8
Effect of mode share(ΔE_{wP})	3321	26.4	5755	20.7	766	18.8
Effect of travel demand(ΔE_c)	4396	34.9	19346	69.7	2663	65.4
Effect of travel distance(ΔE_L)	1006	8.0	1550	5.6	-1703	-41.8
Changes in passenger transportation energy consumption(ΔE_P)	10211	81.1	20176	72.7	4772	117.2
Effect of mode energy intensity(ΔE_{eF})	-7343	-58.4	-1613	-5.8	-3691	-90.7
Effect of mode share(ΔE_{wF})	5064	40.2	2213	8.0	2304	56.6
Effect of $GDP(\Delta E_G)$	24819	197.2	7564	27.2	3686	90.6
Effect of transportation intensity of $GDP(\Delta E_T)$	-20167	-160.1	-580	-2.1	-3001	-73.7
Changes in freight transportation energy consumption(ΔE_F)	2373	18.9	7584	27.3	-702	-17.2
Changes in total transportation energy consumption(ΔE)	12584	100.0	27760	100.0	4070	100.0

Table 1 Decomposition result of energy consumption in the transport sector in Japan (Unit of the energy consumption amount: 10¹⁰kcal)

From the result of the decomposition, it is easy to find that the passenger transportation energy consumption accounts more in total energy consumption. Furthermore, most of the factors analyzed in the passenger transport sector were driving up the total energy consumption across these years. In the freight transportation, some factors give positive effects to the energy consumption and others give negative. Then we discuss all the contributing factors one by one in detail as follows. For convenience of discussion, we call the period 1975-1985 as Period 1 and the period 1985-1995 and 1995-2005 are called Period 2 and Period 3 respectively.

The effect of demand to travel occupies a large proportion among the factors at any time. In Period 1, it contributes 43960 trillion calories to the energy consumption, the largest share in the passenger transportation energy consumption. In Period 2, its contribution surges into 193460 trillion calories, 4 times greater than Period 1. Not only in the passenger transportation energy consumption, but also in the total transportation energy consumption, it is the principal factor which is much larger than the second largest effect. In Period 3, although the breakdown is still large, it is not prevailing anymore and the absolute value calms down. From the decomposition analysis, we can find that the demand to travel in passenger transportation is the factor which effectively affects the energy consumption in the transport sector in all the three periods. It seems that Japanese people highly care for traveling in these years and something has to be done, in the case the energy consumption in the transport sector should be reduced.

In contrast, the factor of travel distance does not have much impact on the passenger transportation. It accounts for 8.0% and 5.6% of the total in Period 1 and 2 respectively, which are the slightest impact among the factors in passenger transportation. In Period 3, it impact on the energy consumption became further smaller. The average travel distance of each passenger increased in Period 1 and Period 2 and decreased in Period 3, but the range of the change remains stable.

The decomposition of energy consumption in the freight transportation found the impact of the GDP factor enormous. In Period 1, which considered with the final stage of the high-speed growth of Japan's economy, the GDP grew significantly and greatly promoted the development of transportation meanwhile stimulated the energy consumption naturally. Its contribution is almost twice the amount of change in transportation energy consumption. In Period 2, the speed of economic growth slowed down but the effect remained positive, and it contributes 27.2% of the change in transportation energy consumption where the whole contribution done by freight transportation is only 27.3%. So it still plays an important role on the energy consumption. Period 2 and 3 are the period 3 decreased to half of that in Period 2, but the share climbed to 90.6%, and remained the dominant factor. It can be seen that the relationship between the GDP and the development of freight transportation is very strong.

On the other hand, transportation intensity of GDP always contributes negative impact to the energy consumption. The trend of its share is opposite to GDP's contribution: in Period 1, the percentage of its contribution reached -160.1%, the most negative factor of all; and in Period 2, it climbed up to -2.1%, however, it returned to -73.7% in Period 3 and retained its significant impact on the decrease of energy consumption. As explained in the previous section, transportation intensity of GDP is a synergetic factor which contains all factors influencing the demand for the freight transportation. It is the supplement for the factor of GDP on the demand of freight transportation.

The analysis in this paper emphasizes the effect of factors in vector form in decomposition result, i.e. the effect of mode energy intensity and transportation mode share. The effect of mode energy intensity greatly varied from Period 1 to 3, and between the passenger transportation sector and the freight transportation sector. This proves that it really shows the different characteristics between the passenger transportation sector and the freight transportation sector and it is right to discuss them separately. In the passenger transportation sector, the effect of mode energy intensity contributes 11.8% of the total in Period 1. The increased energy intensity is that of cars', despite the decreased intensity of ship and airplane. The energy intensity increases the energy consumption. In Period 2, the effect of mode energy intensity contributes -23.3% of the total, mainly due to the improvement of the energy intensity of car. The effect of mode energy intensity recovers in Period 3 to 74.8% and this should be attributed to the increasing energy intensity of car and ship. From the point of absolute amount, the largest change occurs in Period 2, where the change of car's energy intensity is also the largest. The improvement of airplane's energy intensity hardly affects, because its breakdown of turnover is very small. The railway's breakdown of turnover is not small but the energy intensity remains same along these periods, so to change the car's energy intensity is the key to control the change of energy consumption caused by the energy intensity in the passenger transportation sector. In the freight transportation sector, the effects in three periods are all negative, and the effect is not driven only by the car's energy intensity. Particularly in Period 2, the car's energy intensity increased a little but the effect is still negative, because there is a great improvement on the energy intensity of the railway and ship. But we have to admit that the breakdown of cars in the freight transportation is rather high, so the change of the car's energy intensity is still in the prevailing position in affecting the absolute amount of the energy consumption's change. Although the energy intensity of the airplane is high, the breakdown is too little to affect the result. The effect of improving the energy intensity of railway and ship is limited, too.

The analysis of the factor of mode share mainly inspects how the ways of transportation structure affects the energy consumption. It is a pity that we find in all the three periods at both the passenger transportation sector and the freight transportation sector, the effect of mode share contributes positive amount of energy consumptions. Therefore, the structure is changing all the way adversely to the reduction of energy consumptions. Comparing with the initial data and the decomposition results, it can be concluded that the increase of the car's breakdown is the main reason for the increase of the energy consumption. The passenger transportation sector in Period 2 and the freight transportation sector in Period 1 are where the surge of car's breakdown and the eminent increase of the absolute amount occur Therefore, in this analysis, the breakdown of car in the ways of transportation expresses the characteristic of the mode share affect most of all.

4. CONCLUSION AND POLICY IMPLICATIONS

The transport sector is one of the principal sources of energy consumption. Its contribution to the energy consumption increased constantly during the last few decades and is estimated to grow continually in the near future. Therefore we should pay more attention to controlling energy consumption in the transport sector. To inhibit the development of transportation is a direct and valid method, but is apparently far from our real intention and will shock the economy heavily at the same time. The key point is to find a balance between the energy consumption and the economic development so that we can keep the sustainability of resource and the economic growth at the same time.

In this paper, we decompose the change of energy consumption into the effects of several factors by the method of decomposition analysis with vectors. According to the result, it is found that the effect of travel demand and the effect of GDP are the most influential effects to the energy consumption in both the passenger transportation sector and the freight transportation sector. It is a clear conclusion that the effect of the mode share is always giving positive contribution in both the passenger transportation sector and the freight transportation sector. The effect of energy intensity gives irregular contribution across all over the periods. The effect of average travel distance is small but not trivial. In the end, the decomposition result shows that there is no doubt that the passenger transportation and the freight transportation really have different characteristics about energy consumption. The policy implications are as follows.

Firstly, the reduction of energy intensity is the fundamental method to control energy consumption in the transportation sector. In the freight transportation sector, the intensity is decreasing and becoming the least factor to contribute to energy consumption, on the other hand, in the passenger transportation sector, the effect of energy intensity is getting worse. Comparing the initial data and the decomposition result, we found out the energy intensity of passenger cars is the largest factor for energy consumption. Therefore, it is effective to reduce the energy intensity of passenger cars. Recently, more and more people buy cars for their own use and there is a surge of ownership of cars. From the view point of energy saving in the long run, it is suggested that car owners should use environmental cars. Environmental cars are consuming less energy than conventional cars with the reduced energy intensity, or can run on new type energy. The policy the government should emphasize is the one to encourage the use of environmental cars. The Japanese government is giving allowance for the purchase of environmental car right at the moment it is necessary to promote environmental cars' market share. Besides, the government restricts the sales of the cars with less fuel efficiency by

means of administrative force. Furthermore, in some of the environmental model cities set up by the government, environmental public vehicles are running instead of the conventional ones.

Secondly, the effect of the transportation mode share always brought positive influence during the periods analyzed. It is the very factor which should be regulated. It seems that the structure of the transport sector is becoming more and more unreasonable from the viewpoint of reducing energy consumption. Examining the data of the transportation mode share in recent years, we found that the breakdown of the turnover by cars went higher and higher, consuming more energy per transportation amount unit than the other transportation means. In order to reduce energy consumption, there is no doubt policies should encourage other transportation means than cars, such as railway, bicycle and others which consume less energy. Japan has built extensive railway and subway systems in major cities, supplying punctual, inexpensive and comfortable services to the citizens for travelling, but as to the long distance trip across the country, especially the trip for which the Shinkansen is not available, people are tend to use cars or high-speed bus because they are more convenient. It is recommended for JR companies to offer new train service plans for long journey across the nation based on the conventional railway lines. With the advantage of cheap price, punctuality and reliability, this new rail way service will attract many passengers who would otherwise travel by their own cars or high-speed bus. Besides, the Shinkansen or other railway lines can be further developed for freight transportation, which can release the high energy intensity trucks carrying cargos from their work. Still more, the encouragement on riding bicycles and walking is also important. The policy could focus on creating bicycle parking lots, the bicycle lanes and rental-bicycle centers. Meantime, the government should try to advocate the healthy life style by riding bicycles or walking via Medias.

With the rapid construction of the transportation facilities and the growth of communications among people around the country, the turnovers of both the passenger and freight transportation will keep growing into the future and be of great importance to the financial benefit of the country. Besides, GDP has the biggest impact on the energy consumption in the freight transportation sector. It is found that the amount of GDP and the freight turnovers are in direct proportion with each other. That is to say, GDP is the dominant factor which affects freight turnovers deeply. As for the energy consumption, it may be no exaggeration to say that GDP is also the dominant factor in energy consumption on basis of the decomposition result. By the way, the GDP in Japan had grown rapidly in the past and has been stable in recent years, and is estimated to stay so in the near future. It is apparently unwise to restrict the development of the GDP growth or travel demand just for the purpose of controlling the energy consumption in the transport sector. The policy implication for the government is to pay much attention to the sustainable development of economy with proper energy consumption.

Finally, the result shows that the effect of travel distance is decreasing although the travel demand is very large. Perhaps it is because in many cases the travel purpose can be easily satisfied in the short distance for the travelers all over the country. It is suggested that the government encourage people to work at home or a place nearby, and build convenient centers around the residential areas to satisfy the residents' needs. It is already taken into consideration in city planning for the future. Besides, there is an indirect way to develop and widely apply the technology of logistics to the freight transportation, in order to reduce the empty miles by trucks and the travel distance at the same time.

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