NEW INDUSTRIAL STRUCTURE COPING WITHTHE ECONOMIC IMPACTS OF SHIFTING PRODUCTION TO BATTERY-BASED ELECTRIC VEHICLES IN TOYOHASHI IN JAPAN – A CGE MODELING APPROACH-

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Abstract
After nearly a century with the internal combustion engine dominating the personal transportation sector, it now appears that the demands of Battery-based Electric Vehicles (BEVs) production are on the verge of experiencing rapid growth in Japan vehicle market. The broad-scale adoption of the BEVs could bring significant changes for our society in terms of moving the economics away from petroleum and lessoning the environmental footprint of transportation. However as Japanese economy strongly depends on the automobile industry, shifting production systems in the automobile industries influence not only the automobile industry but also other industries. Especially industrial regions where automobile firms are concentrated like in Toyohashi city in Japan will be affected by new production system. Thus, it is worth to acquaint with a new industrial structure for preventing the shortcoming by shifting production. In essence, this paper provides a computable general equilibrium (CGE) model to investigate the economic repercussion of BEVs production in the automobile industries, afterward suggests a new industrial formation to cope with the change of production system to BEVs in Toyohashi city in Japan. The most important database for CGE model calibration is a social accounting matrix (SAM). However input-output (I-O) table and the SAM are not available in Toyohashi city, thus the I-O table and SAM are also estimated in this study.

Keywords: *CGE model, BEVs, gasoline vehicles (GVs), greenhouse gas (GHG), carbon dioxide (CO_2), Toyohashi city, Japan*
***JEL classification*: R10, R11.**

1. Introduction
Since the industrialization, the appearance of cities has been enhancing great changes of people's lives by mass production and mass consumption, Shibusawa & Miyata [13] (2008). On the other hand, industrialization causes many environmental issues such as GHG emissions, climate change, freshwater scarcity, deforestation, global warming, pollution, etc. due to the anthropogenic activities for example fossil foul combustion (e.g, natural gas, coal and petroleum) is used in power industrial process and motor vehicles. Several studies in natural sciences including e.g. Houghton et al., [5] (1996), have warned us of a possible future significant damage on our society due to global warming. Looking at the global environmental issues from the viewpoint of regional competition, it has become a serious problem as to which countries/ regions

and how much they should share the environmental burdens shedding another light on the North and South problem.

To curb the regional problems two major environmental summits: Kyoto Protocol (1997) and Copenhagen Summit (2009), have taken major feature that set binding targets for the industrialize countries including Japan for reducing GHG emissions. Japan had set an object that between 2008 and 2010, and by 2020, GHG emissions will be slashed by 6% and 25% respectively. Thus, GHG emissions diminutions have become one of the main priorities to Japan. Therefore, for an immediate reduction of CO_2 emissions, transportation sector is targeted for Japan to achieve the goal of GHG emissions reduction as per Kyoto Protocol. As the largest and growing fraction of GHG emissions mostly in the form of CO_2 from transportation sector, present a major challenge to global climate change mitigation efforts, Valerie et al., [22] (2010).

Worldwide transportation ranks second after electric power as the largest source of emissions, contributing about 20% of the total in recent trends and future projections, IEA [7] (2006). In the case of Japan similar to the world trend transportation accounts for more than one-fifth of en-use sector CO_2 emissions, MOE [11] (2007). Especially, emissions generated from passenger and freight cars dominate 90% of the sector, MOE [10] (1997), and alone personal vehicles contribute 50% of transportation emissions in Japan, GGIOJ [4] (2008). In addition, it is expected that CO_2 emissions will be increasing because of expending personal vehicles fleets especially in the sub-urban areas like Toyohashi city in Japan (see Table 1). In Japan, environmental consideration lately are bringing pressure on car manufactures to produce BEVs in order to spread of environmentally friendly vehicles hopping CO_2 emissions reduction from transportation sector.

However the problem of global financial downturn in forcing Japan to rethink about the economic development as well as the global economic recessions has also result the collapsed in domestic demand shrunk Japanese economy 1.2% and 5% in the year of 2008 and 2009. These situation putting Japan's national budget into a situation where, the demand for investment social welfare sectors like medical expenses, pension, and nursing care are increasing.

As a result, the proper forecast of the economic impacts of BEVs production seems prior considering the current Japanese economic situation. Because it is expected that the new generation automobiles will become popular in several decades, so the industrial structure may be affected by the new production system. Since the Japanese economy strongly depends on the automobile industry, shifting production system in the automobile industries influence not only the industries related to car manufacturing but also other industries. Especially industrial regions where automobile firms are concentrated like Toyohashi city will be affected by new production system. Therefore, it is worth to acquaint with a new industrial structure for preventing the shortcoming by shifting production. In this paper, we suggest a new industrial structure to cope with shifting production to BEVs in Toyohashi city of Japan, leaving the environmental impact, popularization of BEVs and new energy supply as future research area. In essence, this study provides a CGE model to investigate the economic repercussions of BEVs production in automobile industry of Toyohashi city in Japan, afterwards we suggest a new industrial formation to deal with the new production system of Toyohashi city in Japan.

The city is considered as a study region for three reasons: (1) the numbers of vehicles in the city are increasing rapidly, thus CO_2 emissions are seen an increasing trend, (2) the city has many motor vehicle industries including Toyota Motor Company, one of the world's largest automobile manufacturers by production, and (3) most importantly the GDP of the city is heavily depends on the car export.

The rest of the paper is organized as follows. In section 2, material and methodology of the study are described. Section 3 explains the assumptions of the model and behaviors of the economic agents. In section 4, parameter settings and simulation cases are given whereas Section 5 the results of the simulation are discussed, and finally in Section 6 summarizes the conclusion.

Table 1. Increase in number of personal vehicles and CO_2 emissions in Toyohashi city, Japan (*source*: [21]).

year	total number of personal vehicle	total emissions mt/CO2
1990	189,413	58
1995	226,839	69
2000	251,433	70
2005	264,169	71

2. Material and Methodology

2.1. Study Area

Toyohashi city (see Figure 1) is situated on the southern edge of Aichi Prefecture in Japan. The city borders Shizuoka Prefecture and the Yumihari Mountains. The Pacific Ocean is in the south of the city and the city opens onto Mikawa Bay in the west. Mikawa port is a major port for worldwide trade, and its presence has made Toyohashi an important city as the biggest import and export hub in Japan for automobile, in volume term. Compared to other parts around the world, Mikawa port is roughly on a par with the Garman port of Bremerhaven. There are many motor vehicle industries in Toyohashi city including Toyota Motor Company (one of the world's largest automobile manufactures by production), Mitsubishi, and Suzuki Motors etc. The economy of the city mostly depends on car manufacturing and export. The city has an estimated population of 383, 691 (*source*: [21]).

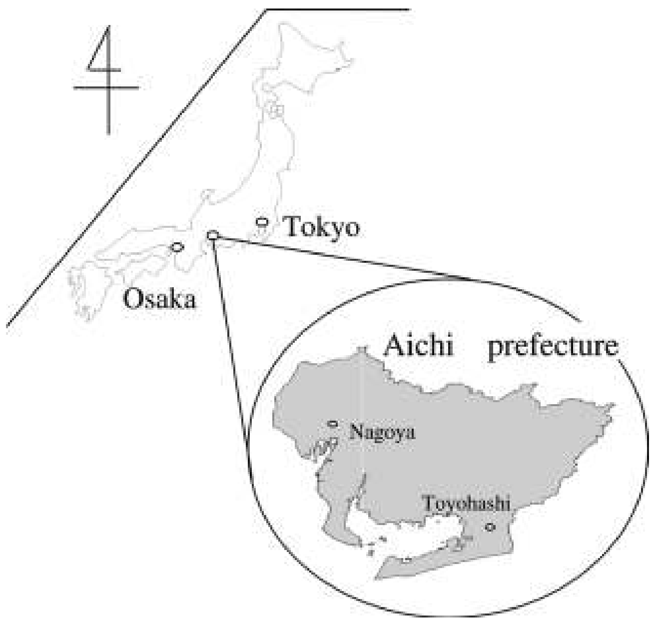

Figure 1. Location of Toyohashi city in Japan (*source*: Naohiro et al., [12] (2005)).

2.2. Methodology

The underlying approach of this study is CGE model. CGE models (both simple and standard) primarily rely on the basic assumptions of microeconomics as their foundations. These models assume one representative household, which consumes goods, and two representatives firm, each of which produces a certain goods. The household is supposed to maximize its utility subject to its budget constraints, while the firms maximize their profits subject to given constraints on production technology. The household and all the firms are price takers, Hosoe et al., [6] (2010). A CGE model describes the whole circular flow of such market economy, while maintaining accounting consistency both at the macro level of individual actors, Abbink, G. A. et al., [1] (1995).

The model presented in this paper is a static CGE model (see Figure 2), thus, there are no time-related elements such as investment and savings, and it is closed economy; that is, no international trade is included. For constructing the model authors referred the literature of Miyata & Shibusawa [9] 2009; and Shoven & Whally [14] (1992).

As a common procedure for constructing the model involves the compilation of a database that describes the economy and is used to assign values to the parameters of the mathematical equations. This process is called the 'calibration' of the model, Thurlow, J. [19] (2004). The most important database for CGE model calibration is a SAM. However the I-O table and the SAM are not available in Toyohashi city, thus the I-O table was firstly estimated. The I-O table was estimated by breaking down 2005 Aichi Prefecture's I-O table which is the most recent table that is available. The original Aichi Prefecture's I-O table consists of 40 industrial sectors. This table is aggregated into a 31 industrial sectors table corresponding to the classification of industrial production. Following this procedure, the 31 (see Table 2) sector table is broken down as Toyohashi city's table by applying FRATAR method, and by using several statistics including the national population census, agricultural census, manufacturing census, and commerce census though the description of the method is skipped.

Table 2. Classification of industries (*source*: [21]).

industries	industries
1. agriculture, forestry & fishery	17. electronic component
2. mining	18. automobile
3. beverage & food	19. aircraft
4. textile	20.other transportation equipment
5. pulp, paper & wooden	21. precision instrument
6. chemical	22. other manufactured
7. petroleum & coal	23. construction
8. plastic	24. electricity, gas & heat supply
9. ceramic	25. water supply & waste disposal
10. other ceramic, stone & clay	26. commerce
11. iron & steel	27. finance & insuance
12. non-ferrous metal	28. reale state
13. metal product	29. transport
14. general machinery	30. information & telecommunication
15. electrical machinery	31. service
16. information & communication electronic equipments	

And developing SAM of Toyohashi city is an extension of I-O table of this city. The estimated results are shown below (see Table 3). From the table, it can be seen that industries produce 3,152 billion yen of commodities and services. However it is a characteristics nature that the external sector's net demand for goods and services produced in the study area shows 251,395 million yen, which seems high. The population of the study area is small, thus the commodities and services must exports to the rest of the world. Looking at the government sector, it obtains its revenue of 567, 985 million yen from net indirect tax, direct tax, and current transfer from the external sector. It is a specific fact that the revenue from the external sector is large. In expending side, it is characteristic that the government savings are small. In the household sector, household obtain 1, 616,800 million yen of income, and then consume 9, 347 million of commodities and services. In the external sector, current transfers between the external sector and the government, and those between the external sector and households a large.

Previous innovation studies using this approach have been rooted in the field of transportation research analysis studying the prospects for transportation and energy systems dynamics. Some of the recent studies have focused on the new generation automobile with technological innovations using the similar approach, Shibusawa & Sugawara [15] (2011); Valerie et al., [22] (2010); Thomas, C. E. [17] (2009); Simon et al., [16] (2012); and Thomas, C. E. S. [18] (2009). Other studies have focused the importance of government policy, infrastructural change for spreading EVs in Japan, Ahman, M. [2] (2006); Brown et al., [3] (2010); and Willett & Toru [23] (2000). The study of Tokunaga et al., [20] describes details of EVs in Japan.

Table 3. Social accounting matrix of Toyohashi city in Japan.

economic sectors (in million yen)		production activities	institutions		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
institutions	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

3. Assumptions of the Model

3.1. Main Assumptions

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.

3.2. Behavior of 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 labor and capital inputs (see Figure 2).

Constant returns to scale are assumed in the technology, cost minimization problem can be written as,

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

with respect to X_{ij}, L_j and K_j

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

$$f_j(L_j, K_j) \equiv A_j L_j^{aj} K_j^{(1-a_j)} \quad (3)$$

where

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_j ,α_{ij} : technical parameters in industry j

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).

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

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

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

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

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.

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

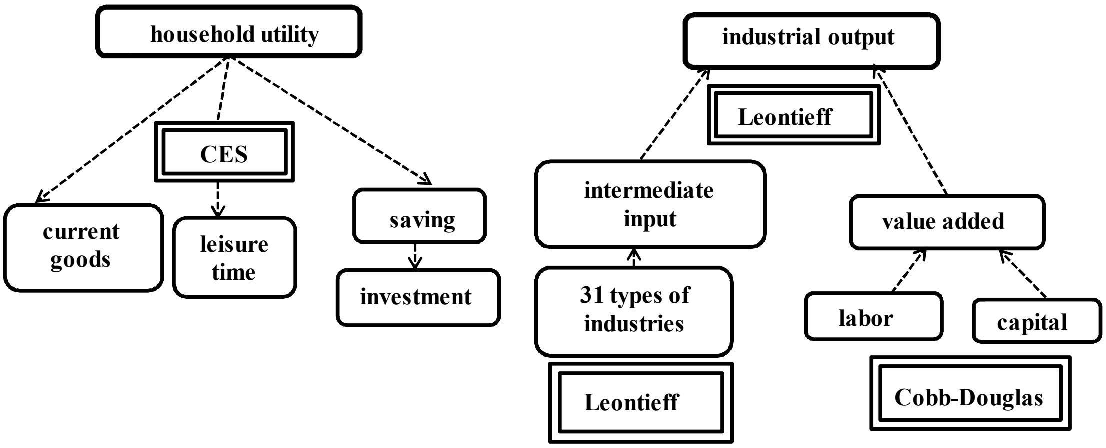

Figure 2. Hierarchical structure of the CGE model.

3.3. Behavior of 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.

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 $(1\text{-}ty)(1\text{-}k_o)(1\text{-}k_r)r\delta$, 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

$$r_s = (1-ty)(1-k_o)(1-k_r)r\delta / p_s \tag{8}$$

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

δ : ratio of capital stock measured by physical commodity unit to that by capital service unit.

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.

$$\max_{C,F} G \equiv \{\beta^{1/v_2} C^{(v_2-1)/v_1} + (1-\beta)^{1/v_2} F\}^{v_2/(v_2-1)} \tag{9}$$

subject to

$$p \cdot C + (1-ty)(1-l_o)w \cdot F = (1-ty)FI - TrHO - SH \tag{10}$$

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

$$C = \frac{\beta[(1-ty)FI - TrHO - SH]}{p^{v_2} \cdot \Omega} \tag{11}$$

$$F = \frac{(1-\beta)[(1-ty)FI - TrHO - SH]}{[(1-ty)(1-l_o)w]^{v_2} \cdot \Omega} \tag{12}$$

$$LS = E - F \tag{13}$$

$$\Omega = \beta p^{(1-v_2)} + (1-\beta)[(1-ty)(1-l_o)w]^{(1-v_2)} \tag{14}$$

where
LS : household labor supply
β : 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 ($=P_S \cdot S$)
Substituting composite consumption (11) and leisure time (12) into (9), the price index of the present good is derived as follows:

$$p_G = \{\beta\, p^{1-v_2} + (1-\beta)[(1-ty)(1-l_o)w]^{1-v_2}\}^{1/(v_2-1)} \qquad (15)$$

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

$$max \quad C \equiv \prod_{i=1}^{31} C_i^{\gamma_i} \qquad (\sum_{i=1}^{31} \gamma_i = 1) \qquad (16)$$

subject to

$$\sum_{i=1}^{31} p_i \cdot C_i = (1-ty)Y - TrHO - SH \qquad (17)$$

where
C_i : household consumption good produced by industry I
p_i : price of good I
Y : household income
($=(1-l_o)w \cdot LS+LI+(1-k_o)(1-k_r)r \cdot KS+KI+TrGH+TrOH$)
From this optimization problem, consumption good i is derived.

$$C_i = \frac{\gamma_i}{p_i}[(1-ty)Y - TrHO - SH\,] \quad (i = 1,\cdots,31) \qquad (18)$$

The price of composite consumption is calculated as follows:

$$p = \prod_{i=1}^{31} \left[\frac{p_i}{\gamma_i} \right]^{\gamma_i} \qquad (19)$$

3.4. The Government

The government sector in this study consists of the national and local governments activities in Toyohashi city. So the concept of the government corresponds to the definition of SNA framework. 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.

$$\sum_{i=1}^{31} p_i \cdot CG_i + TrGH + TrGO + SG = ty \cdot Y + \sum_{i=1}^{31} tp_i (w \cdot LD_i + r \cdot KD_i) + TrOG \qquad (20)$$

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

3.5. 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.

$$\sum_{i=1}^{31} p_i \cdot EX_i + TrOH + TrOG + KI + LI + SO = \sum_{i=1}^{31} p_i \cdot EM_i + TrHO + TrGO + KIO + LIO \qquad (21)$$

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 (= $k_0 \cdot r \cdot KS$)

3.6. Balance of Investment and Saving

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

$$\sum_{i=1}^{31} p_i \cdot I_i = SH + SG + SO + \sum_{i=1}^{31} DR_i \qquad (22)$$

where

I_i: demand for commodity i by other investments,

DR_i: consumption of fixed capital amount of industry i

3.7. Prices of Commodities

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

$$p_j X_j = \sum_{i=1}^{31} p_i x_{ij} + (1 + tp_j)[w \cdot LD_j + r \cdot KD_j] \qquad (23)$$

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

$$P = (I - A')^{-1}[(1 + tp_j)(w.ld_j + r \cdot kd_j)] \qquad (24)$$

where

P: vector of commodity prices,

A': transposed matrix of industries' input coefficients,

[•] : column vector whose elements are in parentheses $ld_j \equiv LD_j / X_j$ and $kd_j \equiv KD_j / X_j$

3.8. Derivation of Equilibrium

The equilibrium condition in the model can be summarized as follows,

Commodity market

$$\begin{bmatrix} X_1 \\ \vdots \\ X_{31} \end{bmatrix} = \begin{bmatrix} a_{11} & \cdots & a_{131} \\ \vdots & \ddots & \vdots \\ a_{311} & \cdots & a_{3131} \end{bmatrix} \begin{bmatrix} X_1 \\ \vdots \\ X_{31} \end{bmatrix} + \begin{bmatrix} C_1 \\ \vdots \\ C_{31} \end{bmatrix} + \begin{bmatrix} CG_1 \\ \vdots \\ CG_{31} \end{bmatrix} + \begin{bmatrix} I_1 \\ \vdots \\ I_{31} \end{bmatrix} + \begin{bmatrix} EX_I \\ \vdots \\ EX_{31} \end{bmatrix} - \begin{bmatrix} EM_I \\ \vdots \\ EM_{31} \end{bmatrix} \qquad (25)$$

Labor market

$$LS = \sum_{j=1}^{31} LD_j \qquad (26)$$

Capital market

$$KS = \sum_{j=1}^{31} KD_j \qquad (27)$$

4. Parameter Setting and Simulation Cases

4.1. 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 parameters in the utility function, estimation of them is made in a standard way with results shown in Table 4 though the description of the estimation method is skipped as well.

Table 4. Utility function parameter.

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

4.2. Simulation Cases

In this section, two cases are simulated and they are as follows:
(1) Business as usual case (Base case) and
(2) Case 1 (where 100% BEVs 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 GVs. Case 1 assumes that the automobile industry produces 100% BEVs. The difference between the two cases is input coefficients in IO table of Toyohashi city. The simulation is conducted by changing the input coefficient of GVs and BEVs (see Table 5). Our main source for the input coefficient was the work of Japan Energy Economics Research Institute [8] (2006), where modeled the demand of input coefficient in the Japan market.

Table 5. Input coefficient of gasoline and battery-based electric vehicles.

industries	gasoline vehicles	battery-based electric vehicles
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. eectrical 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& insuance	0.008	0.008
28. reale state	0.001	0.001
29. transport	0.016	0.02
30. information & telecommunications	0.002	0.002
31. services	0.072	0.072

5. Simulation Results

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

5.1. Amount of Industrial Production

Changes in industrial outputs are shown in Figures 3 and 4. After BEVs being put into operation, the total industrial production 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 BEVs. 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, however the batteries used in BEVs should be much produced demanding a lot of non-ferrous metals. This result has also been confirmed by the IO analysis of Japan's economy, and can be concluded as that it is qualitatively plausible. 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 BEVs production.

The output of automobile industry shows a decrease of -9.3% which is interesting. The reason is attributed to the fact of the less number of parts in BEVs. That is, the economic repercussion of producing BEVs on other relating industries becomes less as compared with GVs. Producing BEVs 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.

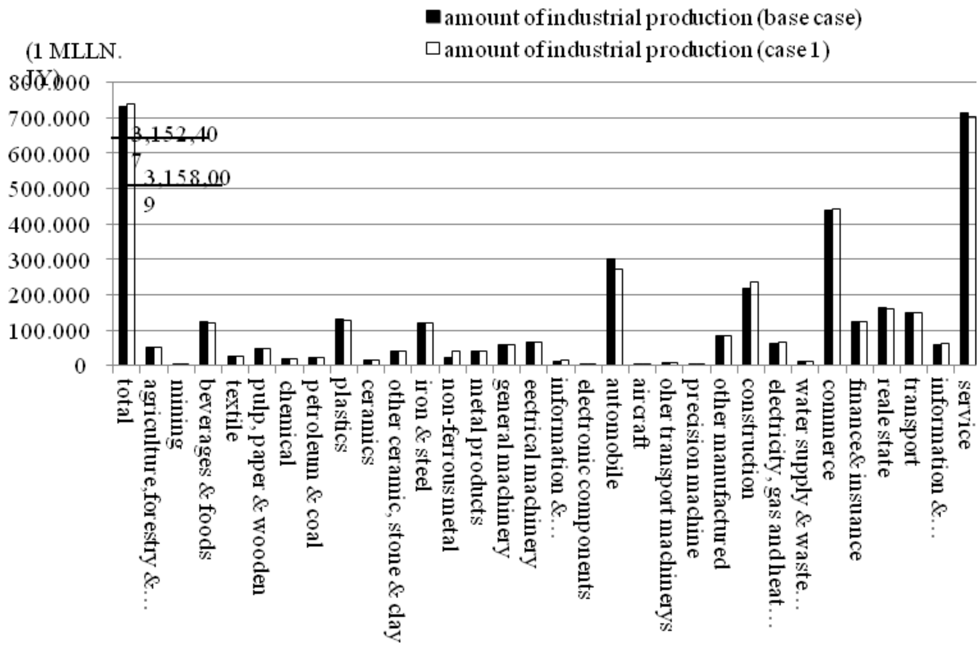

Figure 3. Amount of industrial production.

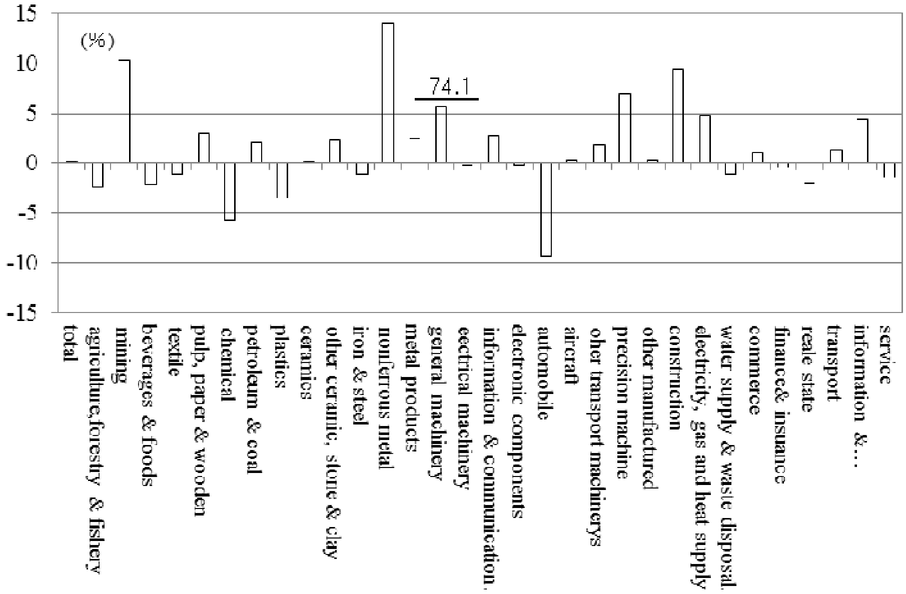

Figure 4. Change rate of industrial outputs.

5.2. City GDP

The city GDP is defined as gross value added in the city. Value added rates are adjusted in order that the sums of coefficients in the column in the automobile industry become the unity. As shown in Figures 5 and 6, the manner of changes in the city's GDP by sector is similar to that of industrial outputs. It is interesting to see an increase in 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 BEVs. Thus increases in wage rate and/or in firms profit are observed in BEVs production resulting in stimulating to household consumption expenditures as a general equilibrium effect, while the repercussion effect of GVs 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%.

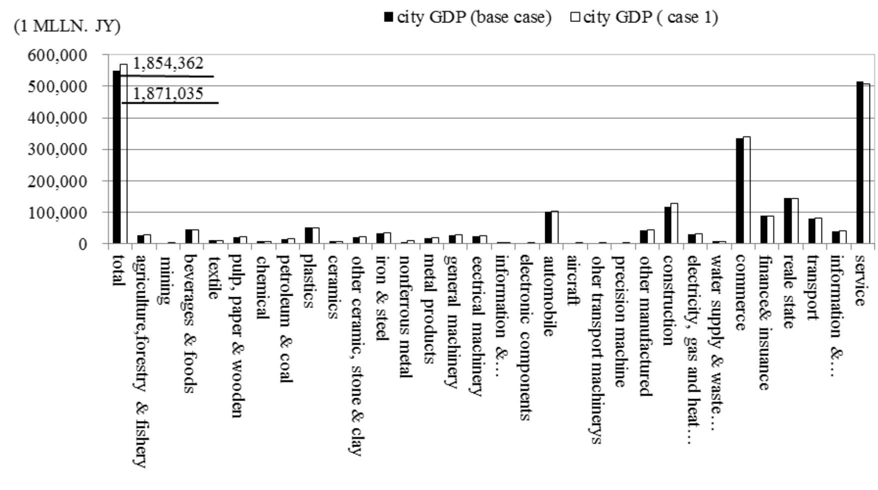

Figure 5. City GDP.

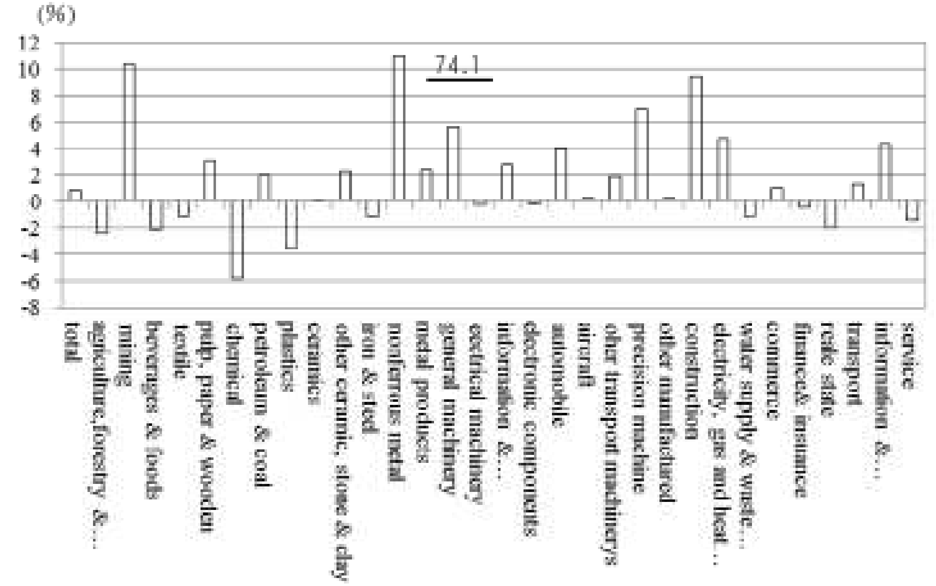

Figure 6. Change rate of city GDP.

5.3. Labor Demand

Looking at changes in labor demands by sector in Figures 7 and 8, it can be seen 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 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.

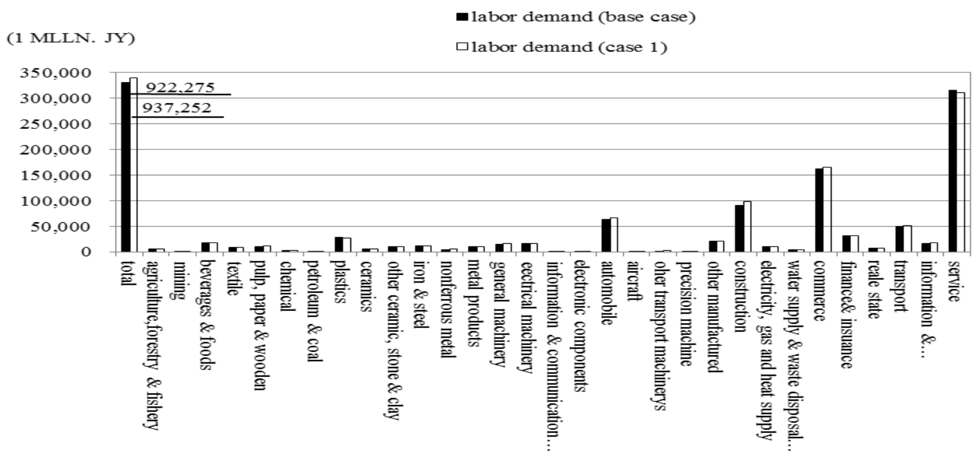

Figure 7. Labor demand in industries.

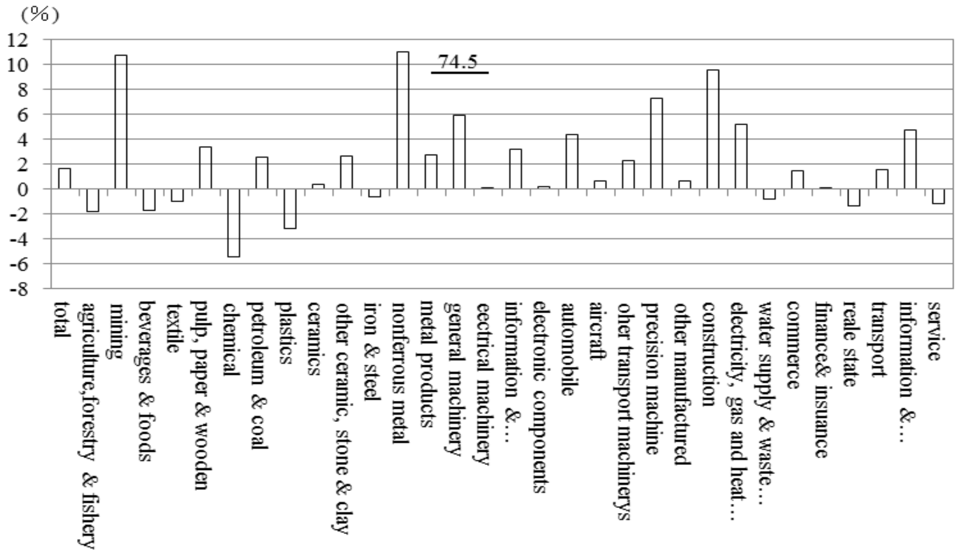

Figure 8. Change rate of labor demand in industries.

5.4. 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 BEVs. Looking at changes in capital demand by industry in Figures 9 and 10, 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.

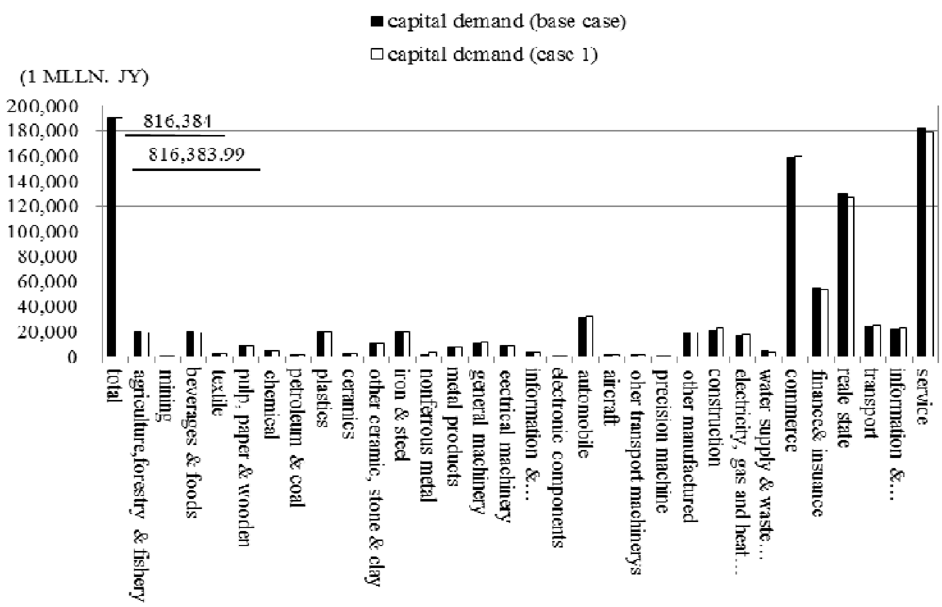

Figure 9. Capital demand.

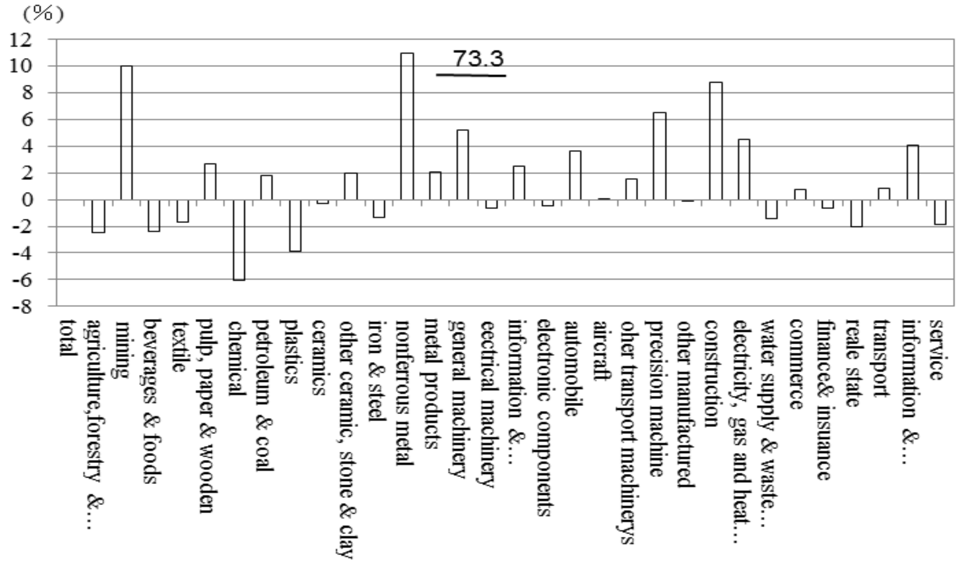

Figure 10. Change rate of capital demand.

5.5. Commodity Prices

Commodity prices are determined by factor prices. 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 BEVs 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 11 and 12, 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 the real wage rate leading to welfare loss.

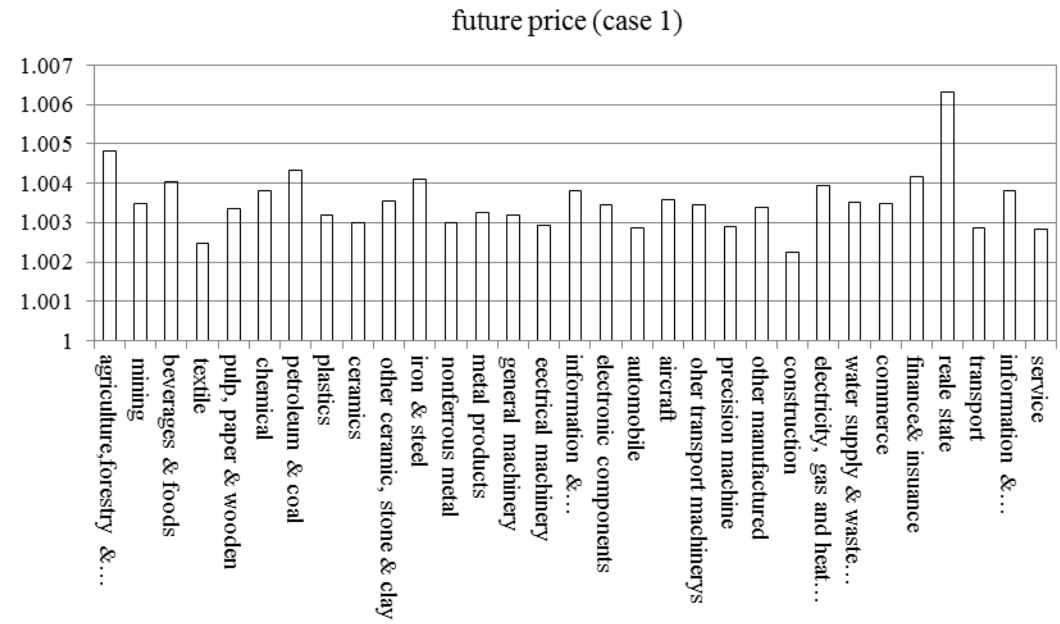

Figure 11. Commodity price.

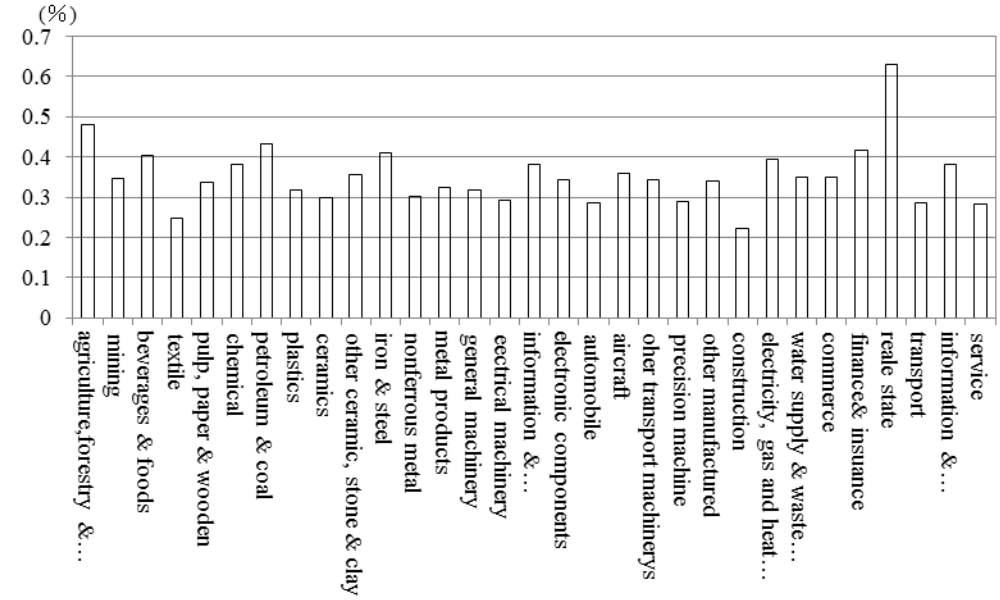

Figure 12. Change rate of commodity price.

5.6. Other Variables

Let us look at Figures 13 and 14 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.

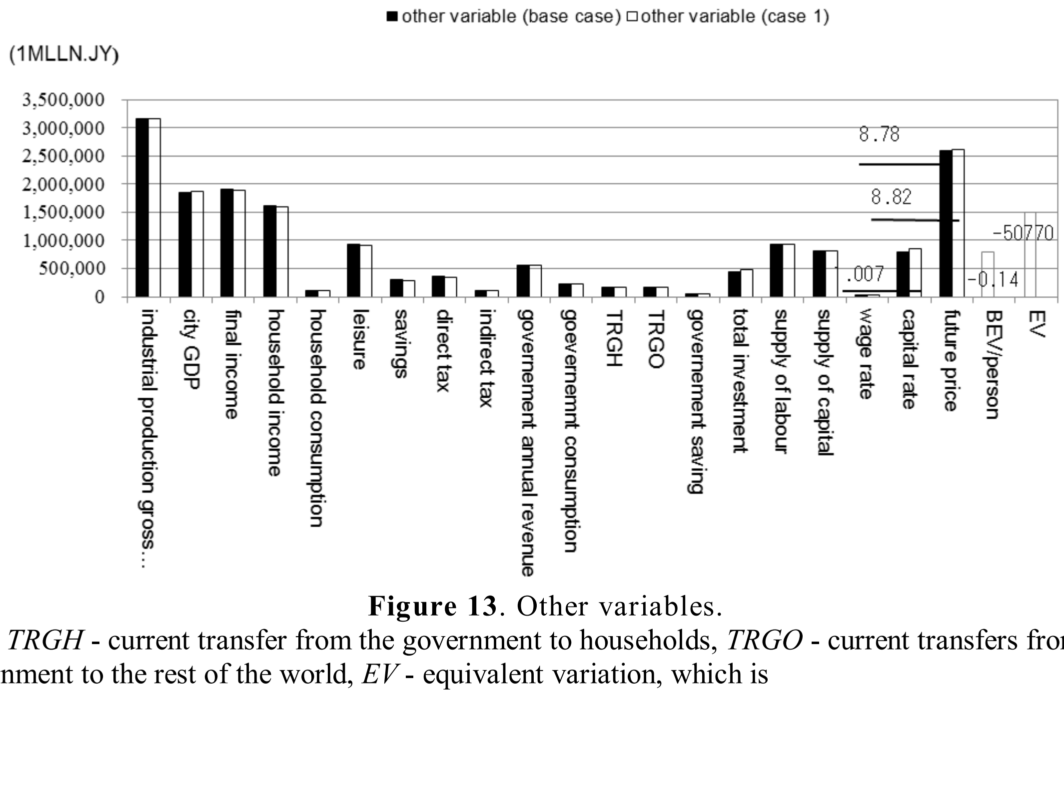

Figure 13. Other variables.

Note: *TRGH* - current transfer from the government to households, *TRGO* - current transfers from the government to the rest of the world, *EV* - equivalent variation, which is

$EV = e(p_G, p_H, u_1) - e(p_G, p_H, u_0) = (u_1 - u_0)[\alpha p_G^{1-\nu_1} + (1-\alpha) p_H^{1-\nu_1}]^{1/1-\nu_1}$ where $e(p_G, p_H, u)$ - expenditure function, p_G and p_H - prices of present and future goods in the base case, u_0 and u_1 - utility levels before and after the BEVs production

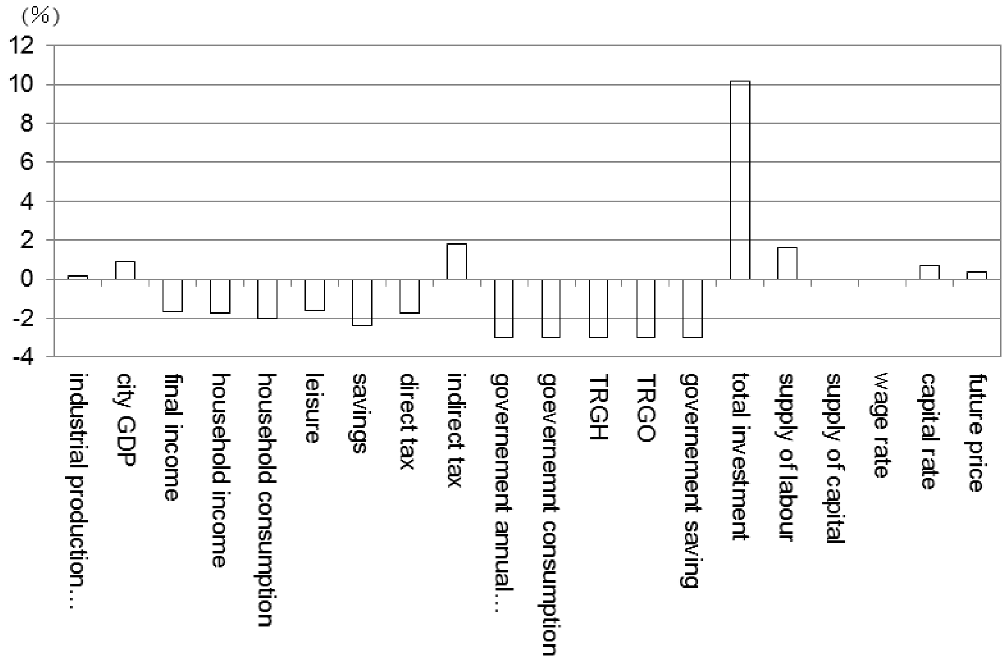

Figure 14. Change rate of other variable.

6. Concluding Remarks

In this paper, we have developed a CGE model to investigate the economic repercussions of BEVs production. We also have focused on a new industrial structure to cope with the change in the BEVs production system of Toyohashi city in Japan. Moreover, we have introduced an I-O table and a SAM for Toyohashi city in this study. By employing the CGE model, the two numerical simulations have been implemented. From the simulation results, some interesting conclusions have been obtained. For example, the output of automobile industry has shown a decrease of -9.3% though the labor demand in that industry depicts a rise of 4.3%. 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. Moreover, it is interesting to see an increase in 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 BEVs. Thus increases in wage rate and/or in firms profit are observed in BEVs production resulting in stimulating to household consumption expenditures as a general equilibrium effect, while the repercussion effect of GVs manufacturing goes to automobile industry itself. That is, the economic impact of producing BEVs on other relating industries becomes less as compared with GVs. Producing BEVs once give a negative impact on Toyohashi's economy. Therefore it suggests the necessity of transformation of the current industrial to compensate the negative impact. At this point, this study highlights on a new industrial structure to cope with a change of production system. Particularly it is suggested to promote industries such as non-ferrous metal (increase rate of 74.1%) manufacturing where a large economic impact appears and to attempt to incorporate such impact into Toyohashi city's economy. The reason is that a lot of non-ferrous metals are necessary for producing batteries used in BEVs. The increase in output of non-ferrous metals might be a little large, however the batteries used in BEVs should be much produced demanding a lot of non-ferrous metals. This result has also been confirmed by the IO analysis of Japan's economy, and can be concluded as that it is qualitatively plausible. Thus it is claimed that this study confines itself to explain the features that have bearing on the development of BEVs.

Moreover, this paper focused on the production process of BEVs, however socio-economic impacts of spread of BEVs seem to be also very important. In this paper we have not considered the importance of subsidies, whilst subsidies may be required to overcome the initial price differential, BEVs will be expensive until a market emerges. It can be expected that spread of BEVs would greatly reduce the CO_2 emissions, however it is also strongly depends on internalizing electricity generated from renewable sources of energies, like solar or/and wind. In addition, lately security in electricity generation is a great concern as Japan has been experiencing nuclear crisis after the Tohoku earthquake and tsunami hit in March 2011. Japan has one of the lowest energy intensities (energy- use per unit of GNP) in the industrialized world, but its aggregate energy-use is still rising. Moreover, new technologies like smart grid must be internalized in our model to stabilize demand and supply of electricity generated from renewable sources of energies. Therefore, our future study will include the popularization of BEVs, and introduce a Battery-based Electric Vehicle society with renewable energies and smart grid technology in Toyohashi city in Japan.

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