18. EVALUATION OF CAR-INDUSTRIAL METABOLISM TOWARDS SUSTAINABILITY

Tohru MORIOKA, Noboru YOSHIDA and MariaTheresa MAGAMPON*

Abstract : Using input-output analysis, trends of the Japanese manufacturing sectors' energy and material intensity were examined over four decades, from 1960 to 1990 . The Japanese automobile industry metabolism, in particular was clarified in terms of material input/consumption typified by hotrolled steel. Inducement by final demand sectors, specifically fixed capital formation was scrutinized to evaluate the materialized industrialization due to car use in industry and household. Results revealed that motor vehicles as capital goods continue to be an important part of the industries' production process and as service both in the business and the private sectors. Despite eco-efficiency, such demands caused continued increase in the total material consumption. Nevertheless, there was an evident decoupling from material and energy use, which increased resource efficiency and reduced carbon dioxide emission per unit output.

KEY WORDS : industrial metabolism, automobile industry, input-output analysis, carbon dioxide emission, energy and material intensity.

1. INTRODUCTION

With the unraveling of the impact of human activity on the environment, the consequences of our interference with the ecosystem became apparent. Anthropogenic material flows often exceed nature's capacity and the current rate of resource consumption is beyond sustainable level (Worldwatch, 1998). Dematerialization strategy or the reduction of man-induced material and energy flow to an environmentally sound extent, reflects efforts to describe the patterns over time and space, and in physical terms, to decouple industrial activities from environmental impacts; and thus analyze industrial transformation (Resource efficiency homepage).

Enterprises or manufacturing industries play a major role in improving the ecological and industrial efficiency of processes and products at the lowest costs possible (Ayres and Simones, 1994). An integrative approach to analyze combinations of various materials that flow together can greatly improve study methods as well as the ability to develop sustainable strategies.

Being a leading industry since 1976, the Japanese automobile industry was chosen as a model, as it represents a mature sector with diverse linkage to other sectors in its whole life cycle, in effect reflecting a very dynamic system (JAMA). Analysis of its metabolism would, therefore, provide important insights on Japans' industrialization and post-industrialization processes. Such studies could also address policy formulations and models to be used by rapidly developing industrial economies especially in the neighboring Asian countries.

The manufacturing sectors' environmental impacts were evaluated in terms of carbon dioxide emission (energy intensity) and material input intensity (exemplified by hot rolled steel), as induced by the different final demand sectors. Assessment of both the direct repercussions and indirect or environmental rucksacks due to automobile production and consumption, was clarified through the automobile industry metabolism in relation to the different supply and demand sectors of the economy. The analysis, likewise, provided useful information on the effect of changes in the final demand structures on material resource industrialization, one of the driving forces in the global environment change.

2. METHODOLOGY

Japan input-output tables for the year 1960 to 1990 (112 x 112 matrix) and the corresponding energy consumption data were used to analyze the complex interrelation among the three factors driving globalization: energy, economy and environment.

The procedure was adopted from Morioka and Yoshida (1995). Using Leontief standard IO model :

$$X = (I - A)^{-1} Y \qquad \text{... eq'n (1)}$$

* Professor, Research Associate and Doctor Student, Department of Environmental Engineering, Osaka University, 2-1 Yamadaoka, Suita-Shi, Osaka 565-0871 Japan.

and applying energy or material input coefficient, **c** :

$$\mathbf{cX = c\,(I - A)^{-1}\,Y} \quad \text{... eq'n (2)}$$

then $$cX = c\,B\,Y \quad \text{... eq'n (3)}$$

where: $B = (I - A)^{-1}$;Leontief inverse coefficient matrix with cell b_{ij}
X = diagonal matrix of output sectors
Y = vector of total final demand

The "embodied" or total energy/material intensity and consumption were calculated and broken down into direct and indirect components. Inducement by the final demand sectors were then derived, while the fixed capital formation (FCF) demand further fractionated into public and private sectors effect using the input-output FCF supplementary matrix.. Figure 1 briefly summarizes the flow of analyses.

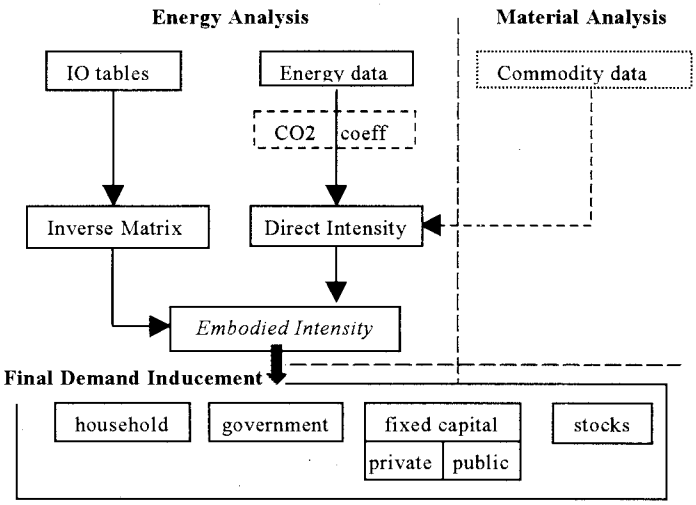


Fig 1. Flow chart of analyses

3. RESULTS and DISCUSSIONS

3.1 Embodied Carbon Dioxide Emission

The environmental impacts associated with a unit of output in production of each of the different industrial sectors of the Japanese economy were described in terms of energy intensity with the corresponding CO_2 emissions, and material intensity, with direct and indirect components.

Figure 2 presents the direct and embodied CO_2 emission from the top ranking sectors, from 1960 to 1990. The general reduction trend in both direct and cumulative quantities of the sectoral emission is a good indicator of the delinking of the production process from the energy input requirements, resulting to reduce discharges and increase energy use or efficiency. This can be accounted to the compliance of the industries on energy and emission regulations in Japan issued during the 1970's (Quality of Environment, 1994; JAMA, 1997).

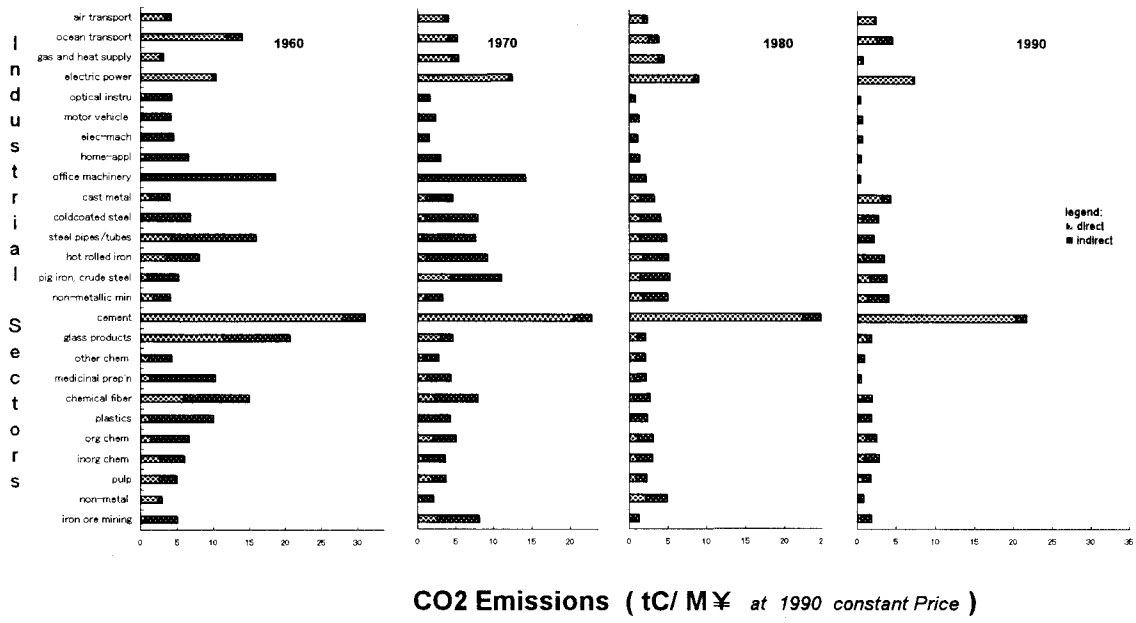


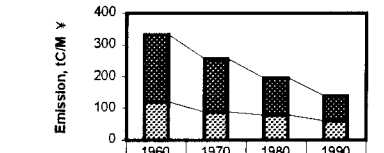
Fig 2. Industrial sectors direct and indirect carbon emissions

If the magnitude of the direct emission value of each sector is compared to its indirect emission, the latter was generally more pronounced except for some heavy industries like cement, electric power, air and ocean transport. The observed pattern holds for the machinery, appliances and instrument sectors. This implies that products produced from a relatively thought "clean" industry have more substantial environmental impacts due to the production of the needed components or supplies (indirect effect), than for the assembly or manufacture of the product itself (direct effect). This is the hidden or latent emission, which make up the environmental rucksack.

Ranking the sectors from highest to lowest according to the amount of emissions, the motor vehicle industry placed way below the top 10. Thus, despite the common notion that this industry is an energy-intensive sector, total and direct emissions turned out to be lower than those of the other heavy- and metal industries.

At the economy level, the overall performance of the Japanese industrial sectors is said to be environment-friendly in terms of energy use and CO_2 emission. As shown in figure 3, the same declining trend in direct and total emissions of the above individual sector can be observed. Despite an increase in final demand for goods and services due to population and production growth, reduced emission level was reached. Economic activities were, therefore, regarded as eco-efficient.

Fig. 3. Total Embodied CO2 Emission Intensity



	1960	1970	1980	1990
indirect intensity	210	168	116	78
direct intensity	121	87	78	62

3.2 Automobile Industry CO_2 Emission Analysis

Inducement by Final Demand Sectors

The automobile industry served as a model sector for analysis, since it is the leading industrial sector since 1976 (JAMA, 1997). It is also known to have tight linkage with other sectors and a high environmental impact during its production and operation processes.

Energy use for manufacturing automobile comprise 10% of the total industrial sectors' requirement and is equivalent to 15% of its life cycle (OECD, 1991). Hence, it is responsible for the 10% of the total manufacturing sectors' CO_2 emission due to energy consumption. It is therefore interesting to know how much, to whom and by whom should emission be accounted for in the production of a unit automobile.

Figure 4 presents the trend of final demand for motor vehicle by the different final demand sectors and their corresponding CO_2 emission inducement. Household, private fixed capital and export shows a continuous increase in demand as a result of growing population and social or business activities, with export having the fastest rate of increase. Except for the household sector, there was a decoupling pattern especially from the year 1980. However, although household associated emissions increased, the rate was slower than that of the final demand increase. To some extent, energy use efficiency was attained. The figures vividly display an improvement in the automobile industry's consumption of energy resource and the subsequent reduction in CO_2 discharge.

Fig. 4a. Final Demand Inducement on Motor Vehicle Production

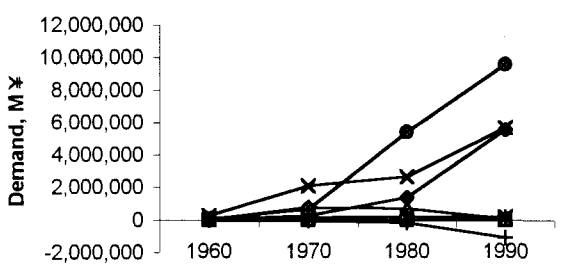
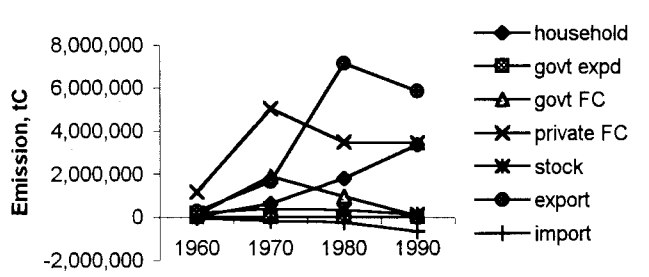
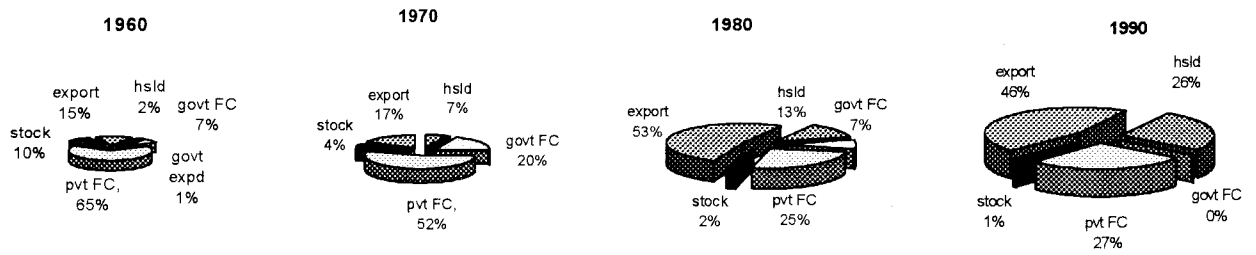


Fig. 4b. Final Demand Inducement on Motor Vehicle CO2 Emission



The proportion of inducement by each of the above final demand sectors is presented in figure 5. The advantage of this kind of graph is that it shows the distribution and shift from one sector to another for a certain period. Household's share (hsld) increased with time, together with export (until 1980). An eye-catching trend was that of the private fixed capital (pvt FC). Its share decreased from 65% to 52% and down to 25% in 1960, 1970 and 1980 respectively. This however, can be quite misleading as this only represents the share of the aggregate emission and should not be mistaken as the actual volume. For the private fixed capital, the inducement was highest in 1970, and decreased from then on. The last two decades were favorable as they imply efficiency in energy use.

Fig. 5 Final demand sectors' share in automobile CO2 emission

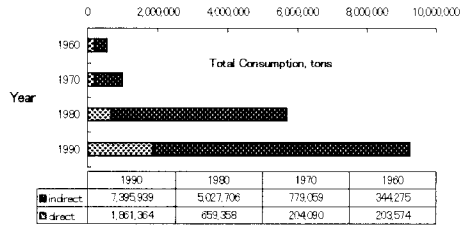


3.3 Material Intensity Analysis

According to the Japan Steel Association statistics , steel stock in Japan amounts to 1,193 million tons. This is about one third of that in US and about 70% of steel stock per capita (Yoichi, 1996). The evaluation of consumption patterns is important for considering minimized material input per services. As steels are used by various industrial sectors, consideration of inter-industrial transaction was therefore considered essential. Thus, the inter-industrial material input was analyzed in industrialization and post –industrialization processes.

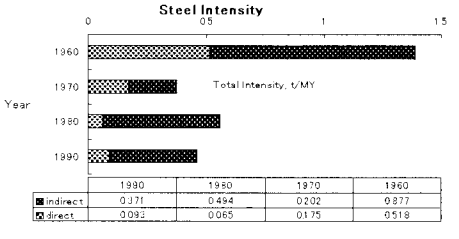
Application of the concept of industrial metabolism involves detailed accounting of material and energy flows through human activities. Input-output approach offers a practicable way to reveal unexpected results due to the interactions of the different sectors in the economy. This method allows the analysis for complex direct and indirect repercussions of economic changes not only in terms of emissions but also in terms of material requirements.

Fig. 6a Automobile Sector's Hotrolled Steel Consumption



	1990	1980	1970	1960
indirect	7,395,939	5,027,706	779,059	344,275
direct	1,861,364	659,358	204,090	203,574

Fig. 6b. Automobile Sector's Hotrolled Steel Intensity



	1990	1980	1970	1960
indirect	0.371	0.494	0.202	0.877
direct	0.093	0.065	0.175	0.518

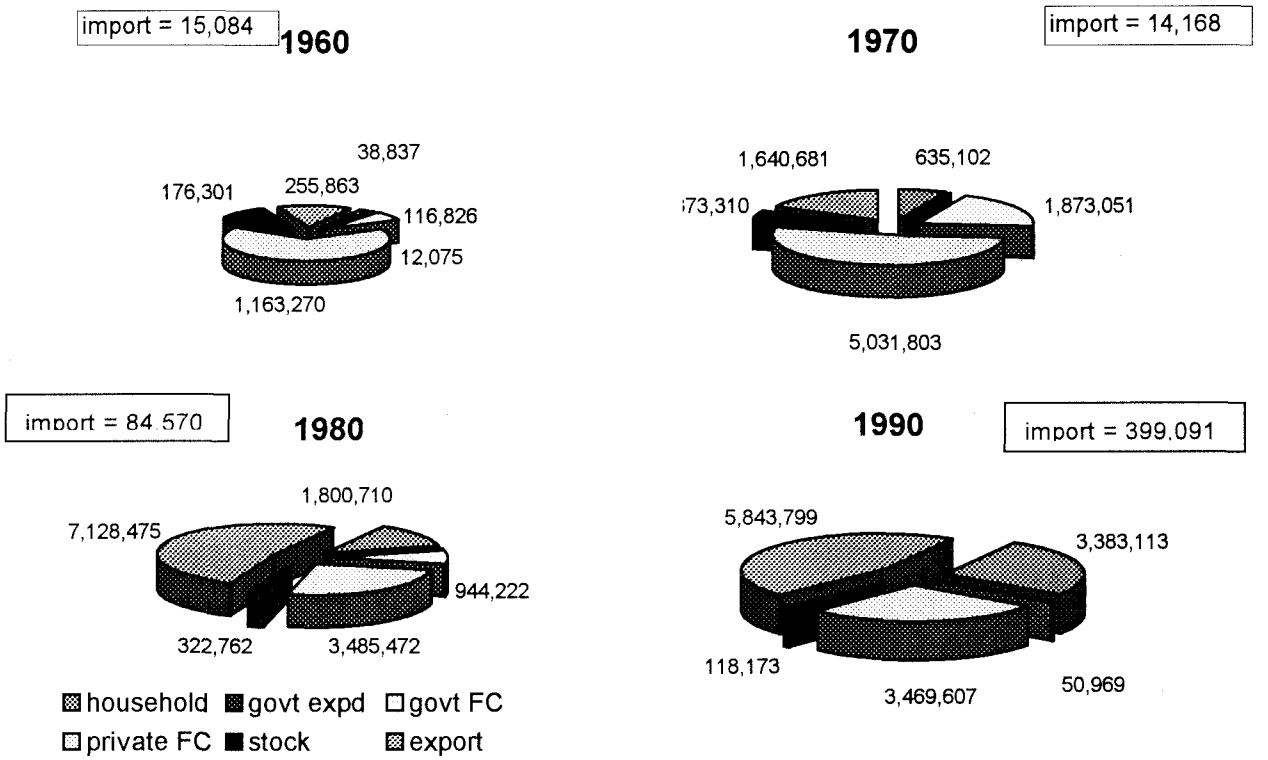
Figure 6 shows motor vehicle's hotrolled steel requirement. As expected, consumption expanded with time. Japan's drastic increase in material consumption since 1980 until the 1990 bubble economy was due to successful takeoff toward export-oriented economic development, represented by the automobile industry. This industry also influenced various related industries through inter-industrial transaction in the process of vehicle production. Inspite of diminished intensity, increased final demand through time caused great amount of cumulated material consumption.

3.3 Inducement by Final Demand

Figure 7 displays the final demand sectors' inducement in automobile hotrolled steel consumption, both in proportion and amount. It was observed that household and export sectors exhibited an increased trend of share to the total automobile steel consumption. On the other hand, the opposite trend was observed for the private fixed capital share of 2/3 to only 1/3 from 1960 to 1990, which indicates a shift in the structural demand effect as induced by the final demand sectors. This can be accounted to the improvements in domestic automobile production, mainly used as capital goods by the private sectors, which led to export boom in the last two decades.

Reduced share of the private fixed capital demand effect also implied better material intensity per unit service as a consequence of energy crisis in the mid 70's.

Fig. 7 Automobile hotrolled steel consumption induced by the final demand sectors in tons



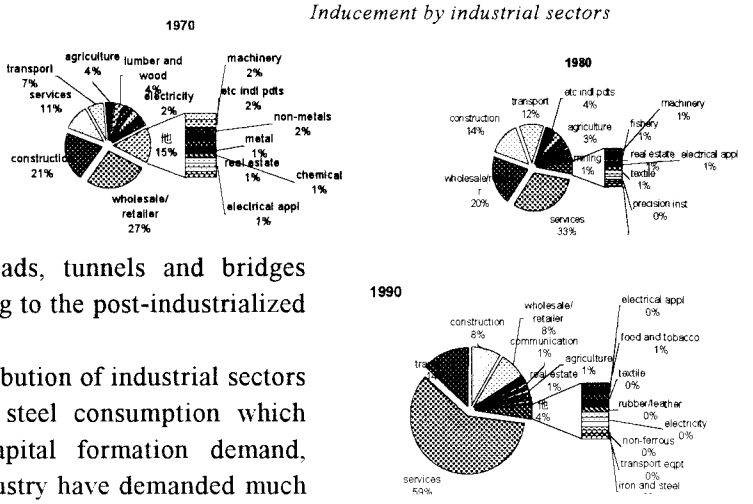
Referring to the same figure, the actual volume of hotrolled steel induced by these demand factors revealed an increased trend due to household and export. Fixed capital demand inducement, however, was of greatest magnitude (5,031,803 tons) during 1970 and then decreased drastically in the following two decades. This is in contrast with the share trend as mentioned above.

Comparing the effect of private fixed capital demand with that of the household, the latter produced greater inducement for all years. On the other hand, when compared with export, its influenced was greater in the first two periods, then fell way behind that of export's during 1980 (3.5 against 7.1 million tons) and 1990 (3.5 versus 5.8 million tons). The overall trend showed a steady increase in material consumption due to private and export demand for car as capital goods. Thus despite eco-efficiency, an increase in total material consumption - due to expansion of the business car use, such as inland express delivery services; and increased mobility needs as dictated by the society - was apparent.

3.4 Inducement by Private Fixed Capital

Vehicles have supported high needs of mobility in daily life and business activities of the country. Moreover, drastic technical innovation and spreading social investment such as roads, tunnels and bridges enhanced high quality of mobility corresponding to the post-industrialized society.

Fig.8 Private Fixed Capital Formation Demand Inducement by industrial sectors



Figures 8 and 9 show the detailed distribution of industrial sectors share in automobile emission and hotrolled steel consumption which comprised the private and public fixed capital formation demand, respectively. As shown in figure 8, service industry have demanded much

mobility year by year; 38%, 52% and 67% in 1970, 1980 and 1990, respectively, as share of the combined wholesale/retailer and service sectors. Construction also gave great contribution: 21, 14 and 8%. Transport itself increased both share and amount which denotes growth of the transport sector as service industry, so called " the third party logistics".

Similar to the above trend, the government or public fixed capital formation inducement was also dominated by the service sectors which contributed a high 80% share in 1990. The other notable sectors include the building and equipment sector (only for 1970), communication, electric, water and transport sector. This can be explained by the structural shift of the Japanese economy from the heavy and traditional industries towards the service industry.

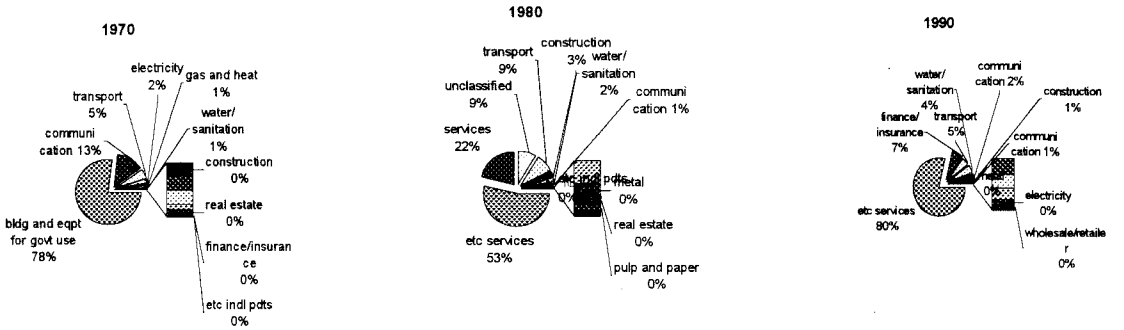


Fig. 9 Public fixed capital formation demand inducement by industrial sectors

4. CONCLUSIONS

Industrial metabolism provided detailed analysis of energy and material flows from one industry to another as well as the embodied emission and consumption brought about by an economic activity. Input-output analysis was an invaluable aid to clarify the complex inter-industry relationship and to evaluate the energy and resource requirement of the economy due to final demand.

Carbon emission and material intensities with final demand repercussions revealed a general reduction pattern, but growing economic activities effected the continued rise in the total volume of emission and material consumption, with time. Indirect component of the embodied emissions for most industries was found to be greater than the direct emission. This implied the importance of industrial linkage role in the ecological rucksack of an economic activity.

Analysis of the hotrolled steel requirement of the automobile industry induced by the different final demand sectors showed a delinking despite the increased demand by the household and export sectors. This increased demand was due to the improvement in automobile domestic production and industrialization needs.

The Japanese automobile industry played an important role in the industrialization process of the nation by providing mobility to the various final demand sectors as capital goods especially in the service sectors. It has strong linkage with many other sectors through inter-industrial transactions both in the production and final consumption phases.

References

Ayres, R. U. and U. E. Simonis. 1994. Industrial Metabolism. Restructuring for Sustainable Development. UN University Press, Tokyo, Japan.

Japan Automobile Manufacturer's Association Homepage (JAMA)

Morioka, T. and N. Yoshida. 1995. Comparison of carbon dioxide emission patterns due to consumers' expenditure in UK and Japan. Journal of Global Environment Engineering 1: 59-78.

OECD, 1991.

Quality of the Environment, 1994. Japan Environment Agency Annual Publication.

Moll, S. and A. Femia. 1997. Production, Material Input and Labour- an illustrative input-output analysis. Proceedings of the ConAccount Workshop. 21-23 January 1997. Leiden, the Netherlands. 184-192.

Worldwatch, 1998. Worldwatch Press Release On Building A New Economy: Building a new economy, the challenge for our generation.