INDEX DECOMPOSITION ANALYSIS ON CARBORN DIOXIDE EMISSION OF PASSENGER CARS IN JAPAN

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Abstract: This paper mainly analysis the change by the Logarithmic mean Divisia index method on the emission of carbon dioxide deduced by passenger cars in Japan. Decomposition analysis is a method that analyzes the effects lead to the change of the emission of carbon dioxide. Based on this method, the analysis of the emission of passenger cars in recent years is done to explain the changes. It is found that the car number in advanced regions in Japan rises successfully every year and affects the carbon dioxide emission crucially and steadily. Population is another effect that brought in great emission at the time which in high speed of economic growth, yet the travel distance by passenger cars is decreased and does negative effect to the emission. Based on the result of this analysis, corresponding strategy such as restricting the use of cars and promoting public transportation is proposed.
Key words: *index decomposition, carbon dioxide emission, passenger cars*

1 Introduction

The environment problem of the earth is drawing more and more attentions from all over the world. Among the problems being concerned, the greenhouse effect is becoming extremely significant which exceeds the normal extent fits the earth. Carbon dioxide is considered to be one of the main greenhouse gases deteriorate the result of the greenhouse effect. Due to the rapid development of the economics, the emission of carbon dioxide grew up steadily over the last few decades, which is considered to be the crucial factor of greenhouse effect. It has already reached an agreement that the emission of carbon dioxide should not increase so fast and has to be controlled tightly as soon as possible by most of the governments. Therefore, we have to analysis the factors that lead to the emission. On this respect, the factors which underlying the carbon dioxide emission should be analyzed to find out the principal reason leads to the emission. Transportation sector is one of the main emission sources of carbon dioxide, which shares about 20% of the total emission in the recent years of the world. Among all kinds of transportation means of passengers, road transport contributes most in total emission. For this reason, it is urgent to analyze the ratio each factor accounts of carbon dioxide emitted by road transport especially by cars.

There are many factors that lead to the variation of the emission; therefore, it is important to tell the influences by all the factors apart in order to draw up low carbon policies on road transportations. Japan has signed the Kyoto Protocol to commit the deduction of carbon dioxide at the beginning and done a lot of effort to fulfill the task. Now the 191 states which have signed and ratified the protocol are in great need of experiences and advices to fulfill the deduction. This paper mainly chooses some common factors which are both reasonable and available to underlie carbon dioxide emitted by cars in the main emission prefectures in Japan by means of index decomposition analysis.

2 Methodology

This paper uses the index decomposition methodology to analyze the influences each factor causes. It is a method which is used to study the impact of changes in product mix on industrial energy demand at the beginning and now it is widely used not only in industrial fields but also in the environmental fields in general. It is first developed right after world oil crises in the 1970s and has continued to be studied and developed until today with more and more achievements every year (Ang,B.W. *et al.* 2000).

Generally speaking, the most popular decomposition methods among analysts can be divided into two groups: methods linked to the Laspeyres index and methods linked to the Divisia index. The Laspeyres index measures the percentage change in some aspect of a group while using weights based on values in some base year. On the other hand, the Divisia index is weighted sum of logarithmic growth rates, where the weights are the components' shares in total value, given in the form of a line integral (Ang,B.W. 2004) . The raw method without any improvement always leaves some factors unexplained so it is probable that the decomposition result cannot explain the reasons so well. Subsequently, it is seldom used to do practical analysis and the perfect decomposition method is found out to give perfect decomposition result with the name of Refined Laspeyres index method and Logarithmic mean Divisia index method (Ang,B.W. *et al.* 2003).

Moreover, the results of the decomposition can be performed in two ways: the multiplicative decomposition and the additive decomposition. In multiplicative decomposition, the change in an aggregate given as a ratio is composed, while in the additive decomposition, the change in an aggregate is decomposed in absolute changes (Ang,B.W. 2004). Although the expressions of the two methods seem to be different, the basic means are almost the same. The only difference is that the addictive decomposition can calculate the ratio of each factor occupied of the gross.

In this paper, we choose the Logarithmic mean Divisia index method with the additive decomposition result, so it is easier to see the ratio each factor accounts for. One more advantage of this method is that there is no need to get the precise value of the emission of carbon dioxide, which is hard to speculate, for it can also give out perfect decomposition result by ratios on each factor, and the decomposition result is enough for the knowledge on the importance of all the factors.

According to the Logarithmic mean Divisia index method (Ang,B.W. *et al.* 2003), 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. 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

$$V^0 = x_1^0 x_2^0 x_3^0,\ V^T = x_1^T x_2^T x_3^T,$$

Here is the decomposition result by the means of the refined Laspeyres index method.

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

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

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

Here $L(V^T, V^0) = \frac{V^T - V^0}{\ln V^T - \ln V^0}$, is the mean weight function defined as the logarithmic average of two positive numbers. So it is easy to calculate the effect each factor brings in between the year 0 and the year T.

3 Data and Result

In this paper, we choose basic regions in Japan as objects for the analysis. Nowadays there are 47 prefectures in Japan altogether, but the economic development of the prefectures is totally different. For this reason, the traffic and its emission varies very much from an advanced prefecture to a less developed prefecture. Apparently, the traffic in advanced prefectures affects the carbon dioxide emissions much more than others; therefore, we pick the advanced prefectures up to do the analysis.

According to The Statistics Data of Transportation (2009), there are six prefectures that play a crucial role on the number of cars, fuel consumptions, traffic demands and distance in Japan. In that case, we choose these six prefectures as case study for the analysis: Tokyo, Kanagawa, Osaka, Aichi, Hyogo, and Fukuoka. These prefectures are the most advanced places lie across Japan from east to west so the result of the analysis can also represent the carbon dioxide emission of transportation situation that the different regions in Japan face.

Considering both the significance of the factors as well as the availability and responsibility of the data, the factors are elected as follows:

$$C=E*N*P*T$$

Here C is the total carbon dioxide emission by cars; E is the fuel emission intensity of cars which means the unit of the emission value per kilometer; N is the average number of cars one person owns; P is the population of the region; T is the average travel distance by each car. Therefore, from year 0 to year T, the change of C can be decomposed into the influence of each factor's change as follows:

The car number effect $C_{\mathbf{N}}$, which reflects the effect that the change of the number of cars owned in each prefecture brings in.

The population effect $C_{\mathbf{P}}$, which reflects the effect that the change of the population in each prefecture brings in.

The travel distance effect $C_{\mathbf{T}}$, which reflects the effect that the change of the travel distance by each car in each prefecture brings in.

Besides, the changes of fuel emission intensity also affect the result of the decomposition, but the change is too tiny in these years and what's more, it shows little prefecture characteristic. For this reason, we do not take this factor into consideration and divide its influences averagely into the other factors on average.

The value of the emission of carbon dioxide by cars is provided by fuel emission intensity, average car possession, population and average travel distance multiplying together. Therefore, the changes of the carbon dioxide emission in passenger transportation are decomposed into the factors stated above:

$$C= C_{\mathbf{N}} +C_{\mathbf{P}} +C_{\mathbf{T}}$$

The data of the populations, car numbers, and travel distance of cars are all available in every recent year, and we found that all the data goes smoothly without obvious abrupt. So it is reliable to pick up any data from the database to do the analysis without worrying about the existence of irregular data. In this case, we choose the year 1995 for the year 0 and the year 2005 for the year T with a ten-year interval to find out which factor is principal during this period. The calculation result is shown as in Table. 1.

Table 1. Decomposition result of carbon dioxide emissions by passenger cars in advanced prefectures in Japan from 1995 to 2005

	Tokyo	Kanagawa	Osaka	Aichi	Hyogo	Fukuoka
Effect of average car possession	-10.8%	-170.1%	377.3%	-135.2%	361.3%	186.7%
Effect of population	-47.2%	-101.0%	96.2%	-1.8%	54.7%	16.6%
Effect of average travel distance of each car	158.0%	371.1%	-373.5%	237.0%	-315.9%	-103.3%

It is found that in the year 2005, the emission value by cars of Tokyo, Kanagawa and Aichi is less than that in the year 1995 and we cast a shadow on the table to show the difference. It is considered that the low-carbon measures work very well in these prefectures. On the other hand, in the other three prefectures, the emission value increased a little during this period. In this analysis, the negative sign in the table above means the effect does opposite effect to the result while the positive figures express that it promote the increasing of the value.

4 Conclusions

From the result of the analysis, we could find that the effect of average car possession contributes to the emission significantly at almost all the regions. Tokyo is an exception because the density of railway is so high and it is very convenient and punctual that travel by car is not a wise choice. In other regions, people are tending to buy cars with the development of the society or the increase of income. On the contrary, the effect of average travel distance of each car does negative effect to contribute the emission. It can be considered as the consummation of the urbanization of the advanced prefectures, people can enjoy their life near around. The effect of population is almost the slightest factor that affects the emission, with the further development of the urbanization, more and more people will move into these regions. It seems there is no need to restrict the migration as long as not to exceed the capacity of the concentrated areas, for the migration also brings in labor and consuming.

It is also can be inferred that the neighbor cities show great transportation character on passenger cars. Tokyo and Kanagawa are the member of the Capital city circle so their decomposition result seem alike, similarly, Osaka as well as Hyogo is in the Kinki city circle, and their decomposition results are close, too. At present, the Japanese Railway and privately-owned railway are connecting everywhere in the city circles conveniently. Therefore, attentions should be paid on that prefectures in the same city area are ought to be considered together on transportation policy making.

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