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Evaluating the Economic Impacts of the Technological Innovation in the Motor Vehicle Industry: The Input-Output Approach

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Abstract

In this paper, the economic impacts of technological innovation, such as electric and hybrid motor vehicles, in the motor vehicle industry in Japan are examined. The motor vehicle industry has developed environmentally friendly vehicles in the face of the global warming issue and the problem of petroleum exhaustion. A new type of motor vehicle will become popular for coming several decades. The industrial structure will be affected by the appearance of a new type of motor vehicles. Since the Japanese economy strongly depends on the motor vehicle industry, the advent of a new age of the automotive industry brings an influence on not only own industry but also other industries. Especially the industrial regions where the motor vehicle firms are concentrated will be affected by a new technology. In this study, we explore the economic impacts of shifting the production system in the motor vehicle industry from the conventional technology to an electric and hybrid vehicle technology using the national and multi-regional input-output models.

This study shows the production of the hybrid motor vehicles has a positive impact and but the production of electric motor vehicles has a negative impact on the Japanese economy comparing with the production of the conventional motor vehicles. At the regional level, we can observe that the production of hybrid motor vehicles has a negative impact on the economy in Chubu region, but has a positive impact on the other regions. Finally, the results of this study suggest that the appearance of new environmentally friendly vehicles brings the different economic benefits to each regional economy in Japan.

JEL Classifications: R11, R15, R41

Keywords: Electric and Hybrid Vehicles, Technological Innovation, Multi-Regional Input-Output Analysis, Economic Benefits

1. Introduction

In endeavors to prevent global environmental resources, CO2 reduction has become the challenge to the human race. The consume fossil fuels in quantity have a significant impact on the global environment. Energy saving is an inevitable problem for the automotive industry. The development of motor vehicles with a new energy system is necessary to prevent the global warming and to solve the problem of petroleum exhaustion. An environmental friendly vehicle technology will play an essential role in our sustainable society in the near future. This paper examines the impacts of producing the electric motor vehicle and hybrid motor vehicle on the economy in Japan.

A new type of motor vehicle will become popular for coming several decades. It is predicted that the automotive industrial structure will be affected by the appearance of a new type of motor vehicle. Since the Japanese economy strongly depends on the motor vehicle industry, the advent of a new age of the automotive industry brings a significant impact on not only own industry but also other industries. Especially the industrial regions, such as Chubu and Kanto regions in Japan, where the motor vehicle firms are concentrated, will be affected by the appearance of a new motor vehicle technology.

In this study, we explore the economic impacts of shifting the production system in the motor vehicle industry from the conventional technology to an electric and hybrid vehicle technology using the national and multi-regional input-output models.

2. The Economic Impacts at the National Level:

(1) The Input-Output Model

The economic impact of shifting the production technology in the motor vehicle sector is examined at national level. In this study, “the economic impact” is measured by the output induced by the demand for a new type of motor vehicles. The production process in the motor vehicle industry involves a new technology. To derive the economic impacts of a new motor vehicle, we adopt the input-output approach, i.e. the model of competitive import type. The output is calculated as

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

X is the vector of gross output and it is interpreted as the output induced by the final demand and exports. A is the input coefficient matrix and \bar{M} is the diagonal import share coefficient matrix. The values of these matrices are directly derived using an input-output table. F is the vector of final demand and E is the vector of exports. These vectors are also exogenously given to derive the economic impacts. I is an identity matrix.

In this study, the Japanese economy is classified into 108 production sectors. The input coefficient matrix at the national level is given from the “2000 Input Output Tables of Japan”. In this study, the introduction of a new technology in the motor vehicle sector is represented by a change in the input coefficient matrix, i.e. $A \rightarrow A_{case}$. If the motor vehicle sector which innovates a new technology produces to satisfy the final demand ΔF and

export ΔE for a new type of motor vehicles, then the economic impact ΔX is calculated as
$$\Delta X = [I - (I - \bar{M})A_{case}]^{-1}[(I - \bar{M})\Delta F + \Delta E].$$

(2) Simulation Cases

In our simulation, 3 cases are examined Case 0 is the base case of business as usual. In this case, the motor vehicle sector produces the conventional motor vehicles with gasoline and diesel oil. The input coefficients of the motor vehicle sector are directly given by “2000 Input-Output Tables” of Japan. In Case 1, we suppose that the motor vehicle sector produces the hybrid motor vehicles (HEVs) only. The input coefficient of the motor vehicle sector is changed so as to reflect a HEV production technology. In Case 2, it is assumed that the motor vehicle sector produces the electrical motor vehicles (EVs) only. Similarly, the input coefficient is changed so as to reflect an EV production technology.

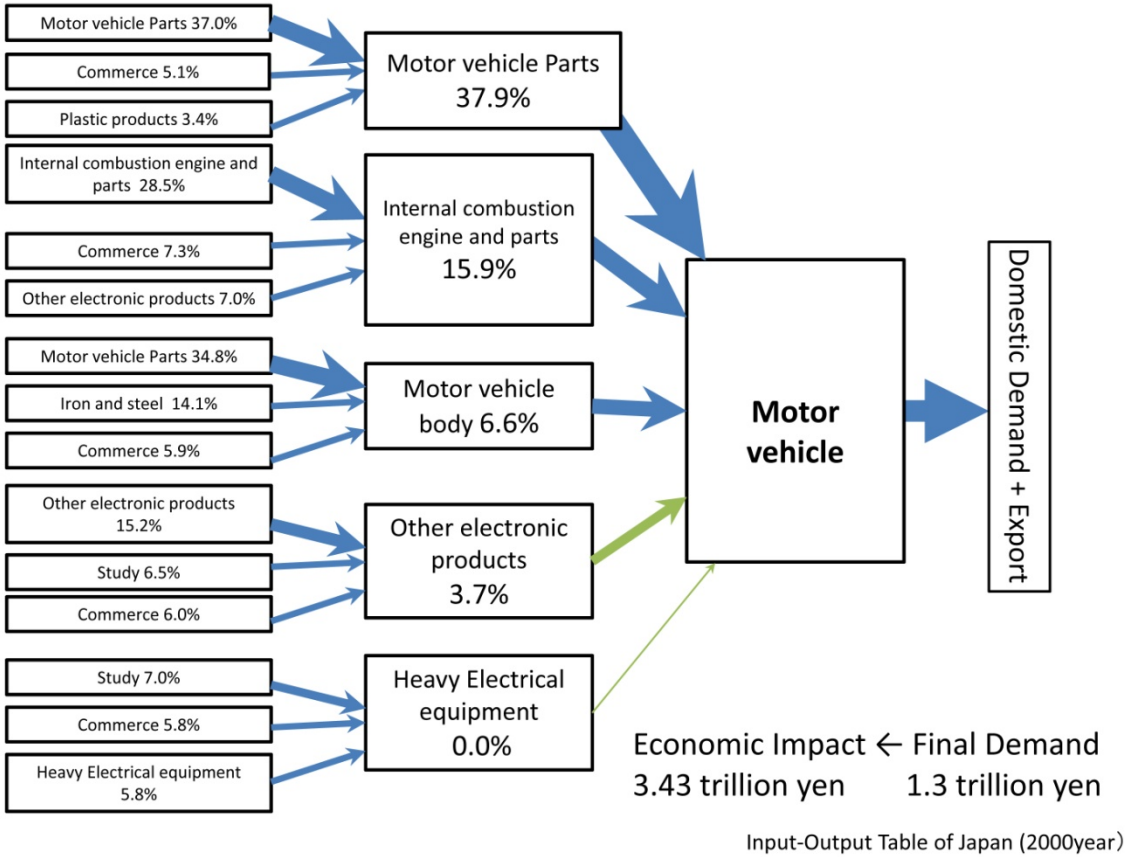


Figure.1 Input Structure of Motor Vehicle Sector

Figure 1 shows the input structure of the motor vehicle sector in Case 0. We can observe that if the motor vehicle sector produces the conventional vehicles with gasoline or diesel oil, then the sector involves “motor vehicle parts” sector (37.9%) and “internal combustion” sector (15.9%) as intermediate inputs. The value of percentage means the input coefficient of the motor vehicle sector. In Case 1 and Case 2, suppose that the input coefficients of “motor vehicle parts” and “internal combustion engine” in the motor vehicle sector decrease. On the other side, the input coefficients of “other electronics and electronic products” and “heavy electrical equipment” in the motor vehicle industry would increase. We suppose that “other electronics and electronic products” sector produces batteries and “heavy electrical equipment” sector produces motors for EVs. For example, in Case 2, since the electric motor vehicles do not involve “an internal combustion engine” as an intermediate input, the input coefficient drastically decreases. In this study, the values of the input coefficient in Case 1 and Case 2 are obtained from a technical report which is published from the Institute of Energy Economics, Japan (2006). Economic impacts under such a technological change in the motor vehicle sector are estimated using the input-output model at the national level.

(3) Simulation Results

In our numerical simulation, an initial impact is exogenously given as an increase in the demand “motor vehicle”. We suppose that the final demand including exports of "motor vehicles" increase by 10%. It counts about 1.3 trillion yen in 2000 input-output table. In Case 0, the economic impact is calculated if the motor vehicle sector produces the conventional motor vehicle. In this simulation, the economic impact is measured by the output induced by an increase in the demand. Similarly, in Case 1 and Case 2, the economic impacts also are calculated if the sector produces the hybrid motor vehicles (HEVs) and the electrical motor vehicles (EVs), respectively.

Table.1 Economic Impacts at National Level

Cases	Induced Products	Ratios
Case 0 Conventional Model	3.43 trillion yen	100%
Case 1 HEV	3.46 trillion yen	101%
Case 2 EV	3.26 trillion yen	95%

Table 1 is the economic impacts of each case when the demand for the motor vehicle of about 1.3 trillion yen increases. If the economic impact of Case 0 is normalized as 100%, the economic impacts of Case 1 and Case 2 are 101% and 95%, respectively.

The economic impacts of producing EVs on each industry are shown in Figure 2

where Case 2 is compared with Case 0. The vertical axis represents the difference between the induced output of Case 2 and that of Case 0. From the input structure in Figure 1, needless to say, we can observe that “motor vehicle body”, “internal combustion engine and parts”, and “motor vehicle parts” sectors directly receive a negative impact respectively. On the other hand, “heavy electrical equipment” and “other electronics and electronic products” sectors directly receive a positive impact. In Figure 2, such a direct impact is ignored and an indirect impact is depicted. In Case 2, it is observed that the outputs of “non-metallic mineral products”, “plastic products”, and “research” sectors increase while that of “casting and forged product”, “pig iron and crude steel”, and “steel material” sectors decrease respectively since the motor vehicle sector produces EVs with a new production technology. The latter sectors are closely related with “internal combustion engine and parts” sector. That is the reason why the outputs of those sectors decrease in Case 2.

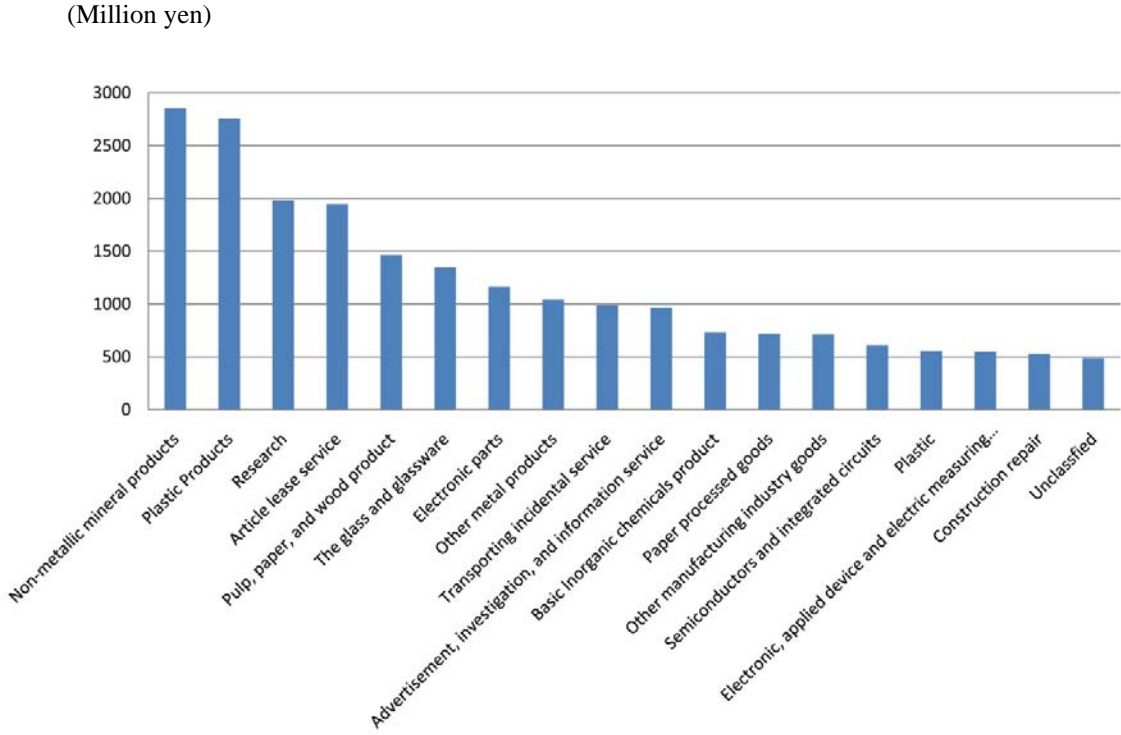


Figure.2 The difference between the impact of Case 2 and that of Case 0
(The case of positive impacts)

3. The Economic Impacts at the Regional Level

(1) The Multi-Regional Input-Output Model

The regional economic impact of shifting the production technology in the motor vehicle sector in a specific region is examined. A technical change in a specific region is considered. To derive the regional gross output, we follow the Chenery-Moses approach

which enables us to internalize the regional technology. The model is formulated as

$$X = [I - TA + \widehat{M}(T^*A)]^{-1}[TF - \widehat{M}(T^*F) + E]$$

X is the gross output. T is the inter-regional trade coefficient matrix and A is the diagonal block matrix of the regional technical input coefficient. These parameters are derived from a multi-regional input-output table. F is the vector of the final demand and E is the vector of exports. These values are exogenously given. \widehat{M} is the diagonal import share coefficient matrix. The variable with * means that the matrix takes a diagonal block form. The import of each region is calculated by $M = \widehat{M}[(T^*A)X + (T^*F)]$

In this study, a new technology in the motor vehicle sector in a specific region is represented by a change in the input coefficient matrix, i.e. $A \rightarrow A_{case}$. If the motor vehicle sector with a new technology in a specific region produces motor vehicles to satisfy the final demand ΔF and export ΔE , then the output induced by the demand ΔX is given as

$$\Delta X = [I - TA_{case} + \widehat{M}(T^*A_{case})]^{-1}[T\Delta F - \widehat{M}(T^*\Delta F) + \Delta E]$$

From this model, we derive the economic impacts of a change of the production technology in the motor vehicle sector in a specific region. In the present circumstances, the HEVs are mostly produced in Chubu region of Japan where Toyota Motor Cop. is located. Also, we can consider a change of transportation condition by changing the inter-regional trade coefficient matrix, i.e. $T \rightarrow T_{case}$. Effects of the decentralization and centralization of the vehicle industry on the regional economy would be estimated by changing the trade coefficients.

Economic impacts at the regional level are estimated by using the multi-regional input-output table in 2000. In Japan, the inter-regional input-output table in 2000 (Ministry of Economy, Trade and Industry of Japan) is available. In this table, the Japanese economy is subdivided 9 regions such as Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, Kyusyu, and Okinawa. In this study, since the Chenery-Moses approach is used, the multi-regional input-output table is reconstructed from the inter-regional table. In the table, the economy is classified into 52 sectors.

In our simulation, changing the structure of the motor vehicle sector in a specific region is handled as a change in the regional technical input coefficient in the sector. The model of the Chenery Moses type is adopted because the regional technical coefficient should be changed. The input coefficient of the motor vehicles sector in a specific region can be specified. Under the multi-regional settings, impacts of producing a new motor vehicle at a specific region on not only its own region but also other regions are estimated. In Japan, the motor vehicle industry is mostly concentrated into Tohoku, Kanto, Chubu, Kinki, and Kyushu regions. In our simulation, by replacing the conventional motor vehicle technology by a new motor vehicle technology in a specific region, the regional economic impacts are estimated.

(2) Simulation Results

The impact of producing HEVs and EVs on the regional economy is examined. In order to evaluate impacts of each regional technological innovation, the regional technical coefficient of the vehicle sector in a specific region, namely Tohoku, Kanto, Chubu, Kinki and Kyusyu, is replaced by a new coefficient for the HEV and EV production. The total impact is also calculated by replacing all the regional technical coefficients simultaneously. In our simulation, the initial impact is specified by 10% increase in the final demand (including exports) of “motor vehicle” in all regions as well as the simulation case at the national level.

Similar to the national model, Case 0 is given by business as usual case where the motor vehicle sector produces the conventional motor vehicles. In Case 1 and Case 2, the economic impacts are estimated under the condition that the motor vehicle sector produces HEVs and EVs in a specific region, respectively.

Table 2 shows the simulation results in Case 0(conventional) and Case 1 (HEV). In both Cases, the output induced by an increase in the demand is shown. In Case 0, the demand of 1.3 trillion brings the output of 3.37 trillion yen in Japan. The total impact is divided into that of 9 regions, 0.019 (trillion yen) in Hokkaido, 0.088 in Tohoku, 1.318 in Kanto, 1.387 in Chubu, 0.313 in Kinki, 0.314 in Chugoku, 0.02 in Shikoku, 0.208 in Kyushu, and 0.001 in Okinawa.

This table also shows the simulation results of economic impacts in Case 1 (HEV). In Japan, the motor vehicle industry is concentrating in Chubu region. We consider a situation that the motor vehicle sector in Chubu produces HEVs only and the conventional vehicles are produced in other regions. In this case, the demand of 1.3 trillion in all regions induces the output of 3.723 trillion yen. If the motor vehicle sectors in all regions produce HEVs, the output would be 3.783 trillion yen. The production of HEVs always brings a larger economic impact wherever the sector produces it. We can find that Chubu region is the most effective region for producing HEVs.

Table 2 Economic Impacts of HEV at the Regional Level

		Unit: trillion yen									
		Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyusyu	Okinawa	Total
Conventional	Vehicle	0.019	0.088	1.318	1.387	0.313	0.314	0.020	0.208	0.001	3.670
Production region of HEV	Tohoku	0.019	0.089	1.319	1.386	0.314	0.314	0.020	0.209	0.001	3.671
	Kanto	0.019	0.095	1.317	1.387	0.334	0.315	0.022	0.213	0.001	3.701
	Chubu	0.020	0.092	1.358	1.367	0.331	0.318	0.022	0.214	0.001	3.723
	Kinki	0.020	0.088	1.320	1.385	0.317	0.314	0.021	0.209	0.001	3.675
	Chugoku	0.019	0.090	1.324	1.384	0.323	0.309	0.021	0.211	0.001	3.682
	Kyusyu	0.020	0.089	1.323	1.384	0.319	0.317	0.021	0.207	0.001	3.680
All reagion		0.020	0.101	1.369	1.359	0.371	0.316	0.026	0.221	0.001	3.783

(3) An evolution of automotive industry

On the long term basis, it is expected the automotive industry evolves toward various ways while corresponding to an environmentally friendly technology. In such a

situation, we may consider several scenarios. One possibility is that the existing vehicle parts industry may change and produces the parts for HEVs and EVs. This scenario is termed as “Parts Industry for HEV” or “Parts Industry for EV”. Another possibility is that the motor vehicle sector may generate a new service with EVs such as a high quality driver safety services or navigation systems if the EV comes into wide use. This scenario is termed as “New Services”. Several scenarios are simulated. Figure 3 shows the simulation results of the evolution of motive industry. In this figure, the regional economic impacts of producing the conventional vehicles are normalized as 100% respectively. The horizontal axis of Figure 3 may reflect an evolution process of the motor vehicle industry in the near future. The appearance of new parts industry for HEVs and EVs would improve the regional imbalance of the economic impacts. Producing EVs with a new service would contribute the regional economic growth.

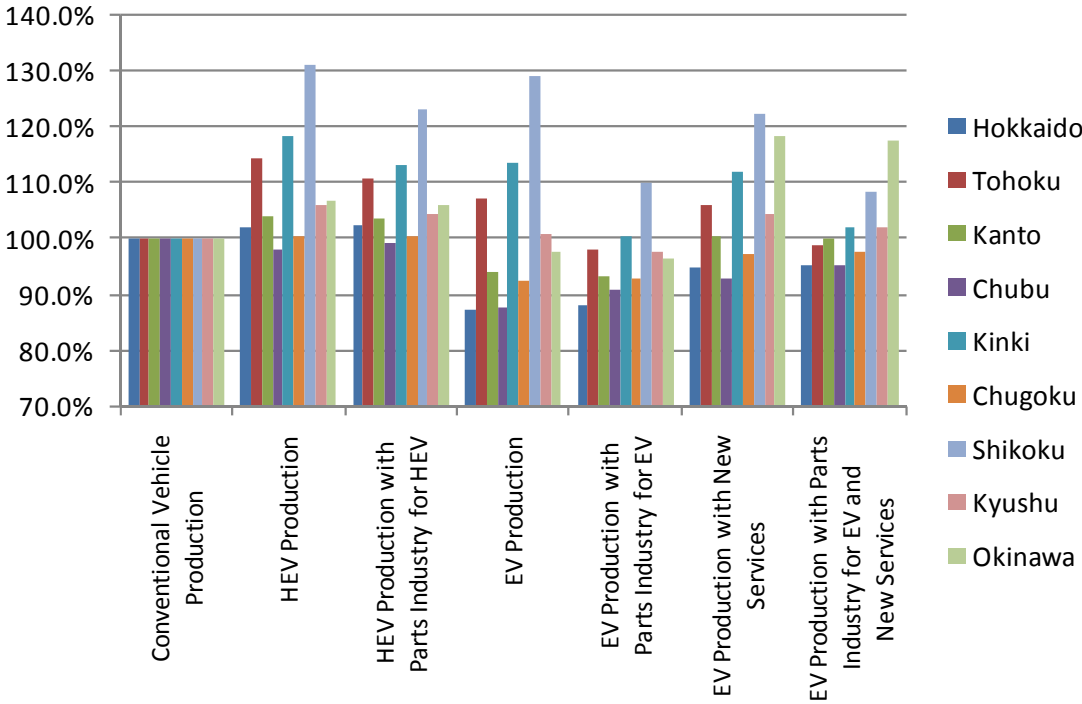


Figure 3 Economic Impacts under an Evolution of Motor Vehicle Industry

4. Concluding Remarks

In this paper, we examined the economic impacts of technological innovation, such as hybrid and electronic motor vehicles, on the economy in Japan at the national and regional levels using the national and multi-regional input-output models. This study shows the production of hybrid motor vehicles has a positive impact and but the production of electric motor vehicles has a negative impact on the Japanese economy comparing with the production of conventional motor vehicles. At the regional level, we can observe that the

production of hybrid motor vehicles has a negative impact on the economy in Chubu region, but has a positive impact on the other regions. It is also shown that the electric motor vehicles bring a positive impact to Tohoku, Kinki, Shikoku, and Kyushu regions. Finally, the results of this study suggest that the appearance of new environmentally friendly vehicles brings the different economic benefits to each regional economy in Japan.

There are remaining several aspects in this paper. Firstly, the input coefficients for the HEV and the EV should be improved using the latest information on a new technology and costs. Secondly, impacts of the demand side such as energy consumption and CO2 reduction should be estimated. Thirdly, the diffusion effects of a new vehicle technology on the productivities of other industries also should be considered.

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