Journal of Global Environment Engineering, Vol. 1, pp. 59–78, 1995

COMPARISON OF CARBON DIOXIDE EMISSION PATTERNS DUE TO CONSUMERS' EXPENDITURE IN UK AND JAPAN

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Abstract

Input-Output analysis was applied to clarify carbon dioxide emission patterns due to consumers' expenditure in UK and Japan for the year 1990. Here, the direct and indirect emission were calculated for each commodity and service of the expenditure, as well as for each sector of final demand and import. The results reveal that: almost all industrial sectors in UK show much higher indirect intensities; consumers' expenditure is the main contributor to the inducement in UK and Japan and export in UK and Gross Domestic Fixed Capital Formation (GDFCF) in Japan are second; in consumers' expenditure, food's and recreation's intensity are higher in Japan and fuel's is higher in UK and car's and public transport's are similar in UK and Japan; in GDFCF, Japan's emission per household in dwelling construction is double to UK's. The results also indicate that emission patterns are reflected by differences in the maturity of post industrialization in modern age in UK and Japan.

KEYWORDS: *International Comparison, Carbon Dioxide, Consumers' Expenditure, Input-Output Analysis*

1. Introduction

1.1 Objective

As indicated by the publication of "The Green Consumer Guide" in 1988, recent consumers' concern for environmentally sound actions has been growing in the world.

This guide book has provided us with ways that are environmentally sound and has encouraged people to select them, such as purchasing food and other products that are environmentally good, and has also played a role as a symbol for such actions.

In parallel to the above, another distinctive way of life innovation to evaluate environmentally sound actions has been attempted. Whereas the former way pays attention to rather direct and separative environmental effects, the latter focusses on indirect and repercussive effects represented as Embodied Environmental Load (EEL).

EEL is an analogical concept to the embodied energy in energy analysis, and has similarity with the concept of Life Cycle Assessment. For example, we consume goods and services to

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live, and this causes various environmental effects. However, we do not bring about environmental effects by only direct consumption of goods and services, but also through indirect effects associated with their imports, production, delivery, disposal, etc.. This embodied environmental load related to the entire life cycle of goods and services should be attributed to our consumption. As mentioned above, EEL consists of indirect and invisible environmental loads, induced through various and ultimate repercussions derived from our consumption of goods and services.

Input-Output (I-O) analysis can clarify economical repercussions from production to consumption, and is therefore efficient for evaluating EEL. Until now, there has been a lot of studies regarding EEL using I-O analysis.

In this paper, we attempt to compare UK with Japan in EEL due to consumers' expenditure using I-O analysis. Although UK and Japan have similarities with each other in the quality of life, they have differences in the socio-economical structure associated with the maturity of post-industrialization in modern age. Moreover, each history and culture determine consumers' preference in their way of living. Therefore, by comparison, we also attempt to grasp the implication for emission patterns with respect to these points.

In addition, "Environmental Karte" and "Environmental Bookkeeping" have been improved over the last ten years in Japan (Morioka, 1986). These are educational and enlightening support systems and enables us to be aware of various direct and indirect environmental effects. In practice, these are both implemented in the initiatives of local governments and consumers' associations in order to encourage and support polishing up individual actions towards societally accepted or recognized actions for environmentally sound integration of societal systems (Morioka, 1994). EEL, as a concept, has already been included in these systems since their beginning, while these systems are now expected to provide sufficient quantitative information regarding EEL for their implementation. In the above sense, the results of this analysis would also give relevant information to these support systems in evaluating consumers' behavior.

1.2 Perspectives, Targets, and Scope

(1) Perspectives

In addition to the variety of the kinds of EEL employed, EEL also shows its variety of objects and/or places to impute, in other words, where we shift EEL. It varies from the neighborhood to other regions, overseas, or moreover to the next generation. In this paper, we will evaluate carbon dioxide emissions due to consumers' expenditure. Carbon dioxide emission is suitable for this analysis as a comprehensive index, because carbon dioxide has close relations to EEL due to energy consumption, and the domestic sector is now considered to contribute extensively to carbon dioxide emission. In addition, we indicate features of EEL and its implication for consumers' expenditure in the following perspectives:

Ultimate Inducement due to Final Demand
Emission due to Consumers' Expenditure
Reflection of Consumer's Expenditure in Investment

(2) Targets

Our main attention will be paid to the following comparison targets for each perspective:

Ultimate Inducement due to Final Demand

- Direct and Indirect Intensity of Each Industrial Sector
- Share and Intensity of Carbon Dioxide Inducement

- Implication for the Industrial Structure

Emission due to Consumers' Expenditure

- Direct and Indirect Emission due to Consumers' Expenditure
- Inducement of Import due to Consumers' Expenditure

Reflection of Consumer's Expenditure in Investment

- Emission due to Each Fixed Capital
- Societal Structure from Division of Stock and Flow

(3) Scope

The scope of this analysis is shown in Fig. 1. Circles with bold lines indicate the inducement of carbon dioxide emission due to the consumer. A series of these circles takes the form of a life cycle in the figure. Our research is confined to the field upstream of this life cycle, excluding waste disposal. Moreover, it is difficult to quantify carbon dioxide emission induced by import, because direct and indirect coefficients associated with each exporter are needed. Therefore, we observe the monetary amount of inducement due to final demand instead of evaluating carbon dioxide emission.

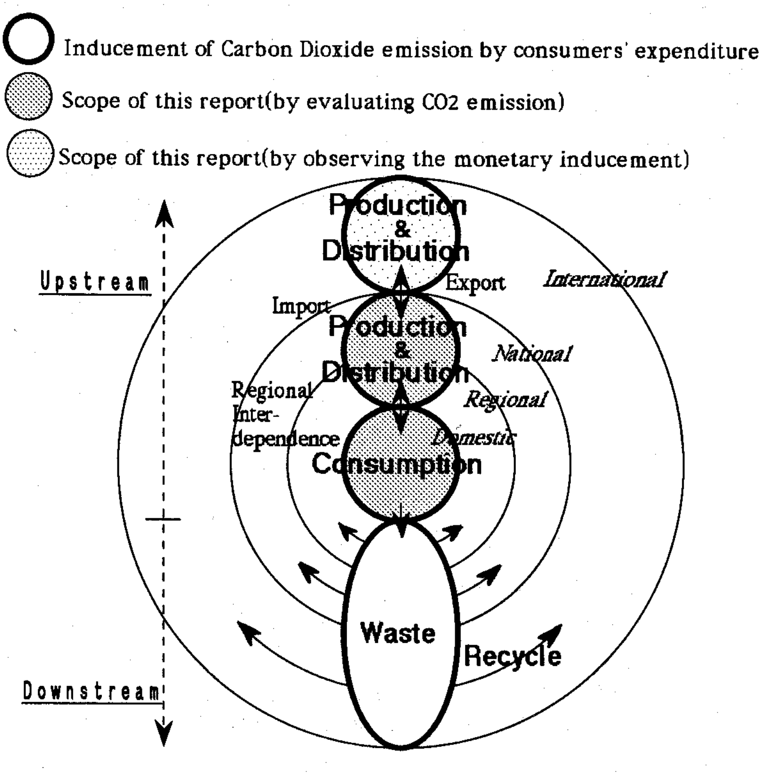


Figure 1. Scope of The Analysis

2. Methodology

2.1 Embodied Energy and Input-Output Analysis

(1) Embodied Energy

"When we consume something, we consume energy" is the basic idea of embodied energy. This idea is the basis of energy analysis, and strictly means that primary energy extracted from the earth is processed by the economy, and ultimately gravitates to the final demand (Thomas, 1977), i.e., consumers' and government consumption and export (See Fig. 2).

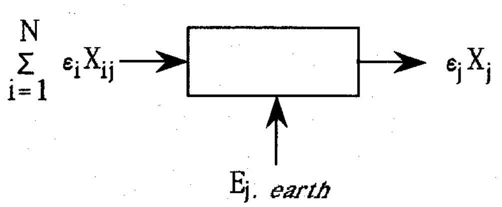
Applying this idea to carbon dioxide emission, we can also explain that it is caused by consumption of indirect or embodied energy. For example, we consume fuels such as coal, gas, etc., and also electricity for heating and power. Fuel consumption causes direct release of carbon dioxide associated with direct energy use. On the other hand, electricity causes no direct release of carbon dioxide, but induces indirect release in its generation associated with fossil fuel consumption. Therefore, the indirect and induced carbon dioxide emission should be added to the direct emission in evaluating the emission due to final consumption.

Associated with the idea of life cycle or "from cradle to grave", the concept of embodied energy should be extended to waste disposal. However, this is outside the scope of this analysis as shown in Fig. 1.

(2) Application of Input-Output (I-O) Analysis

Provided that the amount of fossil fuel consumption is in proportion to the amount of domestic gross output of products, it enables us to quantify direct and indirect carbon dioxide emission due to consumers' expenditure, using the relationship between final demand and domestic gross output in I-O tables.

I-O tables provide a picture of the economy for a specific time period, originally devised by Wasilly Leontief in 1930s. They display the flow of all goods and services in the economy, illustrating the relationship between producers and consumers and the interdependence among the different industries. This is achieved by displaying the transactions of the economy in matrix form.



X_{ij} is the transaction from sector i to sector j
X_j is the total output of sector j
ε_j is the embodied energy intensity per unit of X_j
$E_{j.\ earth}$ is the energy extracted from the earth by sector j excluding electricity. Consumption of electricity is treated as the transaction from electricity sector to sector j.

Figure 2. Model of Energy Balance (Thomas, 1977)

Ultimate Inducement due to Final Demand (Including Consumers' Expenditure) In I-O analysis, it is assumed that the domestic output is all induced by the final demand, such as consumption, investment and export. Assuming that imports are proportional to domestic demand (but not total output), the balancing equation gives:

$$X = [I - (I - \bar{M})A]^{-1}[(I - \bar{M})Y + E] \tag{1}$$

where X is a vector of the values of domestic production; A is a matrix of input coefficients; $\bar{M}$ is a vector of the values of import; Y is a vector of the values of domestic final demand; E is a vector of the values of export; and I is a unit matrix.

Substituting a vector of consumers' expenditure into the above equation gives a vector of induced domestic output. Moreover, the induced domestic output multiplied by a vector of carbon dioxide emission intensity per unit of domestic output, gives the amount of induced carbon dioxide emission. As mentioned above, this equation enables us to estimate the carbon dioxide emission, both directly or indirectly, due to each final demand.

Inducement of Import due to Consumers' Expenditure Also in I-O analysis, imports are assumed to be derivatively induced by final demand. By using the above inverse matrix:

$$B = [I - (I - \bar{M})A]^{-1}$$

induced imports are calculated as follows:

$$[\bar{M}AB(I - \bar{M}) + \bar{M}]Y : \text{ induced by domestic final demand} \tag{2}$$

$$\bar{M}ABE : \text{ induced by export} \tag{3}$$

This research is not conducted to calculate carbon dioxide emission associated with imports. To perform such an analysis, further data, for example, the emission coefficient induced to the supply-side both directly and indirectly, would be needed. Instead of this, we observed the share of the monetary inducement due to each final demand.

Reflection of Consumers' Expenditure in Investment Here, investment means gross domestic fixed capital formation, defined as acquisitions, less disposals, of new or existing tangible fixed assets subdivided by type of asset into:

1) Dwellings
2) Other buildings and structures
3) Machinery and equipment
4) Cultivated assets – trees and livestock –

Although the I-O table itself is a statistic of flows, we can grasp the above as a cross section of stock. Here we will pay attention to the first three assets. These have close relations to consumers and characters of autonomous investment; in 1) obviously as a public investment, and in 2) and 3), these are inputted to markets in order to catch consumers' preference. Therefore, carbon dioxide emission induced by the above investment would indicate consumers' derivative contribution.

2.2 Methodology of The Analysis

Here, carbon dioxide emission patterns due to consumers' expenditure were estimated using UK and Japan I-O balances both for 1990 (UK Central Statistical Office, 1993; Japan Management and Coordination Agency, 1994) and OECD energy statistics for 1990 (OECD, 1993). The flow of this analysis is shown in Fig. 3. The contents of each process are as follows.

(1) Aggregation of Sector Classification

For direct comparison of I-O balance in UK and Japan and for application of OECD energy statistics, the 123 sector classification of the UK I-O balance was aggregated to the 32 classification of the Japan I-O balance. This aggregation was also applied to the table of consumers' expenditure and GDFCF. Aggregating I-O sector classification changes the pattern of output in intermediate and final demand. This affects the inverse matrix and causes some errors. In the case of Japan I-O table for 1990, it was clarified that the aggregated table of 29 sector gives a maximum error of 25 % in comparison with that of 408 sector(Kondo *et al*, 1994). Moreover, a sector of this aggregated table gives the same emission coefficient for each unaggregated sector that consists of the sector. Therefore, the analysis using aggregated tables is available for evaluating the profile of the emission patterns, whereas less aggregated tables are preferable for further improved analysis.

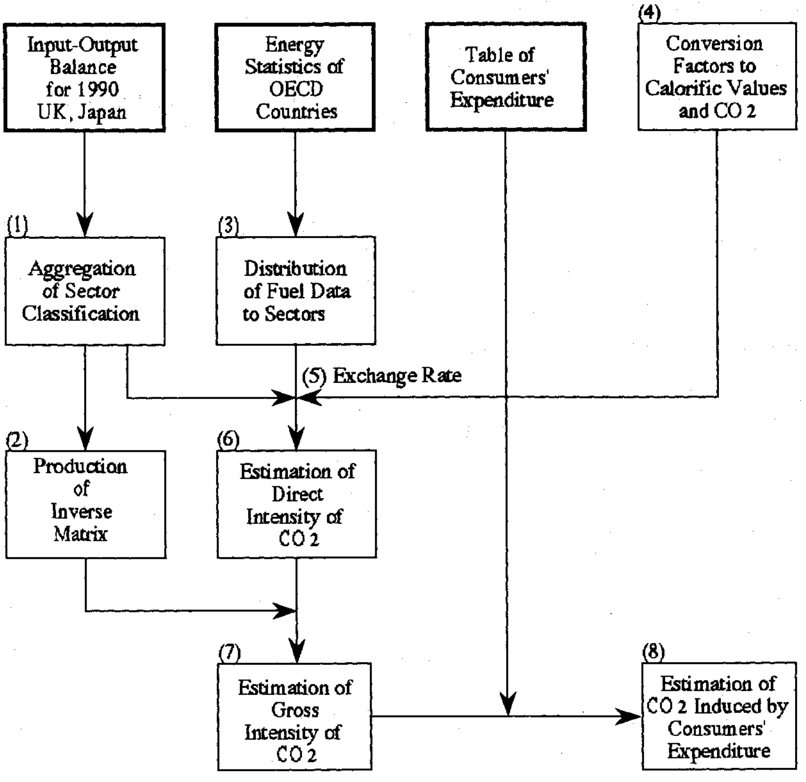


Figure 3. Flow of The Analysis

(2) Inverse Matrix

As mentioned above, the inverse matrix, where import is in proportion to domestic demand, was applied for the model. In order to avoid calculating exceeded repercussion derived from trading margins, especially included in consumers' expenditure, the I-O table is expected to be of producers' price. As the UK balance is made at purchasers' price, we converted it in the table at producers' price using ratios of trading margins for each intermediate input sectors in the UK I-O table of "Supply of products", provided that each intermediate sectors' ratio of trading margin is fixed for each demand sector. This assumption was also applied for the table of consumers' expenditure and Gross Domestic Fixed Capital Formation (GDFCF).

(3) Distribution of Fuel Consumption To Sectors

OECD energy statistics was used for obtaining primary fuel consumption in each sector (OECD, 1993). In this statistics, data are given by each unit peculiar to various kinds of fuel and for each sector, for example, tons, joule, and so on. The major adjustments are as follows:

- Deduction of Oven & Gas Coke transferred to Coke Ovens & Blast Furnaces Gas from total Cokes.
- Deduction of feedstocks from total consumption in Chemical and Petrochemical sector.
- Extraction of private sectors' petrol and oil consumption from total consumption in Transport sector.
- Estimation of lime stone consumption.

(4) Conversion Factors to Calorific Values and Carbon Dioxide Emission Coefficients

Country-specific conversion factors to calorific values were obtained from OECD energy balances (OECD, 1993). TOE-based carbon dioxide emission coefficients were obtained from the data of the Royal Institute for Internatinal Affairs in UK (RIIA, 1988) and of Japan Environment Agency (JEA, 1992) in Japan. The lime stone-derived emission was assumed to be the same as 0.12tC per lime stone ton (Moriguchi *et al*, 1992).

(5) Exchange Rates by Using Purchasing Power Parities(PPP)

The value of GDP based PPP (OECD,1990) was applied for exchange rates: ¥ 323.92 per £. The higher price of services in Japan raises PPP in Japan. Therefore, strictly speaking, intermediate or industrial sectors' input exchanged by PPP in Japan is likely to be overestimated in comparison with final demand.

(6) Estimation of Direct Carbon Dioxide Emission Intensity

The direct emission intensities of carbon dioxide were given by the data on fuel consumption of (3) divided by Gross Domestic Output of (1) for each intermediate input sectors.

(7) Estimation of Gross Carbon Dioxide Emission Intensity

The gross emission intensities of carbon dioxide emission were given by the direct intensity of (6) multiplied by the inverse matrix of (1) (See Section 2.1).

(8) Estimation of Carbon Dioxide Emission Induced by Consumers' Expenditure

Carbon dioxide emission induced by consumers' expenditure was estimated by the values of the table of consumers' expenditure multiplied by the gross emission intensities of (7).

3. Carbon Dioxide Emission Patterns due to Consumers' Expenditure

3.1 Ultimate Inducement due to Final Demand

(1) Direct and Indirect Carbon Dioxide Emission Intensities of Each Industrial Sector

Fig. 4 shows how much carbon dioxide emission is induced per Million ¥, i. e., so-called emission intensity, of total output and of final demand directly and indirectly.

Direct Intensity Although it should be noticed that both intensity patterns are overall similar, there are several differences in the details :

a. UK Sector of higher intensities than Japan

- Mining
  Coal mining and extraction of crude oil and natural gas accounts for 97 % in UK, whereas quarring and gravel extraction accounts for 78 % in Japan (both based on Gross Domestic Output). This mainly causes the differences of energy consumption in extracting.
- Iron and Steel
  Energy consumption per ton of crude steel production, estimated by International Iron and Steel Institute, shows that: based on the 1973 value as 100 in Japan, 88 is the 1982 value in Japan; while in UK 139 is the 1973 value and 123 in 1982 (IISI, 1982). It is obvious that Japan has implemented energy–saving measures thoroughly in the iron and steel production since the 1970s.
- Transport
  Energy consumption in the transport sector per Gross Domestic Products is 0.603 toe per Million ¥ in UK, and 0.285 toe per Million ¥ in Japan (Energy balance of OECD Countries, 1990). This also shows that Japan is tackling energy efficiency. In addition, the energy consumption ratio in the transport sector is considered to vary inversely by nation-wide density in terms of distance from the center of nation-wide populational gravity to each city. As indicated in Fig. 5 (Matsuoka *et al*, 1992), the lower density in UK seems to make carbon dioxide emission in the transport sector per capita higher than Japan.

b. Japanese Sectors of higher intensities than UK

- Agriculture, Forestry, and Fishery
  As indicated by the share of forests, 3 % in UK and 67 % in Japan, the agricultural land use is widely different in UK and Japan.
  Whereas plain and wider farmlands are available in UK, and therefore the agriculture is noted for a high level of efficiency and productivity of wheat and potatoes in crops and dairying or beef cattle and sheep in livestock, agriculture in Japan is known as intensive cultivation of small farmlands for rice and vegetables. Such differences of intensity in agriculture would influence the emission intensity values.
- Ceramic, Stone, and Clay products
  Although differences in the use of fuels, mainly natural gas in UK and coal in Japan, would be one of the reasons, it is difficult for this to cause the Japanese less energy efficiency.

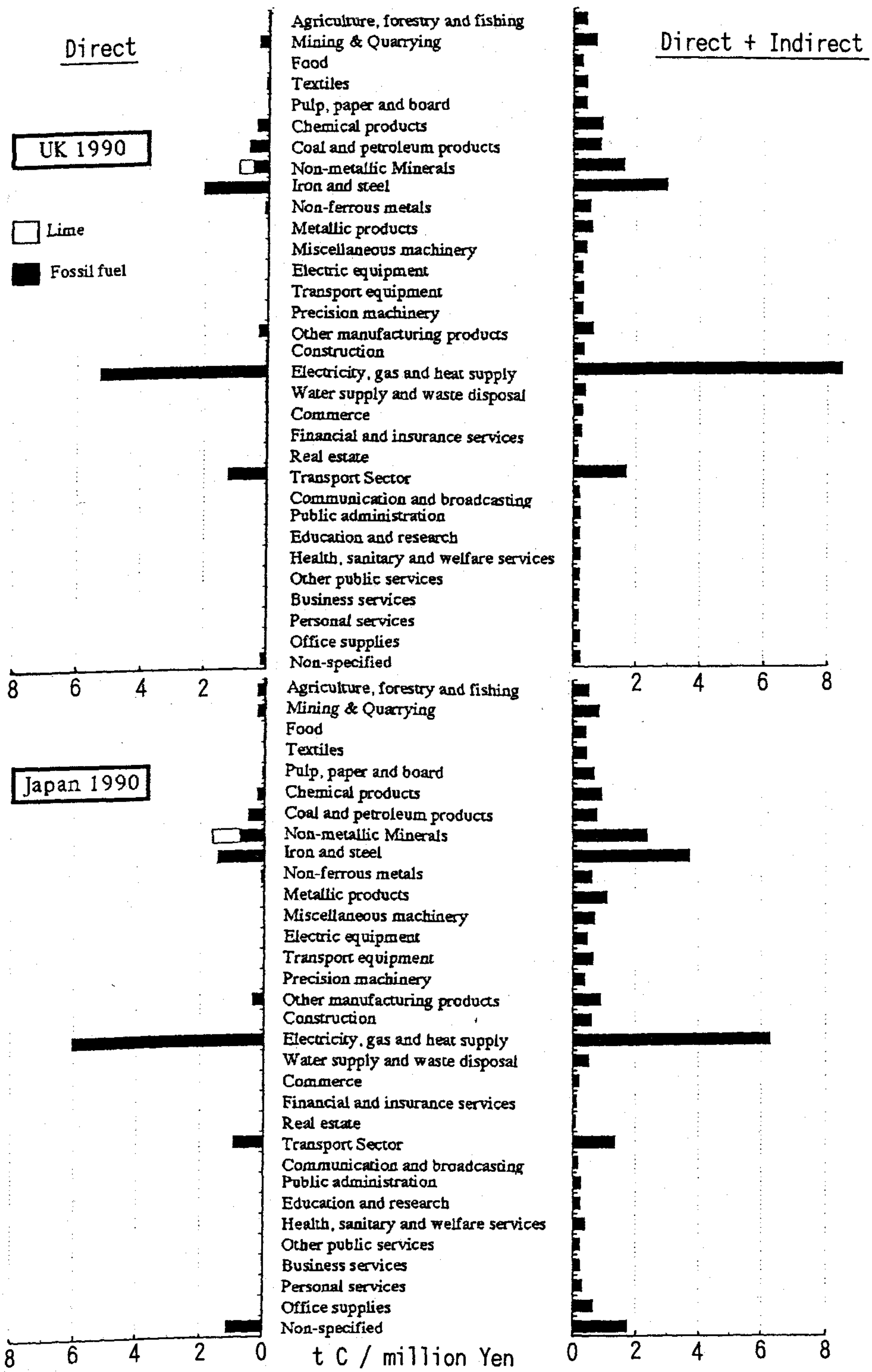


Figure 4. Direct and Indirect CO_2 Emission Intensities of Industrial Sectors

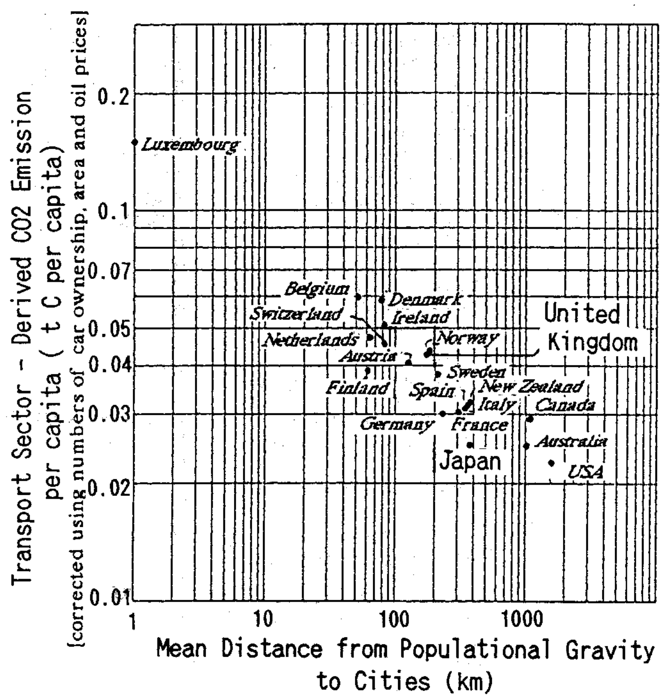


Figure 5. Degree of Nation-wide Density and CO_2 Emission (Matsuoka *et al*, 1992)

Gross Intensity (including direct and indirect intensity) Japan is higher than UK in the degree of differences between direct and indirect intensities. This profile shows that Japan is also higher in proportion of intermediate input to total input and that of goods (compared with services) to intermediate input.

In proportion of the indirect intensity to the gross intensity, the electricity sector shows higher inducement in UK than in Japan. This gives much influence of the contribution to inducement by electricity sector over each final demand sectors. The above inducement is caused by privatisation of the electricity generation industry and the following increase in internal transaction. When the state owned companies was privatised, separate companies were created for the generation and for the distribution of electricity. Accordingly, in UK I-O table for 1990, the much higher figure of the transaction from electricity (generator) to electricity (distributor), are included. In addition, input both in generation and in transaction to distributor are aggregated in the I-O table of this analysis. This makes the indirect intensity higher in the electricity sector in UK.

(2) Direct and Indirect Inducement of Carbon Dioxide Emission due to Final Demand

Fig. 6 and Fig. 7 show how much contribution the final demand sectors give, which input sectors are induced by them, and which output sectors emit carbon dioxide consequently.

Share of the Emission by Each Sector First, Fig. 6 and Fig. 7 show that the highest share, 64% in UK and 47% in Japan, of inducement is caused by consumers' expenditure of all final demand. Second, Consumers' Expenditure, General Government Final Consumption

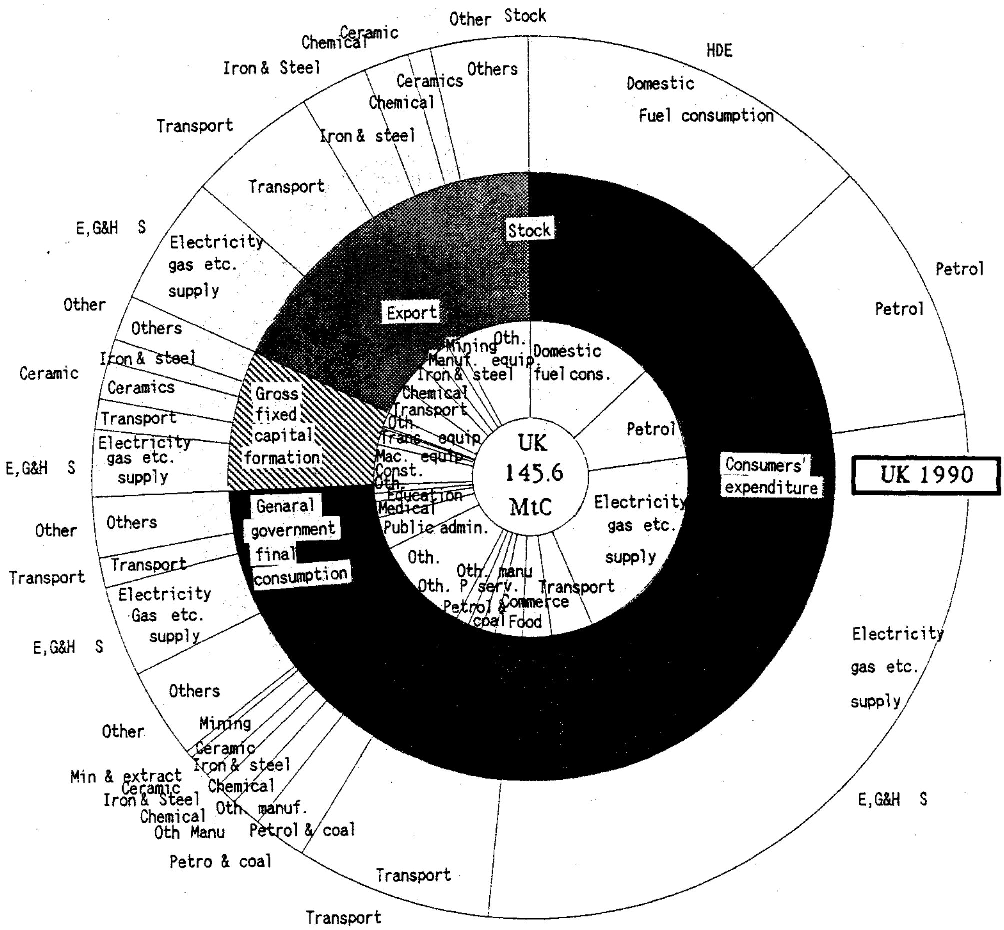


Figure 6. CO_2 Emission Patterns due to Final Demand in UK

(GGFC), and Export give relatively greater contribution in UK than in Japan. Instead in Japan, Gross Domestic Fixed Capital Formation (GDFCF) gives greater contribution. These profiles make us look back on the evolution of the population and economic growth up date in UK and Japan (See Fig. 8, Fig. 9).

In Japan, a population explosion had taken place from the end of the 19th century to 1970s, and since then the rate of the population growth has considerably decreased. The birthrate began to fall in the 1930s. In UK the population explosion started as early as at the end of the 18th century, almost a century earlier than in Japan. High birthrate continued till 1800s, then it slowly fell and since 1870s it has fallen.

Moreover, in Fig. 9 the year 1880 has the highest intensity in UK, which is also the year when UK had the largest share of 41% in coal production in the world. On the other hand, 1970 is the year of the highest intensity in Japan.

Thus, UK and Japan display half a century of time difference in population and economic growth. This indicates the difference in how the maturity of the post industrialization was approached in modern age, and the movement to an aging society in UK and Japan.

Going back to Fig. 6 and Fig. 7, the first and second features in these two figures, mentioned

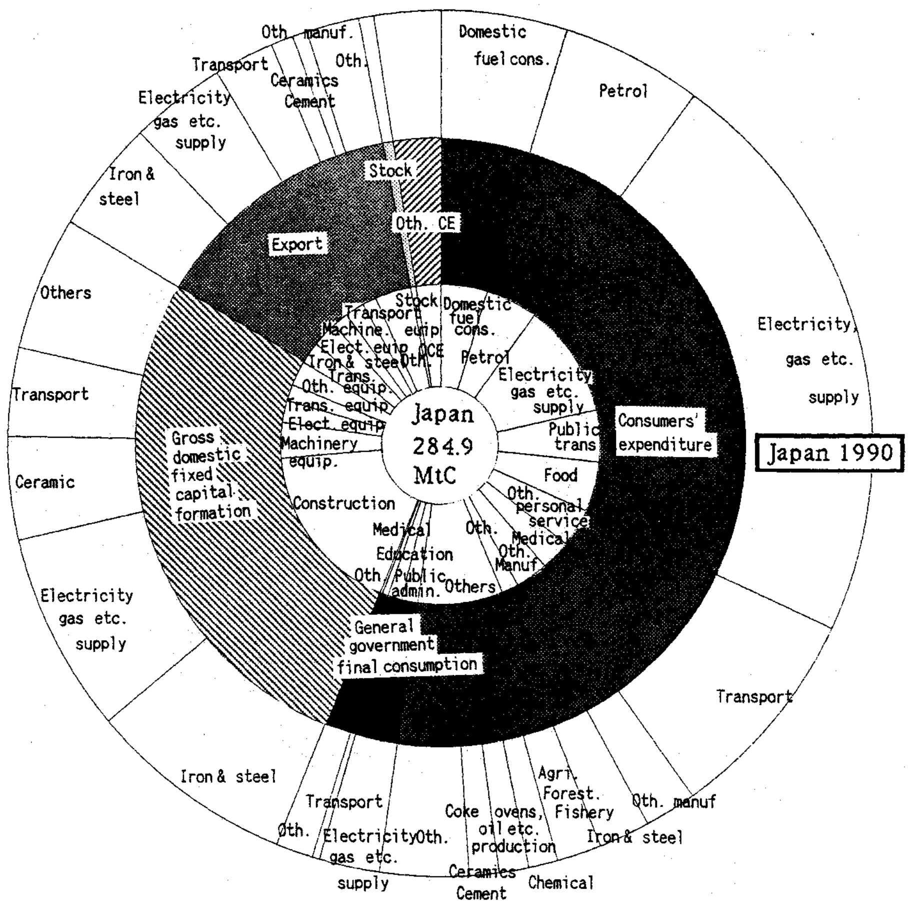


Figure 7. CO_2 Emission Patterns due to Final Demand in Japan

in the beginning, are also reflected by the above profiles, such as the movement to an aging society in UK make GGFC larger; UK, where social capitals are sufficiently provided, needs less expenditure to GDFCF; and goods and services from more service sectors are inputted to demand of export in UK.

Emission Intensities due to Each Final Demand Sector Emission intensities due to each final demand sector are shown in Fig. 10. Consumers' expenditure's intensity is higher in UK than in Japan. This is derived from high fuel and electricity consumption in UK. Export and GDFCF are reversely higher in Japan. These are brought about by differences in induced industrial sectors. In the case of Export, carbon dioxide is induced through transport and chemical industries, and is directly emitted by the electricity and gas and the transport sectors in UK, whereas in Japan carbon dioxide is induced through transport equipment and iron & steel sectors, and emitted by iron & steel and electricity and gas. In the case of GDFCF, although the construction sector is the major inducer both in UK and Japan, direct emission is conducted by transport in UK but by iron & steel in Japan, as well as

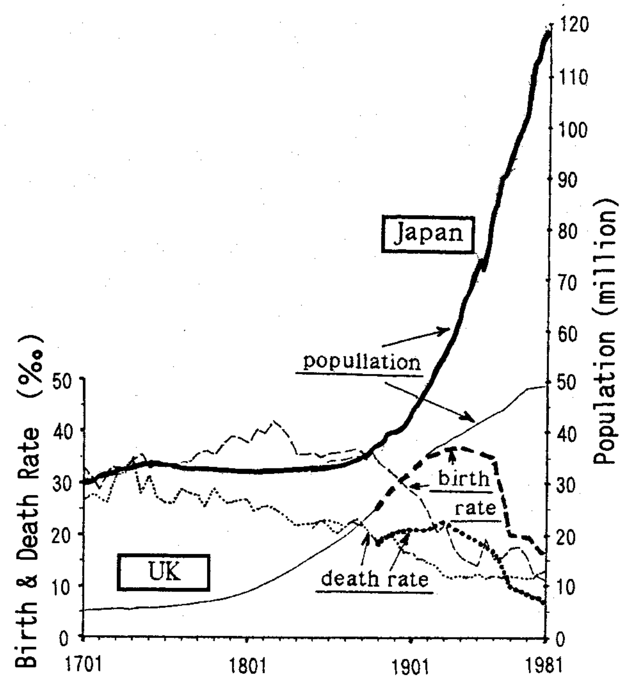


Figure 8. Population growth in UK and Japan, 1700-1980 (Ando and Yamaga, 1994 etc.)

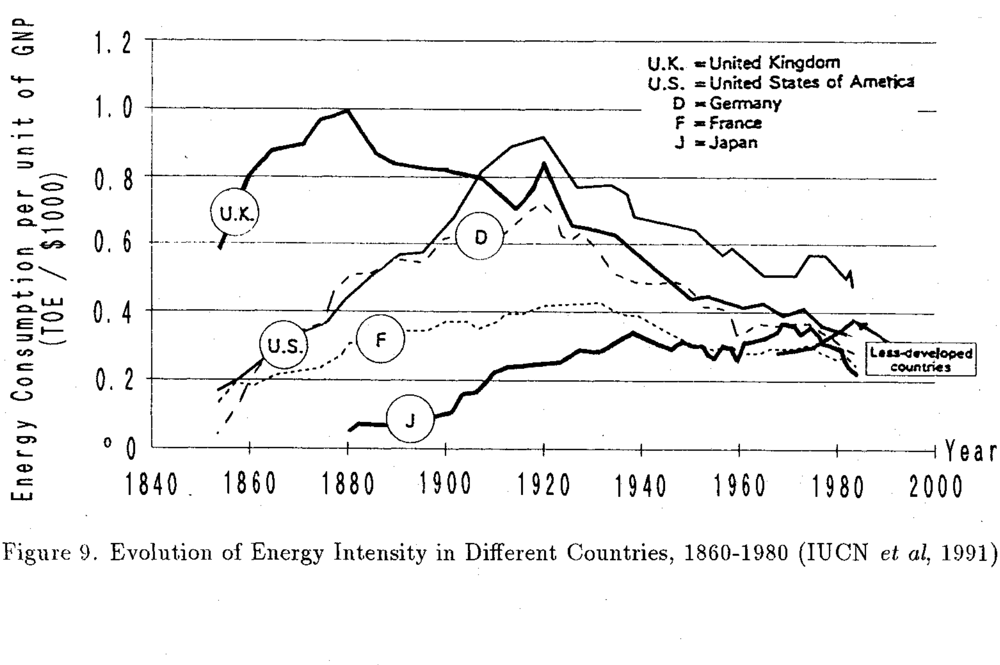


Figure 9. Evolution of Energy Intensity in Different Countries, 1860-1980 (IUCN *et al*, 1991)

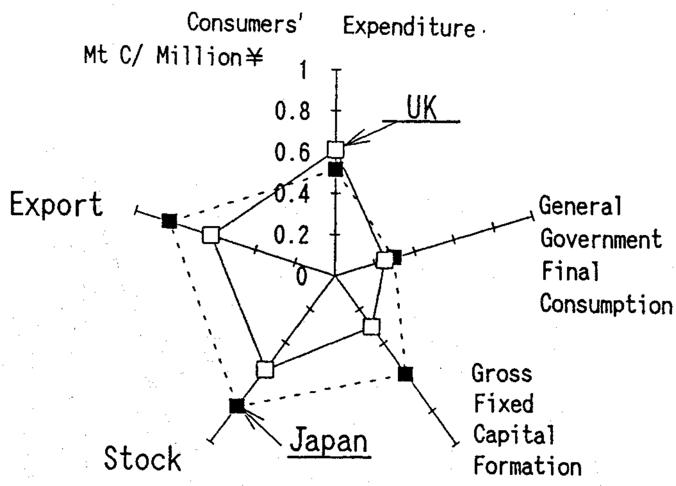


Figure 10. CO_2 Emission Intensities due to Final Demand Sectors

by the **electricity** and **gas** sector. Thus, **iron & steel** gives much more contribution in both **Export** and **GDFCF**.

Direct and Indirect Inducement Directly, the **electricity** and **gas** sector gives greater contribution, and in addition, the **transport** (domestic use excluded) in UK and **iron & steel** sector in Japan.

Indirectly, **public transport** and **food** in **consumers' expenditure**, **public administration** in GGFC, and **construction** in GDFCF are the major contributors both in UK and Japan. However, regarding **export**, lighter industries give larger contribution to the emission in UK than in Japan.

3.2 Emission and Intensity due to Consumers' Expenditure

(1) Emission Patterns in Each Consumption Goods & Services

Fig. 11 shows the household's carbon dioxide emission intensities per Million ¥ of annual consumers' expenditure and the amount of the expenditure for each goods & services in UK and Japan. The amount multiplied by the intensity gives the volume of emission.

Food, Clothing Although Engel's coefficient is slightly higher in Japan than in UK, the amount of the emission due to **food** consumption in Japan is about 1.7 times that in UK, because the expenditure and the emission intensity due to **food** consumption in Japan is higher in UK (both almost 1.3 times that in UK).

However, qualitatively, there are some tendencies of increased energy consumption for food also in UK such as:

- The permeation of DINKS: consumers in UK tend to purchase more cooked meals such as frozen foods.
- Take-away shops servicing aged people living alone.

In clothing, the amount of the emission is almost the same.

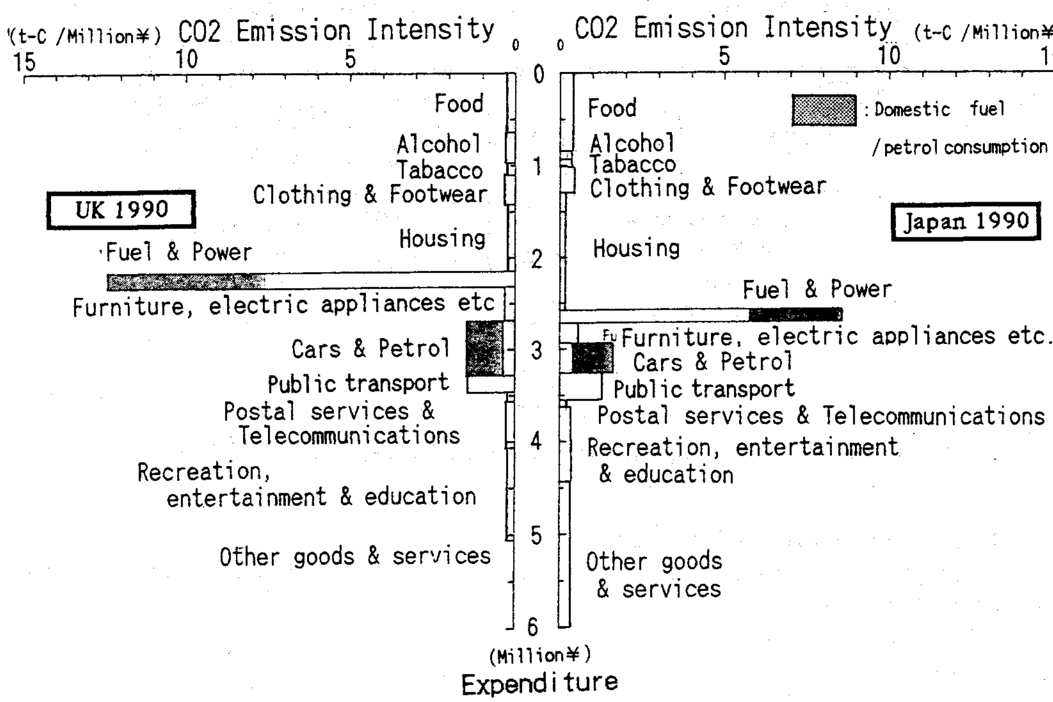


Figure 11. CO_2 Emission Patterns due to Consumers' Expenditure

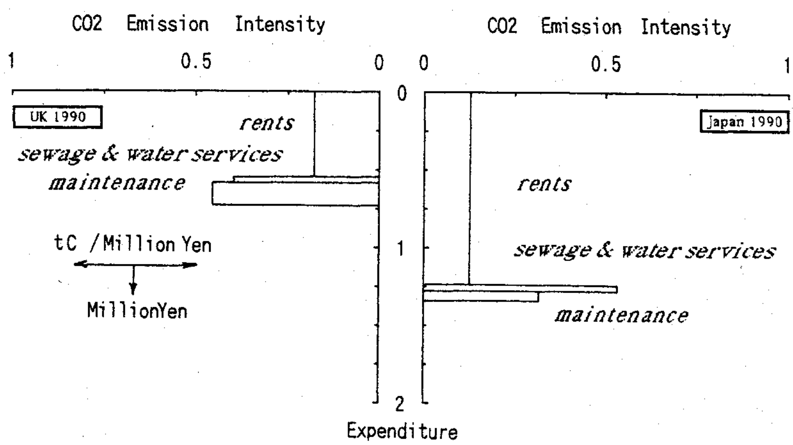


Figure 12. CO_2 Emission Patterns due to Consumption for Housing

Housing Although the amount of emission is almost the same, the intensity and the amount of expenditure are quite different. The expenditure of **housing** consists of *rents*, *sewage & water services*, and *maintenance* (See Fig. 12).

Although *rents* represent the largest contribution in Japan as well as in UK, in terms of the amount of expenditure, in Japan *rents* are almost twice as high as in UK, because of higher land prices in Japan. Moreover, *the maintenance* cost in UK is more than twice as high as in Japan. This is presumably caused by the following factors:

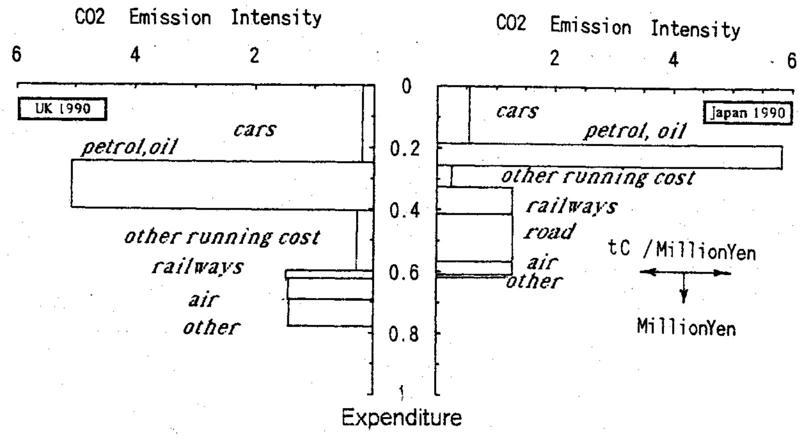


Figure 13. CO_2 Emission Patterns due to Consumption for Transport

- Longer duration time of dwellings in UK.
- *Maintenance* cost would to some extent be transferred to other final demand of GDFCF as dwelling assets.

Transport

a. Emission Intensity

Although transport efficiency in terms of transport distance per unit of expenditure is much higher for public transportation than for cars, the emission intensities are nearly the same.

In detail, the intensity of `cars & petrol` is much influenced by consumption of *fuel and oil.* Moreover, intensities of `public transportation` i. e. *railway*, *road*, *air* etc. are quite similar to each other (See Fig. 13).

b. Share

The difference in the amount of emission seems to be expressed rather by the amount of expenditure than by the intensity in both UK and Japan.

Emission intensity does not differ very much between UK and Japan, and the distinctive features may be seen rather in the shares of using private cars in all means of transportation. Whereas the shares of railway in all transportation based on passenger-km are 6.7 % (UK) and 29.1 %(Japan), shares of private cars are 92.1 %(UK) and 66.7 % (Japan)(Ministry of Transport, 1992). Thus, each transportation sectors share is reflected in the utilization of transport.

Fuel In fuel, a higher intensity and a larger amount of expenditure are both found in UK (See Fig. 14).

a. Intensity

In UK, *gas* and *coal & coke* make the average intensity higher. In Japan, instead *electricity* and *gas* are the main contributors. It means that UK uses its own fuels, whereas Japan depends on import.

b. Amount

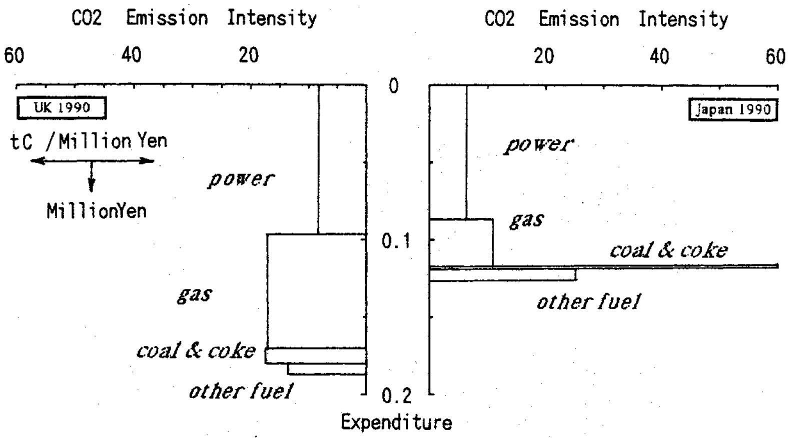


Figure 14. CO_2 Emission Patterns due to Consumption of Fuel & Power

Apart from the difference in the kind of fuels utilized, it is clear that the amount of emission is determined by the amount of energy consumption.

As often said, the difference in energy consumption between UK (as well as other European countries) and Japan is derived from the consumption volume of heating. Energy consumption for heating differs with the climactic condition, heating space, preference of temperature, heating equipment etc. For example, in UK the household's annual energy consumption for heating per degree day is about 3 times as high as in Japan.

Moreover, efforts for energy saving, such as insulation, should also be considered. Insulated houses encompass 12.4 % of all houses (UK DoE, 1991) and 21.2 %(detached), 45.7 %(flat) in Japan (Japan Environment Agency, 1989).

(2) Inducement of Import due to Consumers' Expenditure

Inducement of import by final demand including consumers' expenditure is shown in Fig. 15. This does not include inducement of carbon dioxide. To evaluate it, further information is needed about how much fuel that is induced in all countries which export these import goods. Even in the monetary inducement, the **consumers' expenditure** give contribution most to inducement of import both in UK and Japan. On the other hand, GGDCF's proportion is higher in Japan, and GGFC and **Export** are higher in UK. In addition, the amount of import per household is about 1.8 times as high as in Japan. This also indicates that UK is weighting in consumption.

3.3 Reflection of Consumers' Expenditure in Investment

Fig. 16 shows direct and indirect carbon dioxide emission inducement by the each sector of GDFCF.

(1) Share

In UK, much inducement is shown by the **construction** and **service** sector. In Japan, instead, **social capital** and private sectors' machinery equipment, such as **manufacture**, give greater contribution together with **construction** and **service**.

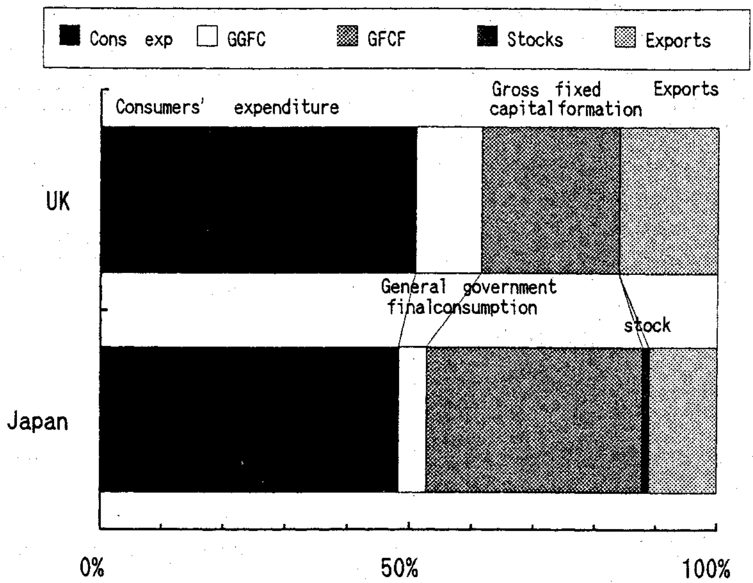


Figure 15. Inducement of Import due to Final Demand

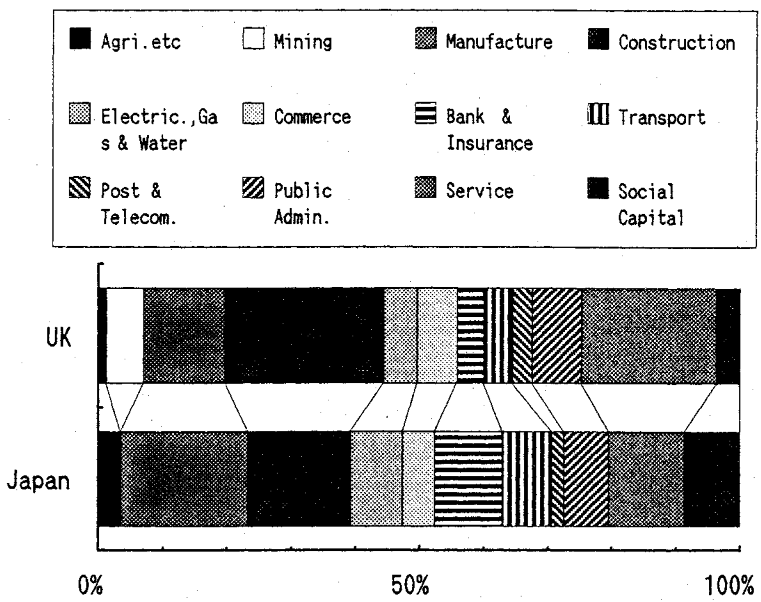


Figure 16. CO_2 Emission Inducement due to Each GDFCF Sectors

Here, `construction` consists of dwelling and construction of office buildings, and dwelling dominates both in UK and Japan. Regarding `construction`, however, emission per household gives the difference; 0.13 t-C in UK and 0.32 t-C in Japan.

In the case of dwelling in Japan, carbon dioxide emission through a life cycle shows that construction produces is 2.3 times (Wooden) and 5.2 times (Steel Reinforced Concrete) as much as maintenance (Suzuki *et al*, 1994). As mentioned above, this indicates the consumers' responsibility for dwelling construction and the necessity of expanding the duration time.

(2) Intensity

Emission intensity of each GDFCF in UK varies from 0.26 to 0.39, whereas in Japan it varies from 0.49 to 0.63.

In detail, construction shows 0.37 in UK and 0.62 in Japan, and bank & insurance give 0.26 in UK and 0.62 in Japan.

This shows that the position of each country is different with respect to the development towards post industrialization in modern age and an aging society.

4. Conclusions

In this analysis, by comparing UK and Japan, the following carbon dioxide emission patterns were clarified:

(1) Higher indirect emission intensities due to each industrial sector were recognized. This reflects the difference in maturity of post industrialization in modern age.

(2) In emission inducement due to final demand, `consumers' expenditure` gives the largest contribution to the inducement, more in UK than in Japan. Each distinctive profile of the emission patterns is reflected by the time difference in evolution of the population and economic growth in UK and Japan.

(3) Regarding direct and indirect emission due to consumers' expenditure, the following emission patterns were described:

- Much higher intensity due to `food` consumption is recognized in Japan.
- Although the amount of emission due to consumption for `housing` is nearly equivalent, the individual components are different. The expense for *rents* in Japan is almost double compared to UK because of higher land prices in Japan; lower *maintenance* cost in Japan seems to reflect shorter duration time of dwellings and much more investment for dwellings.
- The difference in the amount of emission due to consumption for `transport` seems to be expressed rather by the amount of expenditure than by the intensity in both UK and Japan.
- The intensity and amount of emission due to fuel consumption are both higher in UK mainly because of use of its own primary fuels and much higher energy demand for heating.

(4) In monetary inducement of import due to final demand, consumers' expenditure has a large share both in UK and Japan. The amount of import per household in UK is almost double to that in Japan. These also suggest consumers' greater contribution to the inducement of carbon dioxide emission.

(5) In emission inducement by GDFCF, the following facts were recognized:

- Intensity in Japan's double to that in UK
- Dwelling construction-derived emission per household indicates the necessity of extending duration time of dwellings in Japan.

Acknowledgement

The authors would like to express their thanks to Mr. David Hughes of UK Central Statistical Office for helpful guidance on UK Input-Output Balance for 1990, and to Mr. Rob Hetherington of Sheffield Hallam University for numerous useful information on carbon dioxide emission and I-O analysis.

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(Received September 5, 1994; revised version accepted January 20, 1995)