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**Conference Paper**

## A Computable General Equilibrium Analysis of Electric Vehicle Society in Toyohashi City, Japan

51st Congress of the European Regional Science Association: "New Challenges for European Regions and Urban Areas in a Globalised World", 30 August - 3 September 2011, Barcelona, Spain

**Provided in Cooperation with:**

European Regional Science Association (ERSA)

*Suggested Citation:* Khanam, Shamsunnahar; Miyata, Yuzuru; Liu, Yan (2011) : A Computable General Equilibrium Analysis of Electric Vehicle Society in Toyohashi City, Japan, 51st Congress of the European Regional Science Association: "New Challenges for European Regions and Urban Areas in a Globalised World", 30 August - 3 September 2011, Barcelona, Spain, European Regional Science Association (ERSA), Louvain-la-Neuve

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# A Computable General Equilibrium Analysis of Electric Vehicle Society in Toyohashi City, Japan

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## **Abstract:**

In this study, we apply a static computable general equilibrium (CGE) model to investigate the economic repercussions of electric vehicle production in Toyohashi city in Japan. The results demonstrate that after launching electric vehicles, the total industrial output shows only a slight increase. However GDP in automobile industry depicts a relatively large rise. This is due to the fact that the number of parts decreases in automobile industry resulting in a higher gross value added rate. This leads to a growth in the total GDP of Toyohashi city, and a rise in demand for labor. The increase in labor demand may contribute to the current imbalance in Toyohashi city's labor market, however, that increase reduces the household leisure time resulting in welfare loss. Among others non-ferrous metal manufacturing industry gets a significant positive impact, suggesting a new industrial structure to cope with a low-carbon society.

**Keywords:** electric vehicle (EV), CGE model, Toyohashi city, green house gas, smart grid

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## **1. Introduction**

"Global warming", "climate change", and the "greenhouse effect" are common expressions used to describe the threat to human and natural systems resulting from continued emissions of "greenhouse" gases (GHGs)<sup>1</sup> from human activities. Having some amount of greenhouse gases is beneficial. Without them, the average temperature of the Earth's surface would be right around 0 °F-not a very nice place to live. Greenhouse gases also help keep

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<sup>1</sup>GHG is a gas in the atmosphere that absorbs and emits radiations within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. The primary GHG gases in the Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

the Earth's surface at a much more hospitable average temperature—almost 59 °F (Al Gore, 2006). However, the recovery, handling and combustion of the Earth's finite supply of fossil fuels<sup>2</sup> are damaging environment (Laurence O. Williams, 2002), and in the absence of an abrupt shift to non-fossil energy sources, global temperature rise and its attendant impacts are predicted to become increasingly problematic over the coming decades. Thus, since the later half of the 1980s, global warming has been a prominent concern in international policies. As one of the world's leading industrial economies, Japan contributes a significant share, and has accounted for a significant historical share of the emissions that have led to global temperature increases (see Figure 1). As such, it is imperative that Japan, as well as other industrial countries, adopt policies to reduce so called "greenhouse gas" emissions. Japan had set an object that during 2008 to 2010 and by 2020, GHG emissions will be slashed 6% and 25%, respectively. When we talk about greenhouse gases and climate change, carbon dioxide usually gets the most attention. CO<sub>2</sub> usually gets top billing in this because it accounts for 80 % of total greenhouse gas emissions (Al Gore, 2006). Thus CO<sub>2</sub> emissions diminution has become one of the main priorities, as in Japan also the biggest contribution of global warming is CO<sub>2</sub>.

Japan's emissions associated with the energy transformation sectors are estimated to be over 30 percent (including indirect emissions) of Japan's total national CO<sub>2</sub> emissions. As a consequence, substantial efforts to reduce GHG emissions in the power sector—which accounts for over half of energy transformation emissions—could have a significant impact on climate change mitigation in Japan<sup>3</sup>. Besides, the recent nuclear crisis due to the Great East earth quake in Japan encouraged the government of Japan to set numerical goal to power switch by increasing renewable energy's share of the overall electricity power supply to 20 % "as early as possible in the 2020s" and decentralized electricity generations in the local areas. Therefore, it is imperative to consider switching to less carbon-intensive fuels or renewable sources of energies, especially solar energies, and to popularize them to use in each domestic sector in the suburban areas in Japan to reduce the total CO<sub>2</sub> emissions.

The reason of directing the suburban city comes from an influential study in "Cities and Automobile Dependence: An International Sourcebook". It shows that the denser urban areas in the developed countries have a greater mixture of land use and lower car dependency, illustrating a trend to lower energy consumption and emissions (Newman and Jeff Kenworthy, 1989). However, the suburban cities in the developed countries including Japan have a common trend of high car dependency, thus increasing energy consumption and emissions.

Thus, in order to reduce CO<sub>2</sub> emissions especial focus on the suburban areas, this research takes vehicle as the subject and is dedicated to introduce electric vehicles and a low carbon society in Toyohashi city (one of the suburban cities) in Japan as the study region. The reason of choosing the transportation sector is that this sector accounts for about 23% of the total CO<sub>2</sub> emissions which are continuously increasing (see Figure 2), and there are lot of motor vehicle related factories in this city.

Although it is assumed that the electric vehicles will significantly impact on reducing CO<sub>2</sub> emissions, a proper economic assessment of introduction of electric vehicle manufacturing is imperative. The reason is that economic growth has taken priority due to the shrink of Japan's economic growths of 1.2% in 2008 and 5.0% in 2009. And it is also expected that the rapid appreciation of Japanese yen against foreign currencies, and production and export growth will slowdown due to the recent big earth quake hit in March 11 in 2011 in Japan. Therefore, the economic impact of electric vehicle production is worth examining considering the current Japanese situation.

The organization of this article is as follows: Sections 2 explains the structure of the model with mathematical formulation. Section 3 presents a comparison of electric and gasoline vehicles. Section 4 describes the economic-

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<sup>2</sup>the term "fossil fuels" encompasses a spectrum of mineral organic compounds extracted from the earth. They range from solids to liquids and gases. They include coal, petroleum, shale oil, tar sands and natural gas. All fossil fuels produce carbon dioxide, a greenhouse gas, when burned. When there is insufficient air all fossil fuels produce highly toxic carbon monoxide.

<sup>3</sup>Masami Nakata *et, al* (2003), Carbon Dioxide Emissions Reduction Potential in Japan's Power Sector —Estimating Carbon Emissions Avoided by a Fuel-Switch Scenario

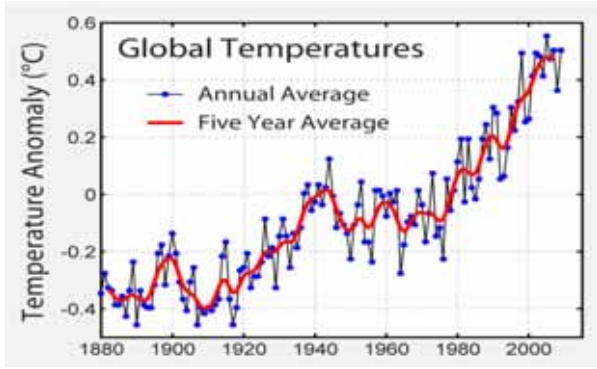


Figure 1. Average Global Temperature to Rise

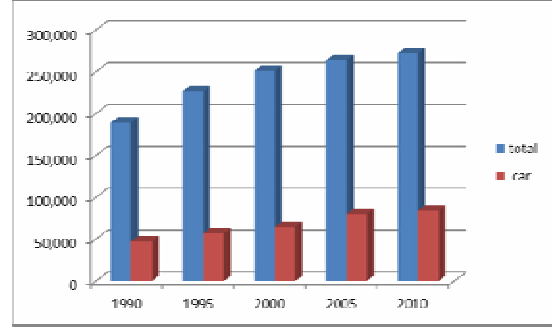


Figure 2. Increasing Number of Vehicles in Toyohashi

accounting matrix of Toyohashi City. Section 5 discusses parameters setting and simulation cases. Section 6 summarizes simulation results. Finally Section 7 presents the concluding remarks with future study.

## 2. The Model

### 2.1 Assumptions of the Model

Main assumptions made in our model are as follows:

- (1) 2005 Toyohashi city's economy is examined. Economic agents are households, firms in 31 industries, the government and the external sector.
- (2) 33 markets are considered. They are 31 commodity markets, one labor market and one capital market. These are assumed to be perfectly competitive, and in equilibrium in 2005.

Table 1. Classification of Industries

industries	industries
1. agriculture, forestry, & fishery	17. electronic components
2. mining	18. automobile
3. beverages and Foods	19. aircraft
4. textile	20. other transportation equipment
5. pulp, paper and wooden	21. precision instruments
6. chemical	22. other manufactured
7. petroleum and coal	23. construction
8. plastics	24. electricity, gas and heat supply
9. ceramics	25. water supply and waste disposal business
10. other ceramic, stone and clay	26. commerce
11. iron and steel	27. finance and insurance
12. non-ferrous metals	28. real estate
13. metal products	29. transport
14. general machinery	30. information and communications
15. electrical machinery	31. services
16. information and communication electronics equipment	

### 2.2 Industries

In industries intermediate input, labor and capital are invested to produce goods. Industries have *Leontief* technology with respect to intermediate input and value added inputs, and *Cobb-Douglas* technology for both intermediate inputs, and labor and capital inputs (see Figure 3).

Due to homogeneity in production technology, industries' behavior becomes cost minimization under the given commodity demands and prices, which can be written as,

$$\min \sum_{i=1}^{31} p_i x_{ij} + (1 + tp_j)(wL_j + rK_j) \quad (j=1, \dots, 31) \quad (1)$$

with respect to  $X_{ij}$ ,  $L_j$  and  $K_j$   
subject to

$$X_j = \min \left[ \frac{1}{a_{10j}} f_j(L_j, K_j), \frac{x_{1j}}{a_{1j}}, \dots, \frac{x_{31j}}{a_{31j}} \right] \quad (2)$$

$$f_j(L_j, K_j) \equiv A_{1j} L_j^{\alpha_j} K_j^{(1-\alpha_j)} \quad (3)$$

where

$p_i$ : price of commodity  $i$

$x_{ij}$ : intermediate input of industry  $i$ 's product in industry  $j$

$tp_j$ : net indirect tax rate imposed on industry  $j$ 's product (indirect tax rate - subsidy rate)

$w$ : wage rate

$r$ : capital return rate

$L_j$ : labor input in industry  $j$

$K_j$ : capital input in industry  $j$

$X_j$ : output in industry  $j$

$a_{0j}$ : value added rate in industry  $j$

$a_{ij}$ : share parameter on intermediate input  $x_{ij}$

$A_{ij}, \alpha_{ij}$ : technical parameters in industry  $j$

Cost minimization problem (1) to (3) yields conditional demands for intermediate goods, labor, and capital in production process.

$$X_{ij} = a_{ij} X_j \quad (4)$$

$$LD_j = \left[ \frac{(1-\alpha_j)r}{\alpha_j w} \right]^{\alpha_j} \frac{a_{0j} X_j}{A_j} \quad (5)$$

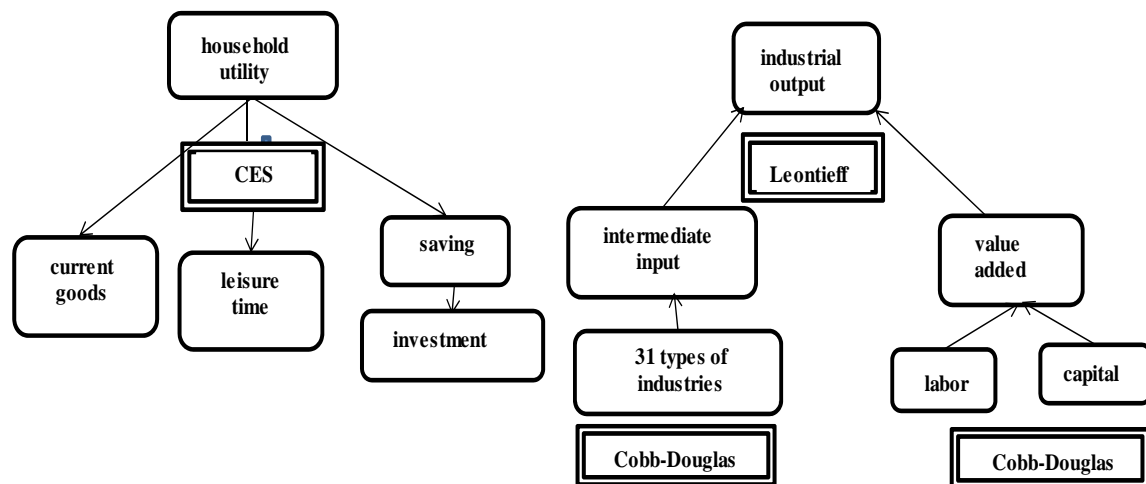


Figure 3. Hierarchical Structure of the Model

$$KD_j = \left[ \frac{a_j w}{(1-a_j)^r} \right]^{(1-a_j)} \frac{a_{0j} X_j}{A_j} \quad (6)$$

where

$LD_j$  : conditional demand for labor in industry  $j$

$KD_j$  : conditional capital demand in industry  $j$

Zero profit condition is realized in industries under perfect competition.

$$profit = p_j X_j - \sum_{i=1}^{31} p_i x_{ij} - (1+tp_j)[w.LD_j + r.KD_j] = 0 \quad (7)$$

### 2.3 Households

Households in Toyohashi city are assumed to be homogeneous with the fixed number of households. Thus one can consider that households share an aggregate single utility function. Households share a *CES* utility function of the current and future goods. Here the current good is defined as a *CES* composite of current consumption goods and leisure time, while the future good is derived from saving.

Households choose a bundle of the current and future goods so as to maximize the utility function with a budget constraint. Then the present good is divided into a composite consumption good and a leisure time (labor supply).

Household income consists of full wage income, which is obtained when households supply their full labor endowment, capital income after capital depreciation, current transfers from the government, labor income, property income, and other current transfers from the external sector. A part of household wage income and capital income is transferred to the external sector.

Household direct tax is imposed on the after current transfers income. Then households are assumed to allocate their after direct tax income on present and future goods. Here direct tax is supposed to include all current transfers from households to the government for simplicity.

To explain the household behavior, first, derivation of future good is described here. The future good implies the future consumption which derived from household saving, however, the saving formulates capital investment. Therefore capital good can be regarded as saving good. Investment is made by using produced goods, and let

their portions in investment be denoted by  $b_i$ . Denoting the price of investment good by  $p_I$ ,  $p_I I = \sum_{i=1}^{31} p_i I_i$  is

realized. Then the price of investment good is expressed as  $p_I = \sum_{i=1}^{31} b_i p_i$ . This can be regarded as the price of

saving good  $p_s$ .

Since the capital returns after direct tax by a unit of capital injection is expressed by  $(1-ty)(1-k_o)(1-k_r)r\delta$ , the expected return rate of the price of saving good  $p_s$ , that is, the expected net return rate of household saving  $r_s$  is written as follows:

$$r_s = (1-ty)(1-k_r)r\delta / p_s \quad (8)$$

where

$ty$  : direct tax rate imposed on households

$k_o$  : rate of transfer of property income to the external sector

$k_r$  : capital depreciation rate

$\delta$  : ratio of capital stock measured by physical commodity unit to that by capital service unit

It is assumed that the expected returns of saving finance the future consumption. Regarding the price of future good as the price of the present consumption good under the myopic expectation, and denoting the household real saving by  $S$ , the following equation holds.

$$p \cdot H = (1 - ty)(1 - k_o)(1 - k_r)r\delta \cdot S \quad (9)$$

This yields  $[p_s p / (1 - ty)(1 - k_o)(1 - k_r)r\delta]H = p_s S$ , and setting the price of future good  $p_H$  associated with the real saving  $S$  as;

$$p_H = p_s p / (1 - ty)(1 - k_o)(1 - k_r)r\delta \quad (10)$$

Then  $p_s S = p_H H$  is realized.

Employing the above-mentioned future good and its price, household utility maximization problem is now specified in the following. Regarding current good, it will be described in a later part.

$$\max_{G,H} u(G,H) \equiv \{ \alpha^{1/v_1} G^{(v_1-1)/v_1} + (1 - \alpha)^{1/v_1} H^{(v_1-1)/v_1} \}^{v_1/(v_1-1)} \quad (11)$$

subject to

$$p_G \cdot G + p_H \cdot H = (1 - ty)FI - TrHO \quad (12)$$

$$FI \equiv (1 - l_o)w \cdot E + LI + (1 - k_o)(1 - k_r)r \cdot KS + KI + TrGH + TrOH \quad (13)$$

where

$\alpha$  : share parameter

$v_1$  : elasticity of substitution between the current good and future good

$G$  : household present consumption

$H$  : household future consumption

$p_G$  : price of current good

$p_H$  : price of future good

$FI$  : household full income

$TrHO$  : current transfers from households to the external sector

$l_o$  : rate of labor income transferred to the external sector

$E$  : household initial labor endowment, which is set up as the double of real working time. This is based on the actual working time and leisure time in Toyohashi city.

$LI$  : labor income transferred from the external sector to households (exogenous variable)

$KS$  : initial capital stock endowed by households

$KI$  : property income transferred from the external sector to households (exogenous variable)

$TrGH$  : current transfers from the government to households

$TrOH$  : current transfers from the external sector to households

Solving this utility maximization problem, demand functions for present and future goods are obtained yielding a household saving function.

$$G = \frac{\alpha[(1 - ty)FI - TrHO]}{p_G^{v_1} \cdot \Delta} \quad (14)$$

$$H = \frac{(1 - \alpha)[(1 - ty)FI - TrHO]}{p_H^{v_1} \cdot \Delta} \quad (15)$$

$$S = p_H H / p_s \quad (16)$$

$$\Delta \equiv \alpha p_G^{1-v_1} + (1-\alpha) p_H^{1-v_1} \quad (17)$$

Then we describe the derivation of demands for composite consumption and leisure time from the current good  $G$ . The current good  $G$  is a composite of consumption and leisure time, and  $G$  is obtained from the following optimization problem.

$$\max_{C,F} G \equiv \{ \beta^{1/v_2} C^{(v_2-1)/v_2} + (1-\beta)^{1/v_2} F^{(v_2-1)/v_2} \}^{v_2/(v_2-1)} \quad (18)$$

subject to

$$p \cdot C + (1-ty)(1-l_o)w \cdot F = (1-ty)FI - TrHO - SH \quad (19)$$

where

$\beta$ : share parameter

$v_2$ : elasticity of substitution between composite consumption and leisure time

$C$ : composite consumption

$F$ : leisure time

$p$ : price of composite consumption good

$SH$ : household nominal saving (=  $P_s \cdot S$ )

Solving this utility maximization problem, demand functions for composite consumption, leisure time, and labor supply are obtained.

$$C = \frac{\beta[(1-ty)FI - TrHO - SH]}{p^{v_2} \cdot \Omega} \quad (20)$$

$$F = \frac{(1-\beta)[(1-ty)FI - TrHO - SH]}{[(1-ty)(1-l_o)w]^{v_2} \cdot \Omega} \quad (21)$$

$$LS = E - F \quad (22)$$

$$\Omega = \beta p^{(1-v_2)} + (1-\beta)[(1-ty)(1-l_o)w]^{(1-v_2)} \quad (23)$$

where  $LS$ : household labor supply

Substituting composite consumption (20) and leisure time (21) into (18), the price index of the present good is derived as follows:

$$p_G = \{ \beta p^{1-v_2} + (1-\beta)[(1-ty)(1-l_o)w]^{1-v_2} \}^{1/(v_2-1)} \quad (24)$$

Moreover, composite consumption good is disaggregated into produced goods through the maximization of a *Cobb-Douglas* sub-sub utility function given the household income and leisure time.

$$\max C \equiv \prod_{i=1}^{31} C_i^{\gamma_i} \quad \left( \sum_{i=1}^8 \gamma_i = 1 \right) \quad (25)$$

subject to

$$\sum_{i=1}^{31} p_i \cdot C_i = (1-ty)Y - TrHO - SH \quad (26)$$



where

$C_i$  : household consumption good produced by industry  $i$

$p_i$  : price of good  $i$

$Y$  : household income ( $= (1-l_o)w \cdot LS + LI + (1-k_o)r \cdot KS + KI + TrGH + TrOH$ )

From this optimization problem, consumption good  $i$  is derived.

$$C_i = \frac{\gamma_i}{p_i} [(1-ty)Y - TrHO - SH] \quad (i = 1, \dots, 31) \quad (27)$$

The price of composite consumption is calculated as follows:

$$p = \prod_{i=1}^{31} \left[ \frac{p_i}{\gamma_i} \right]^{\gamma_i} \quad (28)$$

## 2.4 The Government

The government obtains its income from direct and net indirect taxes of Toyohashi city, and current transfers from the external sector, and then it expends the income on government consumption, current transfers to households, and current transfers to the external sector. The difference between income and expenditures are saved. Nominal consumption expenditures on commodities/services are assumed to be proportional to the government revenue with constant sectorial share. These are expressed as the following balance of payments.

$$\sum_{i=1}^{31} p_i \cdot CG_i + TrGH + TrGO + SG = ty \cdot Y + \sum_{i=1}^{31} tp_i (w \cdot LD_i + r \cdot KD_i) + TrOG \quad (29)$$

where

$CG_i$  : government consumption expenditures on commodity  $i$

$TrGH$  : current transfers to households

$TrGO$  : current transfers to the external sector

$SG$  : government savings

$TrOG$  : current transfers from the external sector

## 2.5 The External Sector

The external sector gains its income from Toyohashi city's imports, current transfers from the government, labor income transfers, and property income transfers. And then it expends the income on exports and transfer of Toyohashi, current transfers to households and the government, labor (employees to the city of Toyohashi) and property income transfers. These are also described as the following balance of payments.

$$\sum_{i=1}^{31} p_i \cdot EX_i + TrOH + TrOG + KI + LI + SO = \sum_{i=1}^{31} p_i \cdot EM_i + TrHO + TrGO + KIO + LIO \quad (30)$$

where

$EX_i$  : export of commodity  $i$

$EM_i$  : import of commodity  $i$

$SO$  : savings of the external sector (=national current surplus)

$LIO$  : labor income transfers to the external sector ( $= l_o \cdot w \cdot LS$ )

$KIO$  : property income transfers to the external sector ( $= k_o \cdot r \cdot KS$ )

## 2.6 Balance of Investment and Saving

Household, government, area department's savings, the total consumption of fixed capital, which determines the total investment.

$$\sum_{i=1}^{31} p_i \cdot I_i = SH + SG + SO + \sum_{i=1}^{31} DR_i \quad (31)$$

where

$I_i$ : demand for commodity  $i$  by other investments

$DR_i$ : consumption of fixed capital amount of industry  $i$

## 2.7 Prices

Cost consists of the following is derived from the Zero profit condition of the industry.

$$p_j X_j = \sum_{i=1}^{31} p_i x_{ij} + (1 + tp_j)[w \cdot LD_j + r \cdot KD_j] \quad (j = 1, \dots, 31) \quad (32)$$

Given a wage and a capital return rate, we can formally calculate commodity prices as follows:

$$P = (I - A')^{-1}[(1 + tp_j)(w \cdot ld_j + r \cdot kd_j)] \quad (33)$$

where

$P$ : vector of commodity prices

$A'$ : transposed matrix of industries' input coefficients

$[\cdot]$ : column vector whose elements are in parentheses

$ld_j = LD_j / X_j$  and  $kd_j = KD_j / X_j$

## 2.8 Derivation of Equilibrium

In this model there are 31 industries, and 33 markets including labor and capital markets. The equilibrium condition in the model can be summarized as follows

*Commodity market*

$$\begin{bmatrix} X_1 \\ \vdots \\ X_{31} \end{bmatrix} = \begin{bmatrix} a_{11} & \cdots & a_{131} \\ \vdots & \ddots & \vdots \\ a_{311} & \cdots & a_{3131} \end{bmatrix} \begin{bmatrix} X_1 \\ \vdots \\ X_{31} \end{bmatrix} + \begin{bmatrix} C_1 \\ \vdots \\ C_{31} \end{bmatrix} + \begin{bmatrix} CG_1 \\ \vdots \\ CG_{31} \end{bmatrix} + \begin{bmatrix} I_1 \\ \vdots \\ I_{31} \end{bmatrix} + \begin{bmatrix} EX_1 \\ \vdots \\ EX_{31} \end{bmatrix} - \begin{bmatrix} EM_1 \\ \vdots \\ EM_{31} \end{bmatrix} \quad (34)$$

*Labor market*

$$LS = \sum_{j=1}^{31} LD_j \quad (35)$$

*Capital rental market*

$$KS = \sum_{j=1}^{31} KD_j \quad (36)$$

To solve all the endogenous variables of the study, it requires a model of all formulas, expression alone is insufficient to balance. Walras law in this study is, Total value of excess demand for labor - Total value of the excess demand of capital = 0. In numerical computation, iteration for the equilibrium prices is made on the capital return rate letting labor be the numeraire ( $w=1$ ).

### 3. Comparison of Electric and Gasoline Vehicles

From the outside, the electric vehicle looks like a gasoline-powered vehicle with the exception that the electric vehicle does not have a tail pipe. However, internally, it is quite a different story. The electric vehicle has several unique components that serve the same function as the more common components in a gasoline powered vehicle. Another significant difference between electric vehicles and gasoline-powered vehicles is the number of moving parts (see Figure 4).

- The electric vehicle has one moving part, the motor, whereas the gasoline-powered vehicle has hundreds of moving parts. Fewer moving parts in the electric vehicle lead to another important difference. The electric vehicle requires less periodic maintenance and is more reliable. The gasoline-powered vehicle requires a wide range of maintenance, from frequent oil changes, filter replacements, periodic tune ups, and exhaust system repairs, to the less frequent component replacement, such as the water pump, fuel pump, alternator, etc. The electric vehicle's maintenance requirements are fewer and therefore the maintenance costs are lower.

Not only difference in the number of parts and maintenance cost, compared with mainstream gasoline and diesel cars of today's car, a car equipped with electric vehicle has a great advantage in terms of energy efficiency and carbon dioxide emissions (see Figures 5 and 6). By using EV instead of gasoline vehicle can reduce energy consumption  $\frac{1}{3}$  and CO<sub>2</sub> emissions by  $\frac{1}{4}$ . Moreover, hybrid cars use gasoline, so there is no fundamental solution for reducing the CO<sub>2</sub> emissions. And fuel cell vehicle, a large amount of infrastructure costs for using hydrogen as a fuel, there is a problem of.

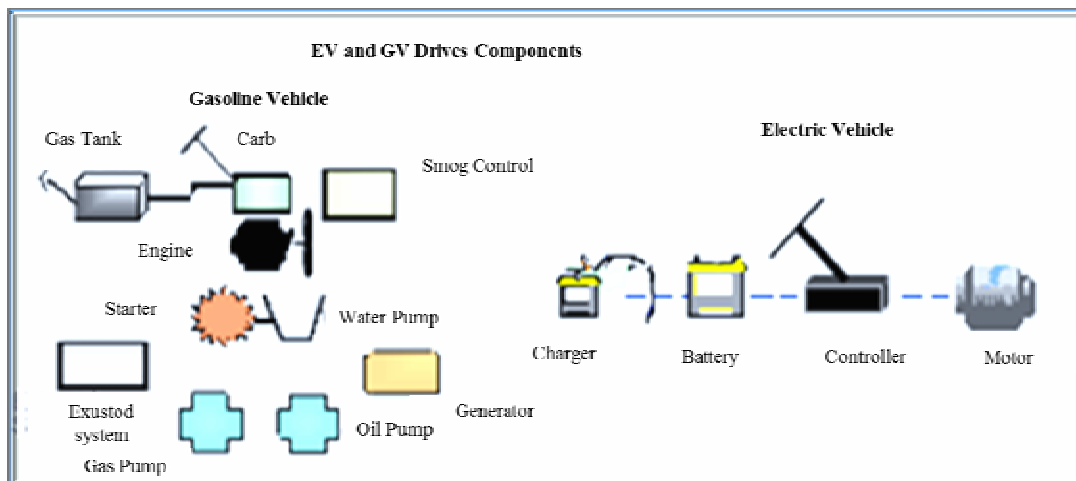


Figure 4. Gasoline and Electric Vehicles Components

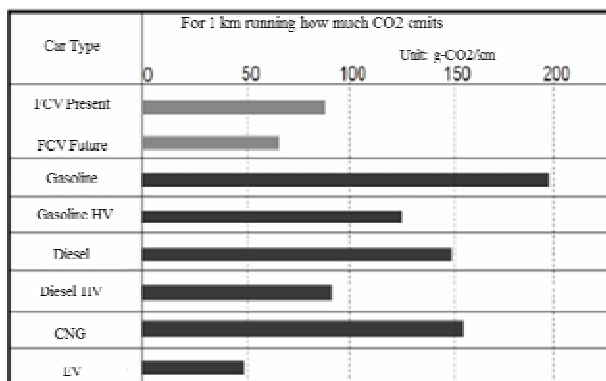


Figure 5. Well to Wheel CO<sub>2</sub> Emissions

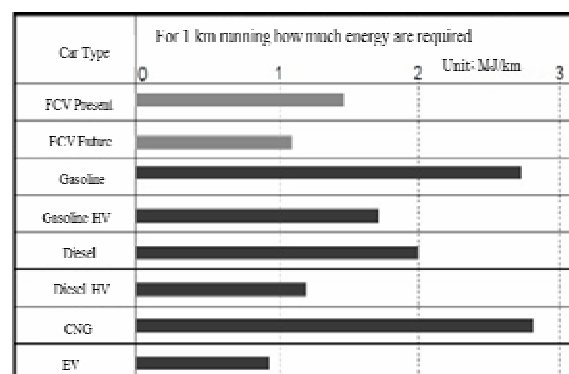
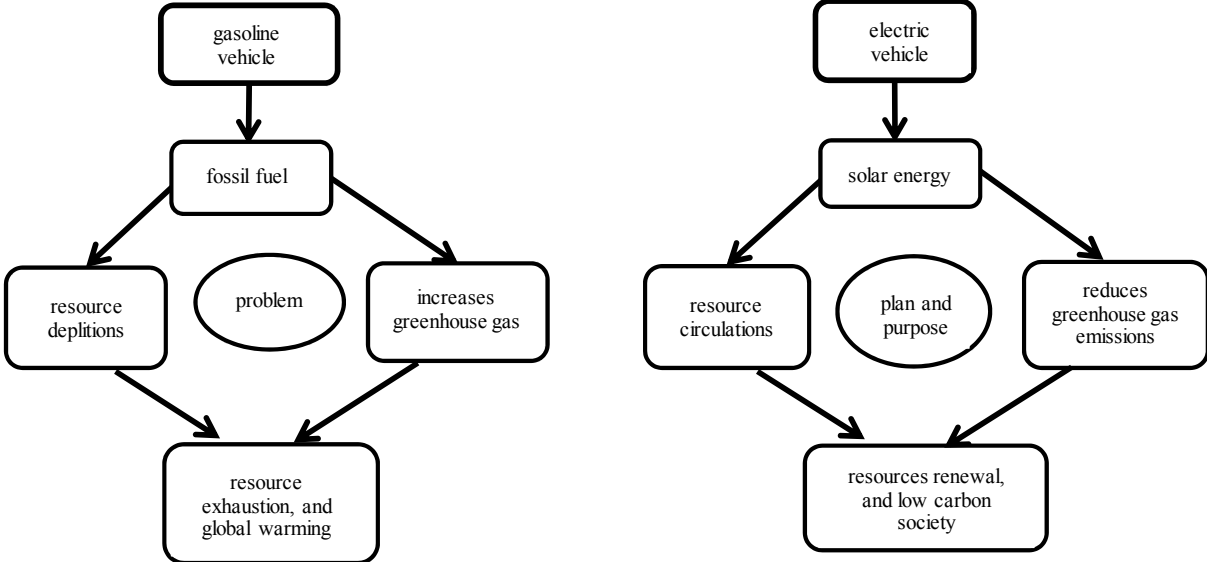


Figure 6. Well to Wheel Energy Consumption

Therefore, electric vehicle is considered the most potential to reduce environmental impacts when it will use renewable sources of energies, and electric vehicles among the next-generation vehicles. In general, electric vehicles, vehicles from the body during running, not CO<sub>2</sub> emissions, noise is very small, is said to be particularly good car in terms of environmental pollution.

In order to solve the environmental problems caused by the gasoline used vehicles, electric vehicle is an implication plan to ensure resource circulations in society, safety and security, and low carbon society (see Figure 7).



**Figure 7. Electric Vehicles to Reduce Emissions, and to Offer Low Carbon Society**

#### 4. Social Accounting Matrix of Toyohashi City

In this section we present a 2005 social accounting matrix of Toyohashi city in Table 2. This matrix was estimated based on Toyohashi city IO table which was estimated 2005 Aichi prefecture IO table. The social accounting matrix is usually applied as a bench mark data set in CGE modeling. In column and row, the same economic agents are located, and each cell in the matrix stands for monetary transaction between economic agents.

Looking at Table 2, we see that industries produce 3,152 billion of goods and services. By the production activities, capital income of 499 billion yen and labor income of 970 billion yen are yielded. The government sector obtains its income of 568 billion yen from direct taxes, net indirect taxes and current transfers. Households get income of 1,617 billion yen and spend a part of income on consumption of 935 billion yen.

**Table 2. Social-Accounting Matrix of Toyohashi City in Japan**

economic sectors (in million yen)		production activities	institution		production factors		capital accumulation	external sector	total
		31 industries	government	households	capital	labor			
production activities	31 industries	1,298,045	230,576	934,725	0	0	437,666	251,395	3,152,407
institution	government	115,703	0	352,756	0	0	0	99,526	567,985
	households	0	162,866	0	446,247	920,522	0	87,165	1,616,800
production factors	capital	498,892	0	0	0	0	0	0	498,892
	labor	922,275	0	0	0	0	0	48,129	970,404
capital finance		317,492	4,302	296,854	0	0	0	0	618,648
external sector		0	170,241	32,465	52,645	49,882	180,982	0	486,215
total		3,152,407	567,985	1,616,800	498,892	970,404	618,648	486,215	8,019,616

#### 5. Parameter Setting and Simulation Cases

##### 5.1. Parameter Setting

For numerical experiments, it is necessary to estimate parameters in functions specified in the model. Parameters in the model are calibrated by employing 2005 actual data of Toyohashi city IO table. The technological parameters in the production functions in industries are specified as Leontief-Cobb-Douglas type, they can easily be estimated by applying the benchmark data set in a usual CGE- modeling framework. The detailed results of parameter estimation are beyond the scope of this paper, therefore, they are skipped.

For the parameter in the utility function, estimation of them is made in a standard way with results shown in Table 3 though the description of the estimation method is skipped as well.

**Table 3. Parameters of Utility Function**

	share parameter
current good	0.78153
future good	0.21847
elasticity of substitution between present and future goods	1.11836
composite consumption	0.52393
leisure	0.47607
elasticity of substitution between composite consumption and leisure time	0.91135

**Table 4. Technical Parameters for Production Function**

industries	rate of value added	efficiency parameter	capital elasticity	labor elasticity
1. agriculture,forestry & fishery	0.54250	1.85774	0.76844	0.23156
2. mining	0.52493	2.24504	0.51748	0.48252
3. beverages and Foods	0.37347	2.44360	0.53752	0.46248
4. textile	0.44729	1.89617	0.21811	0.78189
5. pulp, paper & wooden.	0.43692	2.17002	0.45506	0.54494
6. chemical	0.44717	2.12609	0.61944	0.38056
7. petroleum & coal	0.69676	12.54227	0.65693	0.34307
8. plastics	0.39447	2.11464	0.42606	0.57394
9. ceramics	0.52135	2.17613	0.37122	0.62878
10. other ceramic, stone & clay	0.54631	2.18191	0.52955	0.47045
11. iron and steel	0.29284	2.12529	0.64707	0.35293
12. non-ferrous metal	0.24569	2.19278	0.38253	0.61747
13. metal products	0.46425	2.12257	0.41636	0.58364
14. general machinery	0.48651	2.09038	0.42835	0.57165
15. electrical machinery	0.38780	2.01637	0.36170	0.63830
16. information & communication electronic equipments	0.35981	1.96358	0.69293	0.30707
17. electronic components	0.37254	2.08861	0.55874	0.44126
18. automobile	0.33573	2.02733	0.33258	0.66742
19. aircraft	0.56385	2.05034	0.54168	0.45832
20. other transportation equipment	0.41111	2.09707	0.49222	0.50778
21. precision instruments	0.50591	2.06249	0.36506	0.63494
22. other manufactured	0.50999	2.15192	0.48287	0.51713
23. construction	0.54750	1.73733	0.19116	0.80884
24. electricity, gas & heat supply	0.49900	2.23893	0.62657	0.37343
25. water supply & waste disposal business	0.72940	2.06080	0.51022	0.48978
26. commerce	0.76535	2.09243	0.49384	0.50616
27. finance and insuance	0.71016	1.99127	0.62895	0.37105
28. realestate	0.89483	1.31194	0.94485	0.55150
29. transport	0.54837	2.05486	0.33464	0.66536
30. information & communications	0.70941	2.09228	0.57138	0.42862
31. services	0.72032	1.99349	0.36644	0.63356

**Table 5. Composite Commodity Consumption Elasticity Parameter**

industries	composite commodity consumption elasticity parameter
1. agriculture,forestry & fishery	0.03276
2. mining	0.00000
3. everages & Foods	0.10499
4. textile	0.01229
5. pulp, paper & wooden.	0.00220
6. chemical	0.00440
7. petroleum & coal	0.02698
8. plastics	0.00214
9. ceramics	0.00022
10. other ceramic, stone & clay	0.00094
11. iron & steel	0.00000
12. non-ferrous metal	0.00185
13. metal products	0.00069
14. general machinery	0.00008
15. eectrical machinery	0.00796
16. information & communication electronic equipment	0.00311
17. electronic components	0.00025
18. automobile	0.00733
19. aircraft	0.00000
20. other transportation equipment	0.00008
21. precision instruments	0.00087
22. other manufactured	0.01278
23. construction	0.00000
24. electricity, gas and heat supply	0.02355
25. water supply & waste disposal business	0.00340
26. commerce	0.14922
27. finance& insuance	0.06186
28. realestate	0.16440
29. transport	0.04397
30. information & communications	0.01989
31. services	0.31179

## 5.2. Simulation Analysis

In this section, two cases are simulated and they are as follows:

- (1) Business as usual case (Base case)
- (2) Case 1 (where 100% electric vehicles are produced)

Base case assumes that the automobile industry in Toyohashi city produces motor vehicles following the current system, i.e. most of produced vehicles are gasoline vehicles. Case 1 assumes that the automobile industry produces 100% electric vehicles. The difference between the two cases is input coefficients in IO table of Toyohashi city. Table 6 illustrates input coefficients in gasoline and electric vehicle sectors. The simulation is conducted by changing the input coefficients.

**Table 6. Input Coefficients in Gasoline and Electric Vehicle Sectors**

industries	gasoline car	electric car
1. agriculture, forestry & fishery	0	0
2. mining	0	0
3. beverages & Foods	0	0
4. textile	0.004	0.003
5. pulp, paper & wooden.	0.00005	0.00005
6. chemical	0.004	0.003
7. petroleum & coal	0.001	0.001
8. plastics	0.032	0.025
9. ceramics	0	0
10. other ceramic, stone & clay	0.016	0.015
11. iron & steel	0.07	0.07
12. non-ferrous metal	0.003	0.004
13. metal products	0.001	0.001
14. general machinery	0.002	0.002
15. electrical machinery	0.048	0.03
16. information & communication electronic equipment	0.000048	0.000048
17. electronic components	0.000096	0.000096
18. automobile	0.605	0.35
19. aircraft	0	0
20. other transportation equipment	0	0
21. precision instruments	0.0004423	0.0004423
22. other manufactured	0.0009	0.0009
23. construction	0.001	0.001
24. electricity, gas and heat supply	0.005	0.01
25. water supply & waste disposal business	0.001	0.001
26. commerce	0.016	0.016
27. finance & insurance	0.008	0.008
28. real estate	0.001	0.001
29. transport	0.016	0.02
30. information & communications	0.002	0.002
31. services	0.072	0.072



## 6. Simulation Result

In this section we present the simulation results referring to some important economic variables.

### 6.1. Amount of Industrial Production

Changes in industrial outputs are shown in Figures 8 and 9. Large output level is found in sectors of service, commerce, automobile and construction, and one can see that automobile related industries are large in Toyohashi city because Toyota Motor Company is located near Toyohashi city. After electric vehicles being put into operation, the total industrial output slightly increases. Particularly a large increase is found in non-ferrous metals (increase rate of 74.1%), because a lot of non-ferrous metals are necessary for producing batteries used in electric vehicles. Increases in outputs are also found in mining (10.3%), construction (9.4%), precision machine (7.0%), general machine (5.6%) and electricity, gas and heat supply (4.8%). The increase in output of non-ferrous metals might be a little large, but actually the batteries used in electric vehicles should be much produced demanding a lot of non-ferrous metals. This result has also been confirmed by the input-output analysis of Japan's economy, and can be concluded as that it is qualitatively plausible.

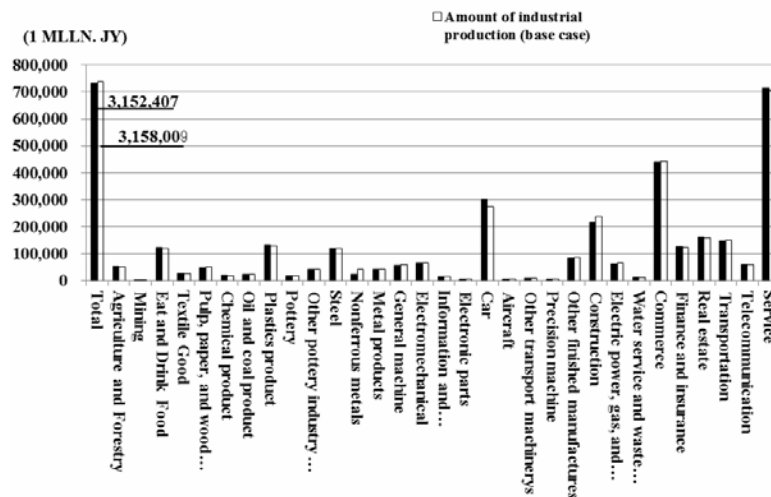


Figure 8. Amount of Industrial Production

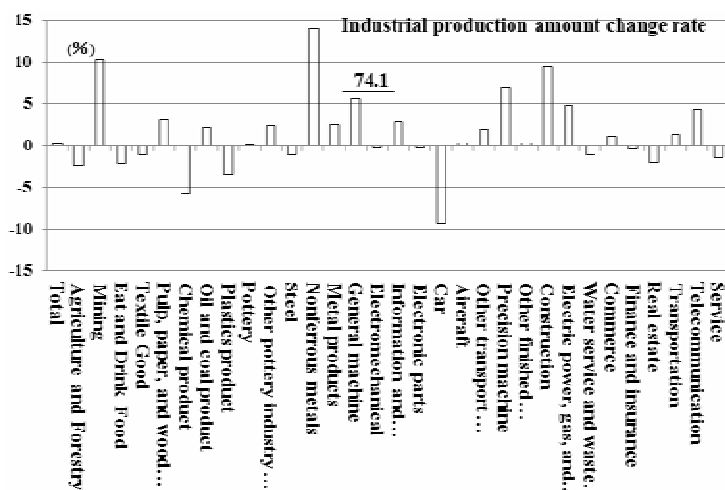


Figure 9. Change Rate of Industrial Outputs

The impact on mining is attributed to an increase in non-ferrous metal output. Regarding the impact on construction, the capital outflow from Toyohashi city decreases due to an increase in output of import oriented industries resulting in an increase in city savings. Thus the capital investment grows leading to an expansion in the construction sector. Increases in precision machine, general machine and electricity, gas and heat supply are obtained from the difference in the component of parts and/or processing in the electric vehicle production.

The output of automobile industry shows a decrease of -9.3%, and it is interesting. The reason is attributed to the fact of the less number of parts in electric vehicles. That is, the economic repercussion of producing electric vehicles on other relating industries becomes less as compared with gasoline vehicles. Producing electric vehicles once give a negative impact on Toyohashi's economy, but it suggests the necessity of transformation of the current industrial structure to compensate the negative impact.

## 6.2 City GDP

The city GDP is defined as gross value added in the city. As shown in Figures 10 and 11, the manner of changes in the city GDP's by sector is similar to that of industrial outputs. However of interesting is an increase in

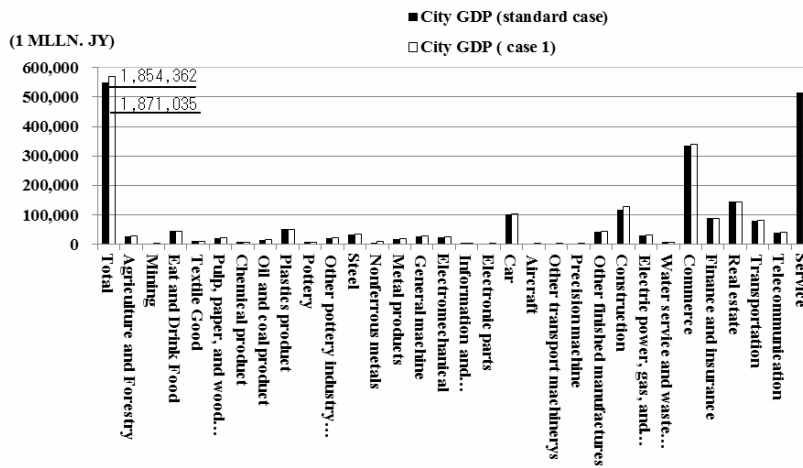


Figure 10. City GDP

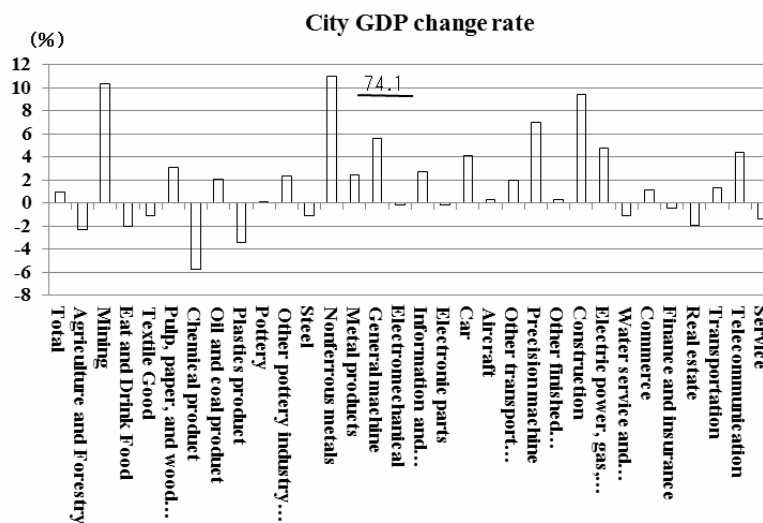


Figure 11. Change Rate of City GDP

GDP of automobile industry by 4.1%. This is because the value added rate in automobile industry rises resulting from the less number of parts is electric vehicles. Thus increases in wage rate and/or in firms profit are observed in electric vehicle production resulting in stimulus to household consumption expenditures as a general equilibrium effect, while the repercussion effect of gasoline vehicle manufacturing goes to automobile industry itself. However despite the fact of increases in wage income and operating surplus, the capital return rate shows a growth resulting from raises in demands for capital and labor. Thus commodity prices go up leading to a decrease in the real wage rate. And household consumption expenditures decrease due to the income effect caused by a fall in the real wage rate. However Toyohashi's total real GDP grows by 0.9%.

### 6.3. Labor Demand

Looking at changes in labor demands by sector in Figures 12 and 13, one can see that changes in labor demands are similar to those in GDP's by sector. That is, although the output of automobile industry shows a decrease, the labor demand in that industry depicts a rise of 4.3%. This is caused by an increase in the gross value added rate in automobile industry. The growth in the total labor demand shows 1.6% which is higher than 0.9% growth in the

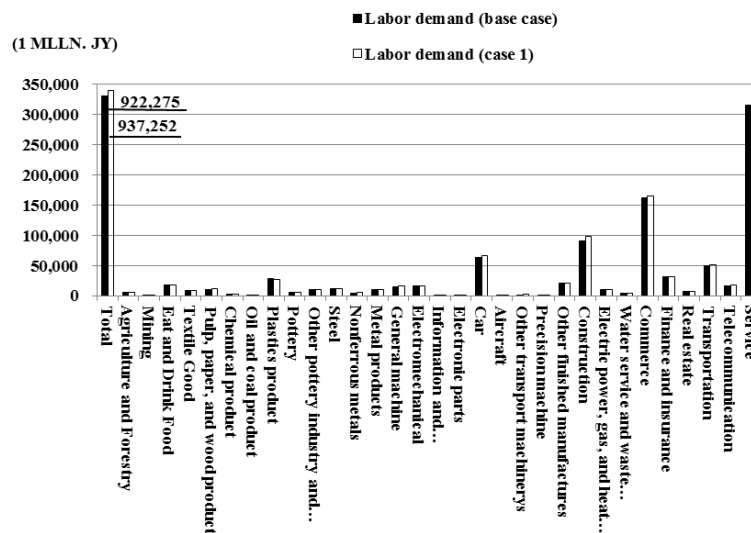


Figure 12. Labor Demand in Industries

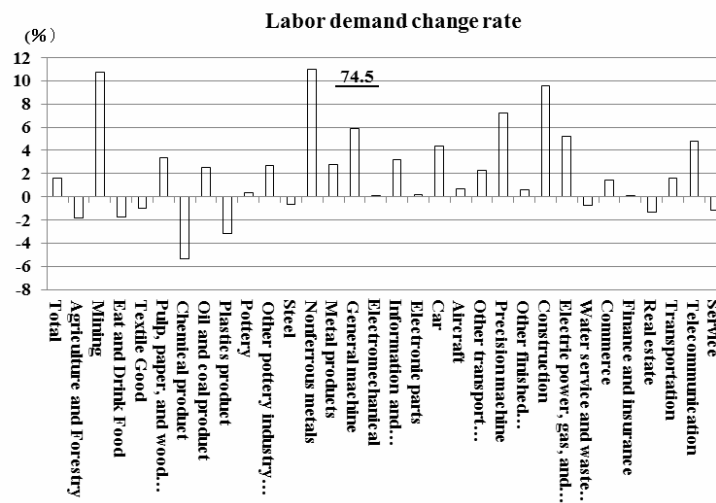


Figure 13. Change Rate of Labor Demand

real GDP. Taking into account the current serious situation of job opportunity in Toyohashi city, the increase in labor demand may be interpreted as a positive fact. However this reduces leisure time implying that the household utility would show a decrease in some case.

**6.4. Capital demand**

Since the total capital endowment by households is fixed in this model, the total demand for capital is not changed after the introduction of electric vehicles. Looking at changes in capital demand by industry in Figures 14 and 15, the manner of changes are similar to that of industrial GDP's. However due to the fixed capital supply, positive growths in capital demands by sector are slightly depressed, and negative growth are enhanced. Particularly the capital demand in automobile industry illustrates an increase of 3.6% while that of labor demand is 4.36% showing a slightly depressed rise.

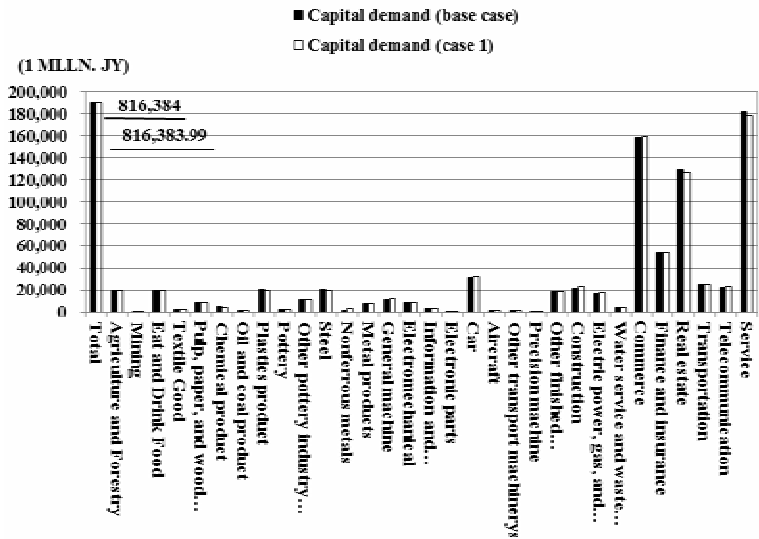


Figure 14. Capital Demand

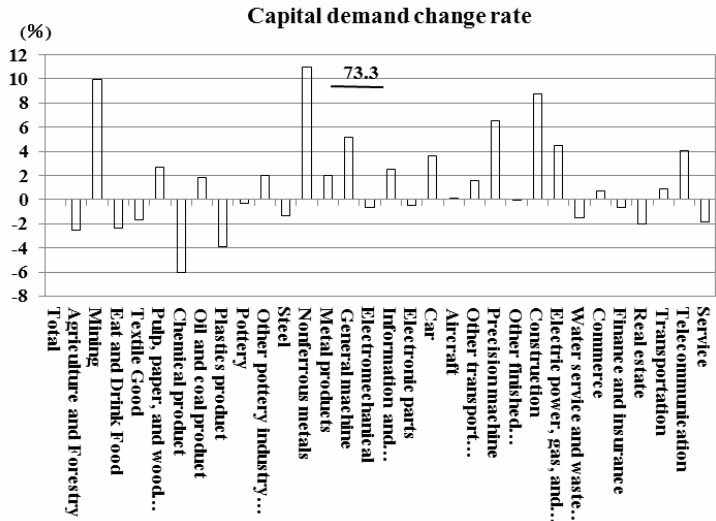
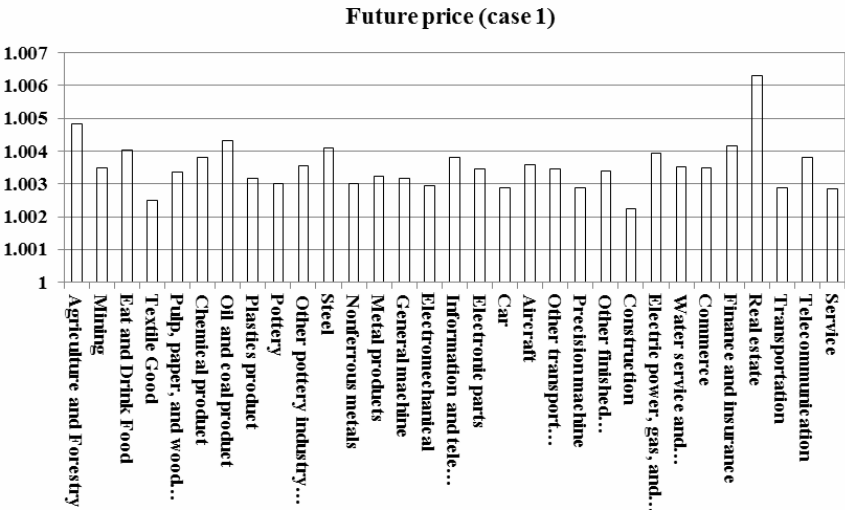


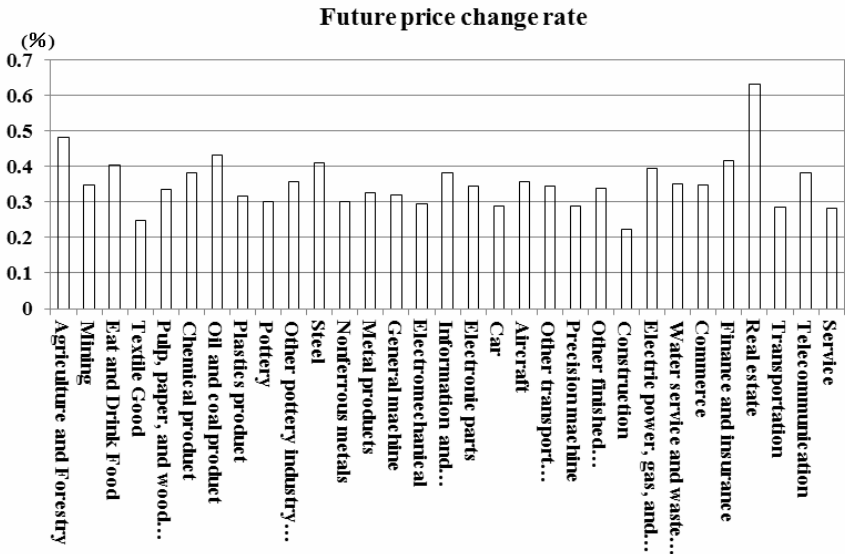
Figure 15. Change Rate of Capital Demand

**6.5. Commodity prices**

Commodity prices are determined by factor prices as presented by equation (33). Since the numerare is set up as labor in this model, the capital return rate is adjusted for equilibrating the markets. The capital return rate is determined so as to equilibrate the total capital supply and demand. After introducing the electric vehicle production, the demand for capital tends to increase resulting in an increase of 0.7% in the capital return rate. Reflecting this rise, all commodity prices go up ranging in the interval of 0.22% to 0.63%. Observing Figures 16 and 17, the highest up is 0.63% in real estate industry, while the lowest one is 0.22% in construction industry. This result is attributed to that the capital input ratio in real estate is largest across industries, and conversely in construction the large part of gross value added consists of labor income. In many cases, increases in commodity prices get lower the real wage rate leading to welfare loss.



**Figure 16. Commodity Prices**



**Figure 17. Change Rate of Commodity Prices**

### 6.6. Other variables

Let us look at Figures 18 and 19 to see changes in other variables. Large increase rates are found in the total investment, net indirect tax, labor supply, capital return rate and the price of composite consumption good. The reason of the large growth in the total investment is that outputs of import oriented industries grows, the capital outflow to the rest of the world decreases, and then finance to investment increases. The reason of the increase in indirect tax is due to a rise in the gross value added. The increase in the labor supply corresponds to a growth in the labor demand associated with up in the gross value added rate. The increase in the capital return rate is due to a growth in capital demand by an increase in the gross value added rate as well. The up in the price of composite consumption good results from the increase in the capital return rate.

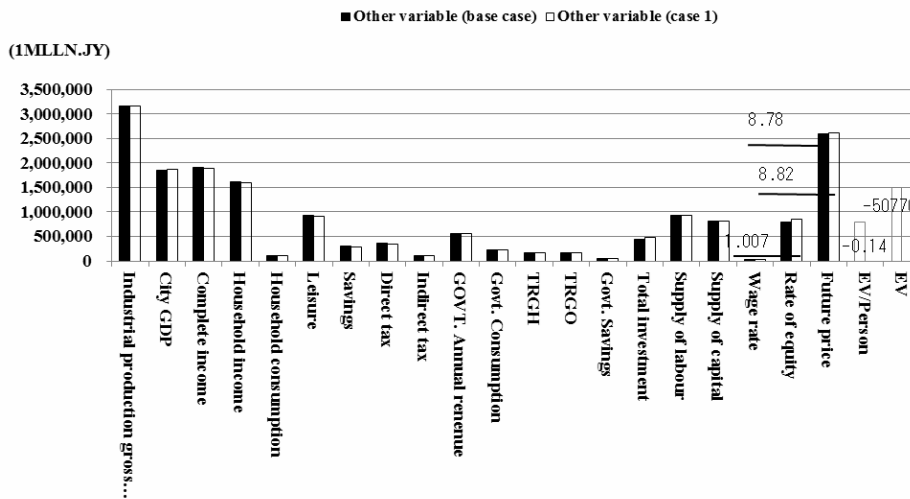


Figure 18. Other Variables

Note:

*TRGH* : current transfer from the government to households

*TRGO* : current transfers from the government to the rest of the world

*EV* : equivalent variation

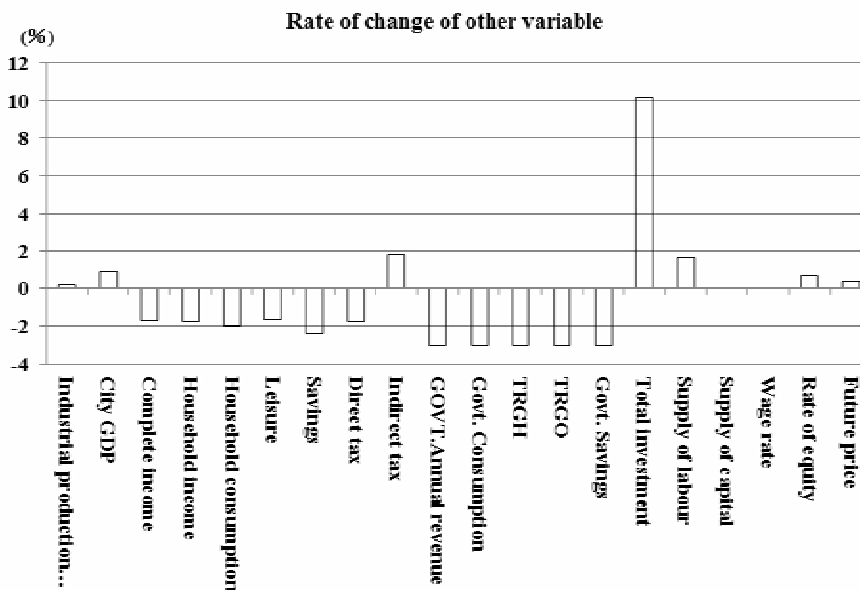


Figure 19. Rate of Change in Other Variables

Conversely falls are found in household income and the government revenue. Those are attributed to that a decrease in the income distributed in Toyohashi city resulting from an increase in current transfers to the rest of the world. In the household sector, due to a decrease in nominal income and a rise in commodity prices, both the household income and leisure time decrease resulting in welfare loss of 50.8 billion yen, being equivalently 140 thousand yen per capita.

## 7. Concluding Remarks

In this study, we have developed a computable general equilibrium (CGE) model to investigate the economic repercussions of electric vehicle production in Toyohashi city in Japan. The simulation are conducted for two cases: (1) business as usual (base case) and (2) 100 % production of electric vehicles in the automobile industry (case 1). The results have demonstrated that after launching electric vehicles, the total industrial output only slightly grows but GDP of the automobile sector increases by 4.1%. The reason is attributed to the fact that the number of parts is reduced in electric vehicle manufacturing resulting in a higher value added rate. This should be highlighted in this study. Moreover the labor demand goes up as well implying a contribution to the current imbalance in Japan's labor market. However there is no concept of unemployment in this CGE modeling, so an increase in labor demand reduces the household leisure time leading to welfare loss. For Toyohashi city, it should focus on a new industrial structure to cope with a change of production system. Particularly it is necessary to promote industries such as non-ferrous metal manufacturing where a large economic impact appears and to attempt to incorporate such impact into Toyohashi city's economy.

This research has just started from a starting line, thus there will be many points worth investigating in the future. Particularly the estimation of city's data is prior to other points. Usually a CGE model heavily depends on an input-output (IO) table. This study estimated Toyohashi city's IO table, but the estimated IO table shows an inconsistency a little. Therefore more precise estimation might be necessary. Finally this paper is focusing on the production process of electric vehicles, however, socio-economic impacts of spread of electric vehicles seems to be more important than production. Spread of electric vehicles would greatly reduce the carbon dioxide emissions. On the other hand, the future low carbon society could require alternative sources of energies like solar, wind, etc., and introduce the smart grid to control electricity supply. Future studies will include these perspectives.

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