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Impacts of Electric Supply Shortage in Japan Simulated by the GTAP, GTAP-E, and Revised GTAP-E Models

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Abstract: The growing risk of electric supply shortage in Japan has necessitated an urgent review of energy policy. As the magnitude of the impacts of electric supply shortage will be largely influenced by the development of energy substitution in industries, it is worthwhile to undertake simulations for different scenarios concerning energy substitution, to evaluate the impacts of electric supply shortage. Two models are used in the simulation: the GTAP and the GTAP-E model. The latter is an extended energy-environment version incorporating an energy substitution structure in the GTAP model. The simulation using the GTAP model considers a scenario without energy substitution, while that using the GTAP-E model considers one with energy substitution. Thus, the comparison of these simulation results indicates the effect of energy substitution on electric supply shortage. The purposes of this paper are two-fold. The first is to analyze the impacts of reduced electric power usage caused by electric supply shortage in Japan, using the GTAP and the GTAP-E models, based on the GTAP 8 database. The second is to compare the simulation results of the GTAP-E and the revised GTAP-E models, the latter of which was released in late 2012. This paper first discusses the methodology used to evaluate the impacts of electric supply shortage using the GTAP model. Second, it proposes a method to create a database for the GTAP-E and the revised GTAP-E models, by adopting a new regional and sectoral aggregation. Third, this paper compares and analyzes the simulation results of each model. The comparison of the simulation results of the GTAP and the GTAP-E models shows that the effect of energy substitution could be significant. The simulation results of the GTAP-E and the revised GTAP-E models are quite similar. Thus, it could be said that the revised GTAP-E model has improved many technical points of the original GTAP-E model, while maintaining its basic structure.

Key words: electric supply shortage; GTAP model; GTAP-E model
JEL code: C68

1. Introduction

The growing risk of electric supply shortage in Japan has necessitated an urgent review of energy policy. As the magnitude of these impacts will be largely influenced by future developments in energy substitution in industries, it is worthwhile to compare simulation results based on different scenarios of energy substitution to evaluate the impacts of electric supply shortage.

By comparing the simulation results of the GTAP model against those of the GTAP-E model, which is an

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extended energy-environment version incorporating an energy substitution structure in the GTAP model, two scenarios can be analyzed; one without energy substitution and the other with it.

First, this paper discusses the methodology to evaluate the impacts of electric supply shortage using the GTAP model. The main issues of the discussion include the variable to which the shock is given, the structure of the closure, investment allocation, and the differences between the GTAP and the GTAP-E models.

Second, the methodology used to create the new database of the GTAP-E model is adapted to a new aggregation of regions and sectors, based on the GTAP 8 database. This new aggregation includes 28 sectors and 12 regions and differs from the original GTAP-E aggregation, which consists of 8 sectors and 8 regions (9 regions in the revised GTAP-E model), thus pointing to the need for creating a new GTAP-E database. Thus, a new GTAP-E database is created. Although the data and parameters of the GTAP and GTAP-E models are common, it is necessary to consider the new data and parameters for the GTAP-E model, particularly in terms of carbon dioxide (CO_2) emissions and carbon tax.

The revised GTAP-E model was released in late 2012. This paper also tries to review the new features of the revised GTAP-E model and compares the methodology of database creation for the GTAP-E and the revised GTAP-E models. Comparison of the databases of these two models indicates that the revised GTAP-E model simplifies the data construction procedure, mainly by shortening the procedure to create the data pertaining to CO_2 emissions and carbon tax.

Third, the simulation results of the GTAP and GTAP-E models and those of the GTAP-E and the revised GTAP-E models, are compared and analyzed. The simulated scenario considers a reduction of 1% in the use of electric power in Japan due to electric supply shortage. The simulation results show that the effect of energy substitution could be significant; when RORDELTA (the binary coefficient which determines the mechanism of allocating investment funds across regions) = 0, for example, a change of -0.97% and -0.55% in the Gross Domestic Product (GDP), for the GTAP model and the GTAP-E model respectively, is noted. The results for the GTAP-E and the revised GTAP-E models are almost similar. Thus, it could be said that the revised GTAP-E model maintains the basic structure of the original GTAP-E model and is also an improvement over its earlier counterpart.

2. Analysis of the Economic Impacts of the Reduced Use of Electric Power in Japan and Overview of the Models

2.1 Analysis of the Economic Impacts of the Reduced Use of Electric Power in Japan

2.1.1 Simulation Methodology

This subsection reviews the various methodologies used to evaluate the impacts of electric supply shortage in Japan. The main items discussed in such studies include the variable to which the shock is given, structure of the closure, and investment allocation.

Previous studies tried to evaluate the impacts of the reduced use of electric power in Japan using the CGE model (Ishikura & Ishikawa, 2011; Yamazaki & Ochiai, 2011). Ishikura and Ishikawa (2011) analyzed the impact of the reduced use of electric power for all of Japan and for the Tokyo metropolitan area, by using their Japanese spatial CGE (SCGE) model. They investigated the effect of a shock to the productivity of the electricity sector in the Tokyo metropolitan area, resulting from the reduced electric supply capacity. Yamazaki and Ochiai (2011) analyzed the impact of the restricted electric supply in the Kanto area on the whole of Japan and in 8 Japanese regions following the Great East Japan Earthquake in 2011. They used the Japanese multi-regional CGE model

developed by the Japan Center for Economic Research. For the simulation, they reduced the quantity of endowment commodities (capital and labor) and demand for electricity of household in the Kanto area.

As the GTAP model cannot divide a country or region into several areas, a shock to a productivity variable in the electricity sector translates to a scenario wherein the productivity in that sector decreases all over the country. However, such a scenario does not reflect reality. Moreover, a shock to a technical change variable in the electricity sector in the GTAP model directly increases the price of electricity quite considerably, which also does not reflect reality. Therefore, this paper tries to investigate the effect of a shock on another variable, namely, the industrial output of the electricity sector in Japan, qo ("Electricity", "JPN"), which is an endogenous variable in the standard GTAP model closure.

However, in order to investigate the effect of a shock on qo ("Electricity", "JPN"), the standard closure of the GTAP model needs to be modified. In this modified closure, qo ("Electricity", "JPN") becomes an exogenous variable and qo ("capital", "JPN"), formerly an exogenous variable in the standard GTAP model closure, becomes an endogenous variable.

2.1.2 Investment Allocation in the Simulation

Investment allocation also plays an important role in the stimulation. It is well known that two options concerning investment allocation are possible in the GTAP model. When RORDELTA = 1, investment funds are allocated across regions to equate the changes in the expected rates of return. In the case of Japan, the capital and investment decreases and increases respectively, and a result, the impacts of reduced electric power usage in Japan become less serious. When RORDELTA = 0, investment funds are allocated across regions to maintain the existing composition of capital stocks; for the case of Japan, both the capital and the investment decrease. As a result, the impacts of reduced electric power usage in Japan become more serious.

Considering that the shock investigated in this study—a reduction of 1% in the use of electric power in Japan due to electric supply shortage—is a phenomenon limited to Japan, this paper will only concern itself with the case of RORDELTA = 0.

2.2 Overview of the Differences between the GTAP and the GTAP-E Models

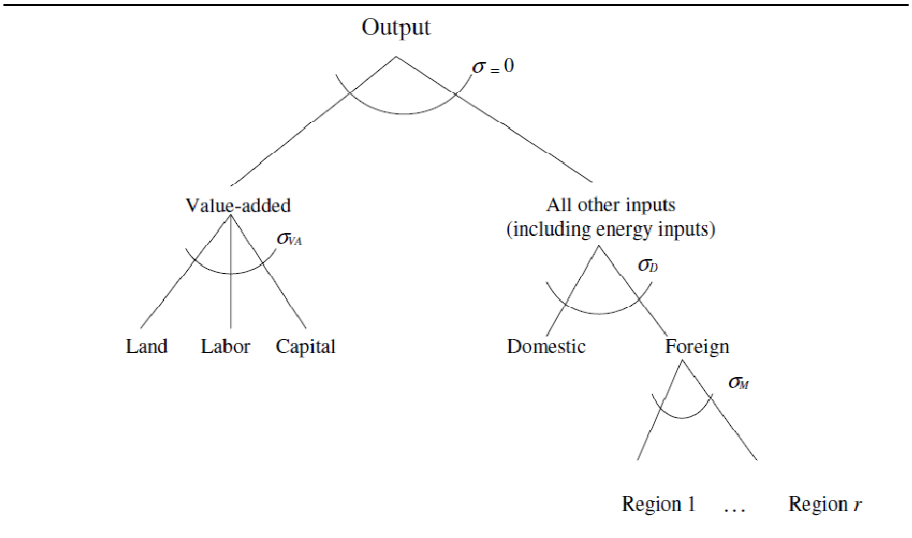

Figure 1 Standard GTAP Production Structure

Source: Burniaux and Truong (2002), Figure 15, p. 30.

Compared with the standard GTAP model, the main feature of the GTAP-E model is its production structure with energy substitution, namely, inter-fuel substitution and fuel-factor substitution. In the GTAP-E model, energy commodities, which include coal, oil, gas, petroleum and coal products, and electricity, are taken out of the intermediate input nest, to be incorporated into the value-added nest. These energy commodities are separated into the electricity and non-electricity groups, and the non-electricity group is classified into the coal and non-coal group. The latter consists of gas, oil, and petroleum products.

The production structure of the GTAP model is provided in Figure 1, while Figure 2 provides the GTAP-E production structure and Figure 3, the GTAP-E capital-energy composite structure.

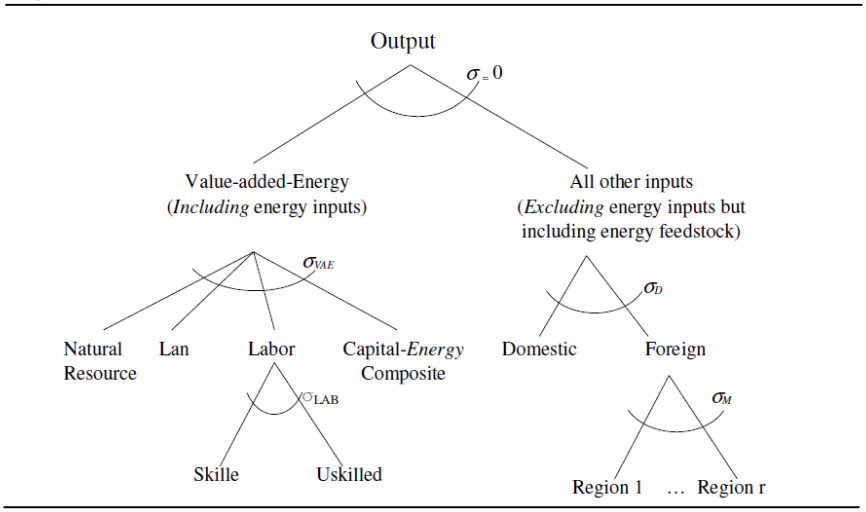

Figure 2 GTAP-E Production Structure

Source: Burniaux and Truong (2002), Figure 16, p. 31

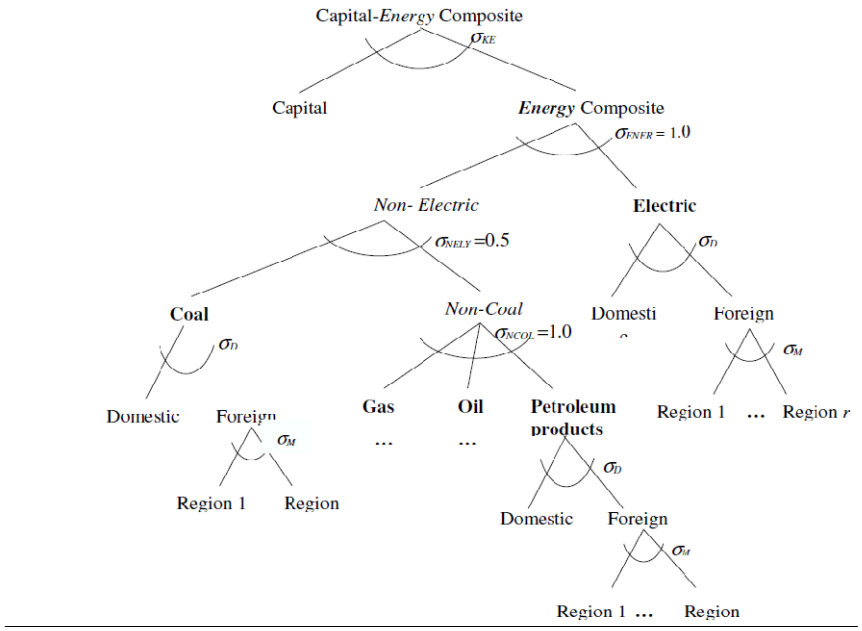

Figure 3 GTAP-E Capital-Energy Composite Structure

Source: Burniaux and Truong (2002), Figure 17, p. 31

Another main feature of the GTAP-E model is that it incorporates data pertaining to CO_2 emissions from the combustion of fossil fuels and provides for a mechanism to trade these emissions internationally. Although CO_2 emissions and carbon taxes are not the topics of focus in this paper, one should understand how to incorporate data pertaining to emissions and carbon taxes while creating a new GTAP-E database.

2.3 Overview of the Revised GTAP-E Model

McDougall and Golub (2007) revised the GTAP-E model described in GTAP Technical Paper No.16 (TP16) by Burniaux and Truong (2002). They maintained the basic structure of the GTAP-E model and revised the solution program, data, stored input and command files, and welfare decomposition program. These revisions were undertaken "to improve the model's user friendliness, adapt it to a wider range of energy-environmental policy scenarios, and correct errors".[1] The revised GTAP-E model was released in late 2012. The modifications in the revised GTAP-E model are shown in Table 1.

Table 1 Modifications in the Revised GTAP-E Model

1	Reimplement emissions trading with trading blocs.
2	Calculate CO_2 emissions bottom-up.
3	Reimplement carbon taxation, not converting rates from specific to *ad valorem*.
4	Reorganize the production structure to group equations by nest, and equip it with the complete set of technological change variables.
5	Introduce the energy nest in private and government consumption.
6	Revise the calculation of the contribution of net permit trading revenue to welfare change, i.e., "CNTco2trd".
7	Introduce change in the ratio of the current account to the regional income, to maintain homogeneity in the presence of a fixed current account.
8	Introduce new tax-income ratio variables, change the ratio of carbon-exclusive taxes to INCOME, del_tnctaxr(r), and change the ratio of carbon tax to INCOME, del_ctaxr(r).
9	Introduce a new variable, del_ctgshr(r), representing the government share of carbon tax payments/permits revenue.

Source: Global Trade Analysis Project; An Energy-environmental Version of the GTAP Modeling Framework GTAP-E Version 6-Pre2 (July 2007).

3. Procedure for Creating the Databases

3.1 Regions and Sectors

The GTAP-E model was developed by aggregation of 8 regions and 8 sectors. The revised GTAP-E model maintains the same sector aggregation as the GTAP-E model. However, the regions are aggregated into 9 groups in the revised GTAP-E model; China and India are separated in the revised GTAP-E model (CHN and IND), while they are aggregated in the same group (CHIND) in the GTAP-E model. Another main difference between these two models is that the European Union (EU) is treated as EU 27 in the revised GTAP-E model and as EU 15 in the GTAP-E model.

Considering that this paper tries to analyze the impacts of reduced electric power usage caused by electric supply shortage in Japan only, and that investment funds are allocated across regions to maintain the existing composition of capital stocks, there will be little impact on other regions. Therefore, the regional aggregation in this paper remains at the relatively small size of 12 regions, after adding some new regions from Asia (Table 2).

Concerning the sectoral aggregation, this paper aims to analyze the impact of electric supply shortage in

[1] McDougall and Golub (2007), *"GTAP-E: A Revised Energy Environmental Version of the GTAP Model"*, GTAP Research Memorandum No. 15.

Japan, especially on the manufacturing sectors. For this purpose, this paper attempts the rather large sectoral aggregation of 28 sectors (Table 3).

Table 2 Regional Disaggregation

No.	New code	Region description	Comprising GTAP 8 countries/regions
1	JPN	Japan	Japan
2	KOR	Korea	Korea
3	CHN	China	China
4	AEEx	ASEAN Net Energy Exporters	Indonesia, Malaysia, Vietnam
5	OASN	Other ASEAN Countries	Cambodia, Lao People's Democratic Republic, Philippines, Singapore, Thailand, rest of Southeast Asia
6	IND	India	India
7	USA	United States	United States of America
8	EU27	EU27	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Bulgaria, Romania
9	OEEx	Other Net Energy Exporters	Mexico, Argentina, Bolivia, Colombia, Ecuador, Venezuela, Islamic Republic of Iran, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Egypt, rest of North Africa, Nigeria, Central Africa
10	EEFSU	Eastern Europe and FSU	Albania, Belarus, Croatia, Russian Federation, Ukraine, rest of Eastern Europe, rest of Europe, Kazakhstan, Kyrgyzstan, rest of the FSU, Armenia, Azerbaijan, Georgia
11	RoA1	Other Annex 1 Countries	Australia, New Zealand, Canada, Switzerland, Norway, rest of the EFTA countries
12	RoW	Rest of the World	Rest of Oceania, Hong Kong, Mongolia, Taiwan, rest of East Asia, Bangladesh, Nepal, Pakistan, Sri Lanka, rest of South Asia, rest of North America, Brazil, Chile, Paraguay, Peru, Uruguay, rest of South America, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador, rest of Central America, Caribbean, Bahrain, Israel, Turkey, rest of Western Asia, Morocco, Tunisia, Cameroon, Cote d'Ivoire, Ghana, Senegal, rest of Western Africa, South Central Africa, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Tanzania, Uganda, Zambia, Zimbabwe, rest of Eastern Africa, Botswana, Namibia, South Africa, rest of South African Customs, rest of the World

Table 3 Sectoral Disaggregation

No.	New code	Sector description	Comprising GTAP 8 sectors
1	AGR	Agriculture	Paddy rice, wheat, cereal grains nec, vegetables, fruit, nuts, oil seeds, sugarcane, sugar beet, plant-based fibers, crops nec, bovine cattle, sheep and goats, horses, animal products nec, raw milk, wool, silk-worm cocoons, forestry, fishing
2	Coal	Coal	Coal
3	Oil	Oil	Oil
4	Gas	Gas	Gas, gas manufacture, distribution
5	Oil_Pcts	Petroleum, coal products	Petroleum, coal products
6	Electricity	Electricity	Electricity
7	OMN	Minerals nec	Minerals nec
8	PFD	Food processing	Bovine cattle, sheep and goat meat products, meat products, vegetable oils and fats, dairy products, processed rice, sugar, food products nec, beverages and tobacco products
9	TXL	Textiles	Textiles, wearing apparel
10	CRP	Chemical, rubber, plastic products	Chemical, rubber, plastic products
11	NMM	Mineral products nec	Mineral products nec

(Table 3 continued)

No.	New code	Sector description	Comprising GTAP 8 sectors
12	I_S	Ferrous metals	Ferrous metals
13	NFM	Metals nec	Metals nec
14	FMP	Metal products	Metal products
15	MVH	Motor vehicles and parts	Motor vehicles and parts
16	OTN	Transport equipment nec	Transport equipment nec
17	ELE	Electronic equipment	Electronic equipment
18	OME	Machinery and equipment nec	Machinery and equipment nec
19	OMF	Manufactures nec	Leather products, wood products, paper products, publishing, manufactures nec
20	CNS	Construction	Construction
21	TRD	Trade	Trade
22	OTP	Transport nec	Transport nec
23	WTP	Water transport	Water transport
24	ATP	Air transport	Air transport
25	CMN	Communication	Communication
26	OFR	Financial services	Financial services nec, insurance
27	OSP	Other services	Water, business services nec, recreational and other services, ownership of dwellings
28	OSG	Public services	Public administration, defense, education, health

3.2 Procedure for Creating the Database for the GTAP-E Model

3.2.1 Data for the GTAP-E Model

As noted earlier, the GTAP 8 database forms the backdrop for the GTAP-E database referred to in this paper. There is a need to modify the regional and sectoral aggregation of the GTAP 8 database as described in TP16. First, it is necessary to download the GTAP-E application package (February 2006) from the GTAP website, and use the files in this package as a reference.

The total number of data elements in the GTAP-E model is 62. Some of these data already exist in the file named GTAP Gsdgdat.har in the GTAP 8 database, while other data need to be added. Table 4 shows the GTAP-E data sourced from the Gsdgdat.har file. Some of them are the same as the data in the Gsdgdat.har file, the only difference being the change in the names.

Table 5 shows the GTAP-E data calculated using the data from the Gsdgvole.har file.

Table 6 shows the GTAP-E data created using other resources. Data in category A take the value of either 0 or 1, except for EMIC (data for emission coefficients of EGYCOM in all regions) and EPLV (these data differ according to the region). EMIC and EPLV are created by applying the data sourced from the GTAP-E database in TP16 to the modified regional and sectoral aggregation..

Data in category B concerns CO_2 emissions. CO_2 emissions data were sourced from the GTAP website for the GTAP 7 database and previous versions. However, with the GTAP 8 database, it is possible to directly use the CO_2 emissions data included in the GTAP Gsdgemiss.har file to create the GTAP-E CO_2 emissions data.

CO_2 emissions data are expressed as million tons of carbon (Mt of C) in the GTAP-E model and as million tons of CO_2 (Mt of CO_2) in the revised GTAP-E model. In order to compare the simulation results of these two models in terms of the economy as well as CO_2 emissions, this paper uses CO_2 emissions data included in the Gsdgemiss.har file of the GTAP 8 database to create the CO_2 emissions data for both the GTAP-E and the revised GTAP-E models. As a result, it indicates CO_2 emissions data as Mt of CO_2 in both the GTAP-E and the revised GTAP-E models.

Table 4 GTAP-E Model Data Sourced from the Gsdgdat.Har File

No.	Name	Dimension	Total	Description
1	ADRV	TRAD_COMM*REG*REG	0	Protection-anti-dumping duty
14	DFNC	TRAD_COMM*PROD_COMM*REG	56138325	Domestic intermediate inputs net of carbon tax (= VDFA)
15	DGNC	TRAD_COMM*REG	9424033	Domestic purchases by government net of carbon tax (= VDGA)
16	DPNC	TRAD_COMM*REG	29585203	Domestic purchases by households net of carbon tax (=VDPA)
17	DPSM	REG	12	Sum of distribution parameters in household demand system
18	DVER	1	5	Format of GTAP data
23	EVFA	ENDW_COMM*PROD_COMM*REG	50187010	Endowments-Firms' purchases at agents' prices
24	EVOA	ENDW_COMM*REG	39560352	Endowments-Output at agents' prices
25	FBEP	ENDW_COMM*PROD_COMM*REG	116558	Protection-Factor-based subsidies
26	IFNC	TRAD_COMM*PROD_COMM*REG	12420364	Imported intermediate inputs net of carbon tax (= VIFA)
27	IGNC	TRAD_COMM*REG	171435	Imported purchases by government net of carbon tax (= VIGA)
28	IPNC	TRAD_COMM*REG	3818223	Imported purchases by households net of carbon tax (= VIPA)
29	ISEP	TRAD_COMM*PROD_COMM*REG*DIR	-869908	Intermediate input subsidies
30	MFRV	TRAD_COMM*REG*REG	16090	Protection-MFA export subsidy equivalent
33	OSEP	TRAD_COMM*REG	-2029728	Protection-Ordinary output subsidies
35	PURV	TRAD_COMM*REG*REG	0	Protection-Price undertaking export subsidy equivalent
37	SAVE	REG	6902885	Savings-Net expenditure at agents' prices
38	TFRV	TRAD_COMM*REG*REG	404458	Protection-Ordinary import duty
39	VDEP	REG	5929564	Capital stock-Value of depreciation
40	VDFA	TRAD_COMM*PROD_COMM*REG	56138325	Intermediates-Firms' domestic purchases at agents' prices
41	VDFM	TRAD_COMM*PROD_COMM*REG	55487951	Intermediates-Firms' domestic purchases at market prices
42	VDGA	TRAD_COMM*REG	9424033	Government-Domestic purchases at agents' prices
43	VDGM	TRAD_COMM*REG	9407932	Government-Domestic purchases at market prices
44	VDPA	TRAD_COMM*REG	29585203	Private households-Domestic purchases at agents' prices
45	VDPM	TRAD_COMM*REG	27878047	Private households-Domestic purchases at market prices
46	VFM	ENDW_COMM*PROD_COMM*REG	45481384	Endowments-Firms' purchases at market prices
47	VIFA	TRAD_COMM*PROD_COMM*REG	12420364	Intermediates-Firms' imports at agents' prices
48	VIFM	TRAD_COMM*PROD_COMM*REG	12200831	Intermediates-Firms' imports at market prices
49	VIGA	TRAD_COMM*REG	171435	Government-Imports at agents' prices
50	VIGM	TRAD_COMM*REG	167519	Government-Imports at market prices
51	VIMS	TRAD_COMM*REG*REG	15725697	Trade-Bilateral imports at market prices
52	VIPA	TRAD_COMM*REG	3818223	Private households-Imports at agents' prices
53	VIPM	TRAD_COMM*REG	3357347	Private households-Imports at market prices
54	VIWS	TRAD_COMM*REG*REG	15321239	Trade-Bilateral imports at world prices
55	VKB	REG	148239120	Capital stock-Value at beginning-of-period
56	VRRV	TRAD_COMM*REG*REG	0	Protection-VER export subsidy equivalent
57	VST	MARG_COMM*REG	542049	Trade-Exports for international transportation (market prices)
58	VTWR	MARG_COMM*TRAD_COMM*REG*REG	542049	Trade-Margins for international transportation (world prices)
59	VXMD	TRAD_COMM*REG*REG	14626997	Trade-Bilateral exports at market prices
60	VXWD	TRAD_COMM*REG*REG	14779190	Trade-Bilateral exports at world prices
61	XTRV	TRAD_COMM*REG*REG	136103	Protection-Ordinary export tax
	POP	REG	6620	Population (data present in Gsdgdat.har but not included in the downloaded GTAP-E data)
	FTRV	ENDW_COMM*PROD_COMM*REG	4822184	Taxes-Factor Employment tax revenue (data present in Gsdgdat.har but not included in the downloaded GTAP-E data)

Table 5 GTAP-E Model Data Created by Using the Data from the Gsdgvole.Har File

No.	Name	Dimension	Total	Description
7	CVOL	REG*EGYCOM	12716	Demand of energy comm. in metric ton of oil equivalent (Mtoe) (excluding crude oil to P_C)
19	DVOL	REG*EGYCOM	16331.25	Volume of domestic production in Mtoe (calculated using EVF, EVH, EVT(export), and EVT(import))
31	MVOL	REG*EGYCOM	4453.84	Volume of imports in Mtoe (calculated using EXI(import))
62	XVOL	REG*EGYCOM	4453.84	Volume of exports in Mtoe (calculated using EXI(export))

Table 6 GTAP-E Model Data Created Using Other Resources

A. Data (mainly taking the value 0 or 1)				
No.	Name	Dimension	Total	Description
5	CTLV	REG*EGYCOM	0	Total value of carbon taxes in millions of USD
6	CTRA	REG	0	Value of permit trading in millions of USD (1997)
8	CWFD	TRAD_COMM*PROD_COMM*REG	9744	Carbon tax power on domestic uses by firms (= 1)
9	CWFI	TRAD_COMM*PROD_COMM*REG	9744	Carbon tax power on imported uses by firms (= 1)
10	CWGD	TRAD_COMM*REG	336	Carbon tax power on domestic demands by government (= 1)
11	CWGI	TRAD_COMM*REG	336	Carbon tax power on imported demands by government (= 1)
12	CWPD	TRAD_COMM*REG	336	Carbon tax power on domestic demands by households (= 1)
13	CWPI	TRAD_COMM*REG	336	Carbon tax power on imported demands by households (= 1)
20	EMIC	REG*EGYCOM	902.51	Emission coefficients in Mt of C per exajoule (EJ)
21	EMTR	REG	0 or 1	Dummy variable for participation to permit trading (1 = permit trad.)
22	EPLV	REG*EGYCOM	16846.53	Energy price levels in USD per toe
32	NTAX	REG	0	Nominal carbon tax in USD per ton of C
34	PGDP	REG	12	GDP deflator
36	RTAX	REG	0	Real carbon tax in USD per ton of C
B. CO_2 emissions data				
2	CO2	REG*EGYCOM	26524.31	CO_2 emissions in Mt of CO_2
3	CO2Q	REG	26524.31	CO_2 emissions quota (Mt of CO_2)
4	CO2T	REG	26524.31	Total CO_2 emissions (Mt of CO_2)

3.2.2 Parameters for the GTAP-E Model

The total number of parameters in the GTAP-E model is 15 (Table 7). Some of these parameters already exist in the Gsdgpar.har file of the GTAP 8 database, while other data need to be added.

Most of the new GTAP-E parameters are substitution elasticities between capital and energy or between energy goods. As these elasticities take the value of either 1 or 0.5, it would be easy to create GTAP-E substitution elasticities, except in the case of ESBV (the substitution elasticities for primary factors).

First, it is notable that ESBV has one dimension only—(PROD_COMM)—in the standard GTAP model, while it has two dimensions—(PROD_COMM*REG)—in the GTAP-E model. That is, in the GTAP model, the elasticities of ESBV by sector are common for all regions, while in the GTAP-E model, they differ according to the regions.

Table 7 Parameters in the GTAP-E Model

A. Parameters taken from the Gsdgpar.har file				
No.	Name	Dimension	Total	Description
1	SLUG	5		Binary parameter for factor mobility: 1 = sluggish, 0 = mobile
2	RDLT	1		Investment allocation binary coefficient (1 or 0)
3	SUBP	TRAD_COMM*REG	161.75	Constant Difference of Elasticities (CDE) substitution parameter
4	INCP	TRAD_COMM*REG	338.31	CDE expansion parameter
5	ESBD	TRAD_COMM	86.69	Armington Constant Elasticity of Substitution (CES) for domestic/imported allocation
6	ESBM	TRAD_COMM	182.11	Armington CES for regional allocation of imports
7	ESBV	PROD_COMM*REG	441.85	Substitution elasticities for primary factors (dimension = REG for the standard GTAP model)
8	ETRE	ENDW_COMM	-6.50	Constant Elasticity of Transformation (CET) between sectors for sluggish primary factors
9	RFLX	REG		Expected rate of return flexibility parameter
10	ESBT	PROD_COMM	0	Elasticity of intermediate input substitution
B. New parameters for the GTAP-E database				
11	ELKE	PROD_COMM*REG	144.0	Substitution elasticities between capital and energy
12	ELLY	PROD_COMM*REG	288.0	Substitution elasticities between electricity and non-electricity
13	ELCO	PROD_COMM*REG	144.0	Substitution elasticities between coal and non-coal
14	ELFU	PROD_COMM*REG	288.0	Substitution elasticities between remaining fossil fuels
15	EMTR	REG	0	Dummy variable for participation to permit trading (1 = permit trad.)

Two options exist for creating the new ESBV for the GTAP-E database: (1) by taking the elasticities of ESBV from TP16, or (2) by taking the elasticity of substitution in value-added-energy subproduction (EFVE) from the revised GTAP-E model. As the revised GTAP-E model is based on the GTAP 8 database, this paper applies the EFVE elasticities of the revised GTAP-E model to the ESBV elasticities in the corresponding regions.

A comparison of ESBV in the GTAP-E model (based on GTAP 5) and EFVE in the revised GTAP-E model (based on GTAP 8) shows that their differences are relatively small for the energy and agricultural sectors (Table 8). Thus, in this paper, the EFVE elasticities of the energy and agricultural sectors are directly applied to their respective ESBV elasticities. It should be noticed, however, that in some sectors, especially the gas sector in JPN and the coal sector in the EEFSU, the differences become rather considerable.

Although this paper aggregates the 22 non-energy and non-agricultural sectors, these sectors are aggregated into one of the two categories in both the GTAP-E and the revised GTAP-E model: En_Int_Ind (energy intensive industries) and Oth_Ind_ Ser (other industries and services). En_Int_Ind includes minerals nec; chemical, rubber, plastic products; mineral products nec; ferrous metals; and metals nec. All the other sectors are included under Oth_Ind_Ser.

Table 9 shows that for En_Int_Ind, the ESBV in the GTAP-E model (1.19 for all regions) and the average EFVE in the revised GTAP-E model (1.15; each region has its own elasticity, ranging from 1.04 to 1.20) are similar to the average sectoral elasticities of ESBV in En_Int_Ind in the GTAP model. There is only one exception; the OMN (minerals nec) in En_Int_Ind is small compared with the other sectors in En_Int_Ind. Moreover, for Oth_Ind_Ser, the ESBV in the GTAP-E model (1.36 for all regions) and the average EFVE in the revised GTAP-E model (1.37; each region has its own elasticity, ranging from 1.33 to 1.42) are similar to the average sectoral elasticities of ESBV in Oth_Ind_Ser in the GTAP model.

Table 8 ESBV of the GTAP-E Model and EFVE of the Revised GTAP-E Model

ESBV in the GTAP-E model (TP16)								
	1 USA	2 EU	3 EEFSU	4 JPN	5RoA1	6 EEx	7 CHIND	8 ROW
1. Agriculture	0.029	0.152	0.086	0.220	0.147	0.118	0.113	0.112
2. Coal	3.999	3.986	3.996	3.997	3.972	3.928	3.993	3.923
3. Oil	0.400	0.391	0.400	0.400	0.397	0.398	0.400	0.390
4. Gas	0. 041	0.353	0.952	1.308	1.035	0.758	0.867	0.392
5. Oil_Pcts	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260
6. Electricity	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260
7. En_Int_Ind	1.118	1.188	1.188	1.188	1.188	1.188	1.188	1.188
8. Oth_Ind_ Ser	1.358	1.358	1.358	1.358	1.358	1.358	1.358	1.358
EFVE in the revised GTAP-E model (9X8)								
	1 USA	2 EU27	3 EEFSU	4 JPN	5 RoA1	6 EEx	7 CHN	8 IND	9 ROW
1. Agr	0.245	0.242	0.245	0.237	0.237	0.243	0.242	0.245	0.243
2. Coal	3.841	3.600	3.279	3.984	3.763	3.956	3.602	3.995	3.812
3 Oil	0.391	0.391	0.389	0.400	0.392	0.396	0.369	0.387	0.386
4. Gas	0.204	0.446	0.610	0.007	1.373	1.070	0.286	0.284	0.543
5. Oil_pcts	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260
6. Electricity	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260
7. En_Int_Ind	1.218	1.219	1.158	1.240	1.039	1.099	1.155	1.132	1.100
8. Oth_Ind_ Ser	1.346	1.330	1.418	1.362	1.357	1.373	1.354	1.404	1.375

Table 9 ESBV and EFVE in En_Int_Ind and Oth_Ind_Ser

		ESBV in the GTAP model	ESBV in the GTAP-E model	EFVE in the revised GTAP-E model (different according to the region)
		12×28 (GTAP 8.0)	8×8 (GTAP 5.0)	8×9 (GTAP 8.0)
En_Int_ind	OMN	0.20	1.19	1.04～1.20 (average: 1.15)
	CRP	1.12		
	NMM	1.26		
	I_S	1.26		
	NFM	1.26		
Oth_ind_ser	PFD	1.26	1.36	1.33～1.42 (average: 1.37)
	TXL	1.26		
	FMP	1.26		
	MVH	1.26		
	OTN	1.26		
	ELE	1.26		
	OME	1.26		
	OMF	1.26		
	CNS	1.40		
	TRD	1.68		
	OTP	1.68		
	WTP	1.68		
	ATP	1.68		
	CMN	1.26		
	OFR	1.26		
	OSP	1.26		
	OSG	1.26		
CGDS	CGDS	1.00	1.00	1.00

Taking these points into consideration, this paper tries to update the ESBV of the sectors classified in En_Int_Ind and Oth_Ind_Ser of the GTAP-E model in two steps. First, the coefficients for each region are calculated by dividing the EFVE of each region by the average EFVE of the sectors belonging to En_Int_Ind or Oth_Ind_Ser (1.15 for En_Int_Ind, for example). Next, the ESBV of each sector and region is obtained by multiplying the ESBV in the GTAP model by the coefficients calculated above.

3.3 Procedure for Creating the Database for the Revised GTAP-E Model

3.3.1 Data for the Revised GTAP-E Model

The revised GTAP-E model simplifies the procedure of data construction, mainly by shortening the procedure to create the data for CO_2 emissions and carbon tax. The total number of the data in the revised GTAP-E model is 54, while the total number of data in the GTAP-E model is 62.

Regional aggregation of the revised GTAP-E model is updated to better adapt it to the actual world. The other new feature in the revised GTAP-E model is the manner of calculation of the CO_2 emissions data; it is calculated in Mt CO_2 in the revised GTAP-E model and as Mt of C in the GTAP-E model. As mentioned previously, this paper tries to apply the new features of the revised GTAP-E model to the GTAP-E model. Therefore, China and India are separated, the EU is treated as EU27, and CO_2 emissions data is evaluated in Mt CO_2 for both models, in order to enable a direct comparison of the results.

Some of the revised GTAP-E model data already exist in the Gsdgdat.har file of the GTAP 8 database, while the rest must be added. Table 10 shows the data in the revised GTAP-E model database taken from Gsdgdat.har file.

Table 10 Revised GTAP-E Model Data Sourced from the Gsdgdat.Har File

No.	Name	Dimension	Total	Description
1	DVER	1	5	Format of GTAP Data
2	DREL			GTAP data release identifier
3	SAVE	REG	6902885	Savings-Net expenditure at agents' prices
4	VKB	REG	148239120	Capital stock-Value at beginning-of-period
5	VDEP	REG	5929564	Capital stock-Value of depreciation
6	POP	REG	6620	Population
7	VDGA	TRAD_COMM*REG	9424033	Government-Domestic purchases at agents' prices
8	VIGA	TRAD_COMM*REG	171435	Government-Imports at agents' prices
9	VDGM	TRAD_COMM*REG	9407932	Government-Domestic purchases at market prices
10	VIGM	TRAD_COMM*REG	167519	Government-Imports at market prices
11	VDPA	TRAD_COMM*REG	29585203	Private households-Domestic purchases at agents' prices
12	VIPA	TRAD_COMM*REG	3818223	Private households-Imports at agents' prices
13	VDPM	TRAD_COMM*REG	27878047	Private households-Domestic purchases at market prices
14	VIPM	TRAD_COMM*REG	3357347	Private households-Imports at market prices
15	EVOA	ENDW_COMM*REG	39560352	Endowments-Output at agents' prices
16	EVFA	ENDW_COMM*PROD_COMM*REG	50187010	Endowments-Firms' purchases at agents' prices
17	VFM	ENDW_COMM*PROD_COMM*REG	45481384	Endowments-Firms' purchases at market prices
18	VDFA	TRAD_COMM*PROD_COMM*REG	56138325	Intermediates-Firms' domestic purchases at agents' prices
19	VIFA	TRAD_COMM*PROD_COMM*REG	12420364	Intermediates-Firms' imports at agents' prices
20	VDFM	TRAD_COMM*PROD_COMM*REG	55487951	Intermediates-Firms' domestic purchases at market prices
21	VIFM	TRAD_COMM*PROD_COMM*REG	12200831	Intermediates-Firms' imports at market prices
22	VIMS	TRAD_COMM*REG*REG	15725697	Trade-Bilateral imports at market prices
23	VIWS	TRAD_COMM*REG*REG	15321239	Trade - Bilateral imports at world prices

(Table 10 continued)

No.	Name	Dimension	Total	Description
24	VXMD	TRAD_COMM*REG*REG	14626997	Trade-Bilateral exports at market prices
25	VXWD	TRAD_COMM*REG*REG	14779190	Trade-Bilateral exports at world prices
26	VST	MARG_COMM*REG	542049	Trade-Exports for international transportation (market prices)
27	VTWR	MARG_COMM*TRAD_COMM*REG*REG	542049	Trade-Margins for international transportation (world prices)
28	FBEP	ENDW_COMM*PROD_COMM*REG	116558	Protection-Factor-based subsidies
29	FTRV	ENDW_COMM*PROD_COMM*REG	4822184	Taxes-Factor employment tax revenue
30	ISEP	TRAD_COMM*PROD_COMM*REG*DIR	-869908	Intermediate input subsidies
31	OSEP	TRAD_COMM*REG	-2029728	Protection-Ordinary output subsidies
32	ADRV	TRAD_COMM*REG*REG	0	Protection-Anti-dumping duty
33	TFRV	TRAD_COMM*REG*REG	404458	Protection-Ordinary import duty
34	PURV	TRAD_COMM*REG*REG	0	Protection-Price undertaking export subsidy equivalent
35	VRRV	TRAD_COMM*REG*REG	0	Protection-VER export subsidy equivalent
36	MFRV	TRAD_COMM*REG*REG	16090	Protection-MFA export subsidy equivalent
37	XTRV	TRAD_COMM*REG*REG	136103	Protection-Ordinary export tax
38	DPSM	REG	12	Sum of distribution parameters in household demand system
39	VTSS	TARSET*TRAD_COMM*REG*REG	404458	Value of imports including different tariff components
40	DFNC	TRAD_COMM*PROD_COMM*REG	56138325	Domestic intermediate inputs net of C tax (= VDFA)
41	DGNC	TRAD_COMM*REG	9424033	Domestic purchases by government net of C tax (= VDGA)
42	DPNC	TRAD_COMM*REG	29585203	Domestic purchases by households net of C tax (= VDPA)
43	IFNC	TRAD_COMM*PROD_COMM*REG	12420364	Imported intermediate inputs net of C tax (= VIFA)
44	IGNC	TRAD_COMM*REG	171435	Imported purchases by government net of C tax (= VIGA)
45	IPNC	TRAD_COMM*REG	3818223	Imported purchases by households net of C tax (= VIPA)

Table 11 shows the revised GTAP-E data created using resources other than the Gsdgdat.har file. Here, the nominal carbon tax (NTAX) equals 0, and the government share of permits revenue (GSHR) equals 1.

Table 11 GTAP-E Model Data Created by Using Other Resources

A. Data (mainly taking the value 0 or 1)				
No.	Name	Dimension	Total	Description
46	NTAX	REG	0	Nominal carbon tax in USD per ton of CO_2
47	GSHR	REG	12	Government share of permits revenue
B. CO_2 emissions data				
48	CO2Q	REG	26524.31	CO_2 emissions quota, $MtCO_2$
49	CODP	TRAD_COMM*REG	2971.95	Emissions from private consumption of domestic product, $MtCO_2$ (= MDP for energy sectors)
50	COIP	TRAD_COMM*REG	752	Emissions from private consumption of imported product, $MtCO_2$ (= MIP for energy sectors)
51	CODG	TRAD_COMM*REG	0.04	Emissions from government consumption of domestic product, $MtCO_2$ (= MDG for energy sectors)
52	COIG	TRAD_COMM*REG	0.01	Emissions from government consumption of imported product, $MtCO_2$ (= MIG for energy sectors)
53	CODF	TRAD_COMM*PROD_COMM*REG	18066.81	Emissions from firms' usage of domestic product, $MtCO_2$ (= MDF for energy sectors)
54	COIF	TRAD_COMM*PROD_COMM*REG	902.51	Emissions from firms' usage of imported product, $MtCO_2$ (= MIF for energy sectors)

One of the differences between the GTAP-E and the revised GTAP-E model databases is that the CO_2 emissions data are classified as CO_2 emissions from firms' usage, from private consumption, and from government

consumption in the revised GTAP-E model. Each of these is further subdivided into CO_2 emissions from domestic product and CO_2 emissions from imports. CO_2 emissions data of energy sectors (except electricity) are created using the data in the Gsdgemmis.har file. CO_2 emissions in all the other sectors are considered to be zero.

3.3.2 Parameters for the Revised GTAP-E Model

The total number of parameters in the revised GTAP-E model is 26 (Table 12). Some of these parameters already exist in the Gsdgpar.har file of the GTAP 8 database, and some of the data needs to be added newly.

Table 12 Parameters in the Revised GTAP-E Model

A. Parameters taken from the Gsdgpar.har file				
No.	Name	Dimension	Total	Description
1	DVER	1		Format of GTAP data
2	DREL			GTAP data release identifier
12	SUBP	UP_COMM*REG	138.23	CDE substitution parameter
13	INCP	UP_COMM*REG	289.86	CDE expansion parameter
5	ESBT	PROD_COMM	0	Elasticity of intermediate input substitution
6	SLUG	5		Binary parameter for factor mobility: 1 = sluggish, 0 = mobile
7	ETRE	ENDW_COMM	-6.5	CET between sectors for sluggish primary factors
8	ESBD	TRAD_COMM	86.69	Armington CES for domestic/imported allocation
9	ESBM	TRAD_COMM	182.11	Armington CES for regional allocation of imports
10	RDLT	1		Investment allocation binary coefficient
11	RFLX	REG	120	Expected rate of return flexibility parameter
12	SUB1	TRAD_COMM*REG	161.75	CDE substitution parameter
13	INC1	TRAD_COMM*REG	338.31	CDE expansion parameter
B. New parameters for the revised GTAP-E database				
No.	Name	Dimension	Total	Description
14	EGEN	REG	12	Elasticity of substitution in government energy subconsumption
15	EGNN	REG	12	Elasticity of substitution in government non-energy subconsumption
16	EGUG	REG	6	Elasticity of substitution in the top of government consumption nest
17	EPEN	REG	12	Elasticity of substitution in household energy subconsumption
18	EFEN	PROD_COMM*REG	288	Elasticity of substitution in energy subproduction
19	EFKE	PROD_COMM*REG	144	Elasticity of substitution in capital-energy subproduction
20	EFNC	PROD_COMM*REG	288	Elasticity of substitution in non-coal energy subproduction
21	EFNL	PROD_COMM*REG	144	Elasticity of substitution in non-electricity energy subproduction
22	EFVE	PROD_COMM*REG	441.85	Elasticity of substitution in value-added- energy subproduction
23	TRBL			Set TR_BLOCK emissions trading blocs
24	MAPB			Mapping REGTOBLOC from REG to TRBL
25	PYRT			Total payment rates with the appropriate bases in percentage
26	PAYD			CES between primary factors in production

There are two types of substitution parameters (SUB1 and SUBP) and expansion parameters (INC1 and INCP) in the revised GTAP-E model. SUB1 and INC1 are almost the same as SUBP and INCP, and are already included in the Gsdgpar.har file. The difference between SUB1 and SUBP and between INC1 and INCP is that the former treats each energy goods, while the latter aggregates them into one category, “eny”, which includes coal, oil, gas, petroleum and coal products, and electricity. By aggregating these energy sectors into one group, “eny”, and using the data-agg function of GEMPACK (for example, aggregating 9 regions and 8 sectors), the same

substitution parameters and expansion parameters for "eny" are obtained for the revised GTAP-E model. The EFVE elasticities are obtained using the same method as described for the ESBV in the GTAP-E model.

4. Economic Impacts of Electric Supply Shortage in Japan

4.1 Comparison of the Simulation Results of the GTAP and the GTAP-E Models

The simulation results of the GTAP and the GTAP-E models are compared and analyzed in this section. The simulation scenario considers a reduction of 1% in the use of electric power in Japan due to electric supply shortage.

4.1.1 Macroeconomic Changes

As described in 2.1, the simulation in this paper fixes RORDELTA as 0. When RORDELTA = 0, there is a change of -0.97% and -0.55% in Japan's GDP for the GTAP model and the GTAP-E model, respectively. The comparison of the results of these two models indicates that the energy substitution structure plays an important role in the impact analysis of changes in the energy supply. The impacts in the other regions are, on the other hand, quite small.

The impacts of electric supply shortage in both models become less serious when RORDELTA = 1, due to the increase in investment. When RORDELTA = 1, the simulated change in Japan's GDP is -0.80% and -0.49% for the GTAP model and the revised GTAP-E model, respectively.

Tables 13 and 14 show the simulation results for macroeconomic changes expressed in percentage form and in terms of millions of USD, respectively.

Table 13 Macroeconomic Impacts Due to a 1% Reduction in the Use of Electric Power in Japan (percentage)

	Change in GDP		Change in Import		Change in Export	
	GTAP model	GTAP-E model	GTAP model	GTAP-E model	GTAP model	GTAP-E model
JPN	-0.97	-0.55	-0.64	-0.41	-1.09	-0.66
KOR	0.00	0.00	-0.04	-0.02	-0.02	-0.01
CHN	-0.01	0.00	-0.06	-0.03	0.00	0.00
AEEx	0.00	0.00	-0.01	0.00	0.01	0.01
OASN	0.00	0.00	-0.02	-0.01	0.00	0.00
IND	0.00	0.00	-0.02	-0.01	0.04	0.03
USA	0.00	0.00	-0.02	-0.01	0.02	0.02
EU27	0.00	0.00	0.00	0.00	0.01	0.01
OEEx	0.00	0.00	-0.03	-0.02	0.03	0.01
EEFSU	0.00	0.00	-0.03	-0.02	0.02	0.01
RoA1	0.00	0.00	-0.01	0.00	0.03	0.01
ROW	0.00	0.00	-0.02	-0.01	0.01	0.01

4.1.2 Changes in Industry Output

As the changes in the GDP for the other regions are quite small, the analysis in this section concentrates on the simulation results of Japan. It is evident that Japanese industrial output decreases and percentage changes in the manufacturing sectors are bigger than those in the service sectors.[2]

[2] For the GTAP model, output increases slightly for the coal sector only and decreases for all the other sectors. For the GTAP-E model, output decreases for all the sectors. In this paper, the default aggregation for the endowment commodities is 5. In this case, labor is divided into "Sklab" and "UnSklab". When labor is not divided as such, the output of the coal sector decreases by -0.1% in the GTAP model.

Table 14 Macroeconomic Impacts Due to a 1% Reduction in the Use of Electric Power in Japan (millions, USD)

	Change in GDP		Change in Import		Change in Export		Change in EV	
	GTAP model	GTAP-E model	GTAP model	GTAP-E model	GTAP model	GTAP-E model	GTAP model	GTAP-E model
JPN	-42,481	-23,863	-4,540	-2,882	-8,648	-5,239	-25,908	-14,617
KOR	8	8	-172	-93	-76	-31	-19	-16
CHN	-238	-140	-560	-313	-48	-23	-431	-264
AEEx	-20	-12	-44	-14	56	44	-118	-72
OASN	-12	-7	-73	-31	-19	3	-72	-45
IND	-7	0	-51	-24	90	62	7	0
USA	13	17	-482	-249	280	213	-37	-47
EU27	130	120	70	131	817	590	249	152
OEEx	-45	-26	-325	-187	366	169	-731	-369
EEFSU	-62	-36	-165	-86	137	65	-281	-134
RoA1	-43	-25	-85	-41	264	150	-227	-121
ROW	2	8	-231	-108	132	104	-172	-99

The simulation results for industry output are shown in Figure 4 (percentage change) and Figure 5 (millions, USD). Both results have the same tendency; in the simulation results of the GTAP model, percentage changes are bigger for the manufacturing sectors than for the service sectors. In the gas sector, the percentage change attains a value as large as -5.5%, but according to the corresponding result in millions of USD, the amount of the change in the gas sector is actually small. NFM (metals nec) and ELE (electronic equipment) record a percentage change of -1.5%, while the corresponding value for both OME (machinery and equipment) and OMN (minerals nec) is -1.4%.

Compared with the result of the GTAP model, percentage change in the GTAP-E model is less serious due to the energy substitution structure in the latter. For the GTAP-E model, it takes the value -3.5% in the gas sector, -0.9% in NFM and ELE, and -0.8% in OME, FMP (metal products), NMM (mineral products nec), and OMN.

In the service sectors, the percentage change remains between -1.4% (construction) and -0.5% (water transport) for the GTAP model, and between -0.8% (construction) and -0.3% (water transport) for the GTAP-E model.

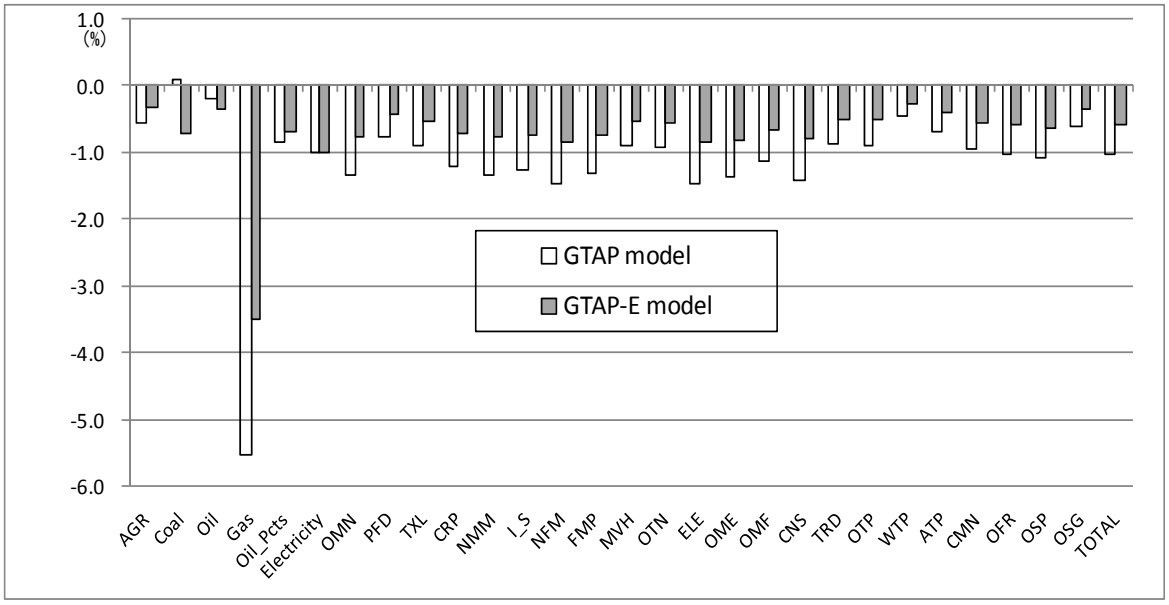

Figure 4 Impacts on Japan's Industrial Output Due to a 1% Reduction in the Use of Electric Power (percentage)

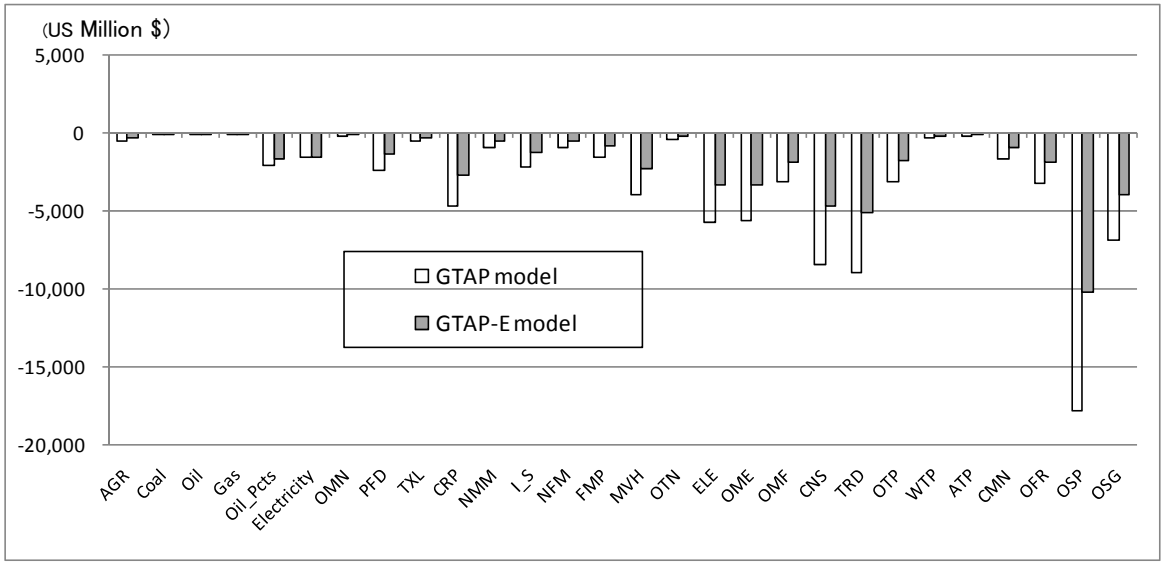

Figure 5 Impacts on Japan's Industrial Output Due to a 1% Reduction in the Use of Electric Power (millions, USD)

Although the percentage changes in service sectors are smaller than those in the manufacturing sectors, the changes evaluated in terms of millions of USD are bigger for the service sectors than for the manufacturing sectors.

Table 15 shows the impact of the 1% reduction in the use of electric power for 3 sector groups: agriculture and forestry and fishing, manufacturing, and services. The results of the GTAP model indicate changes of USD 34 billion and USD 52 billion for the manufacturing and service sectors, respectively. The corresponding numbers for the GTAP-E model are USD 21 billion and USD 30 billion, respectively.

The total reduction for the GTAP and GTAP-E models is USD 87 billion and USD 51 billion (about 60% of the result of the GTAP model), respectively.

Table 15 Impacts of a 1% Reduction in the Use of Electric Power in Japan for 3 Sector Groups

	Change (%)		Change (US million $)	
	GTAP model	GTAP-E model	GTAP model	GTAP-E model
Agriculture, forestry, fishing	-0.57	-0.33	-541	-310
Manufacture sectors	-1.14	-0.68	-34,381	-20,554
Service sectors	-0.95	-0.56	-52,199	-30,493
total	-1.02	-0.60	-87,121	-51,357

4.1.3 Change in Private Consumption

Figures 6 and 7 show the simulation results for private household consumption. It decreases mainly for the service sectors. According to the simulation results of the GTAP model, percentage changes in the private consumption of manufacturing sector commodities range from -0.6% to -0.7%, and those for service sector commodities, from -0.6% to -1.0%. For example, private consumption decreases by USD 7.6 billion for other services and by USD 3.6 billion for trade. In the manufacturing sectors, the private consumption of processed food decreases by USD 1.5 billion.

The percentage change in the GTAP-E model is comparatively less serious for private consumption. In the GTAP-E model, percentage changes in the private consumption of manufacturing sector commodities range from -0.3% to -0.4%, while the corresponding range for service sector commodities is -0.3% to -0.6%.

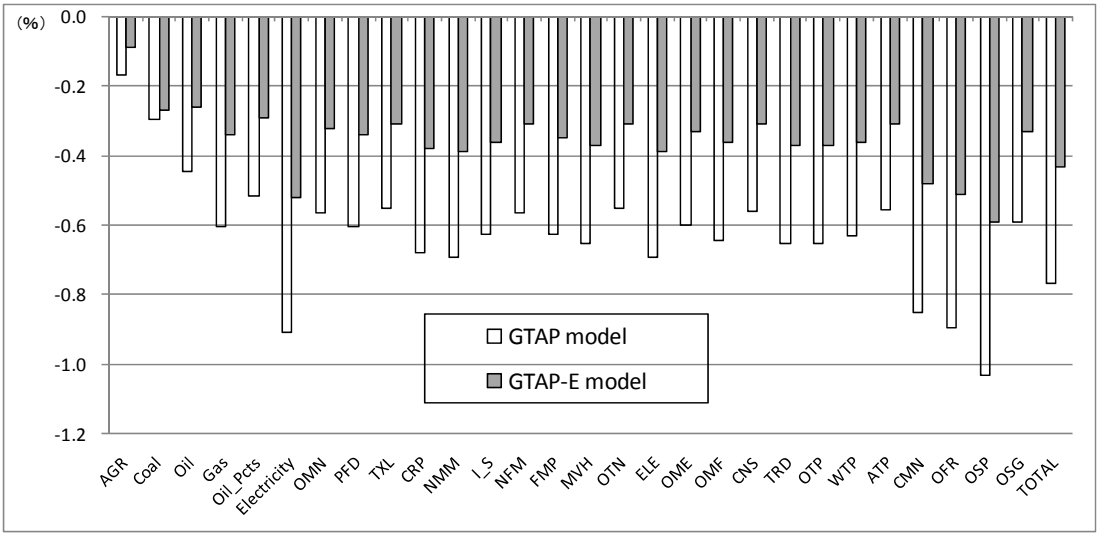

Figure 6 Impacts of a 1% Reduction in the Use of Electric Power on Private Consumption in Japan (percentage)

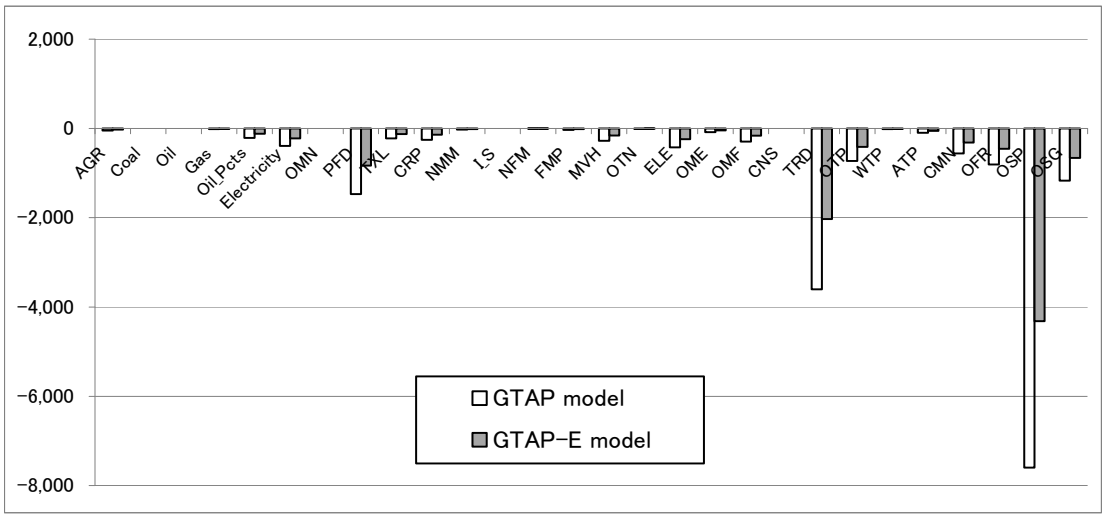

Figure 7 Impacts of a 1% Reduction in the Use of Electric Power on Private Consumption in Japan (millions, USD)

Table 16 shows the impact of a 1% reduction in the use of electric power in Japan in the 3 commodity groups. The GTAP model recorded changes worth USD 3.3 billion and USD 15 billion for manufacturing sector commodities and service sector commodities, respectively. The corresponding values according to the GTAP-E model are USD 1.9 billion and USD 8.5 billion. The results indicate total reductions of USD 18 billion and USD 10.4 billion according to the GTAP and the GTAP-E model, respectively.

Table 16 Impacts of a 1% Reduction in the Use of Electric Power in Japan for 3 Commodity Groups

	Change (%)		Change (US million $)	
	GTAP model	GTAP-E model	GTAP model	GTAP-E model
Agriculture, forestry, fishing	-0.17	-0.09	-51	-28
Manufacturing sectors	-0.62	-0.35	-3,308	-1,860
Service sectors	-0.82	-0.47	-14,973	-8,478
total	-0.77	-0.43	-18,331	-10,367

4.1.4 Changes in the Supply Price

Changes in the electricity supply price can play a crucial part in the simulation of the impact of the electric supply shortage. If the supply price of electricity increases too much, the simulation would become unrealistic.

The electric supply shortage results in an increase in the supply price for most sectors in Japan. The supply price of electricity increases by 0.48% and 0.28% in the simulations by the GTAP model and the GTAP-E model, respectively. Figure 8 shows the simulation results for the supply price. The change in the supply price does not exceed 0.7% for both models.

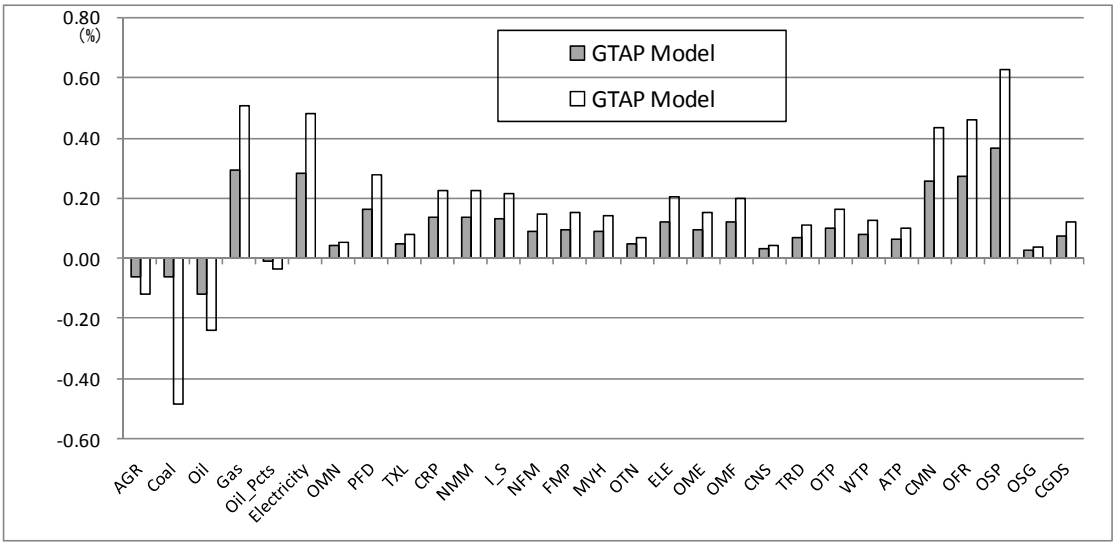

Figure 8 Impacts of a 1% Reduction in the Use of Electric Power on the Supply Price in Japan (percentage)

4.2 Comparison of the Simulation Results of the GTAP-E and the Revised GTAP-E Models

The simulation results of the GTAP-E and the revised GTAP-E models are compared and analyzed in this section. The simulation scenario is the same as that in 4.1, namely, a reduction of 1% in the use of electric power in Japan due to electric supply shortage.

Table 17 Macroeconomic Impacts Due to a 1% Reduction in the Use of Electric Power in Japan (percentage)

	Change in GDP		Change in Import		Change in Export		Change in CO_2 emissions	
	GTAP-E model	Revised GTAP-E model	GTAP-E model	Revised GTAP-E model	GTAP-E model	Revised GTAP-E model	GTAP-E model	Revised GTAP-E model
JPN	-0.55	-0.54	-0.41	-0.40	-0.66	-0.65	-0.77	-0.77
KOR	0.00	0.00	-0.02	-0.02	-0.01	-0.01	0.03	0.02
CHN	0.00	0.00	-0.03	-0.03	0.00	0.00	0.00	0.00
AEEx	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02
OASN	0.00	0.00	-0.01	-0.01	0.00	0.00	0.01	0.00
IND	0.00	0.00	-0.01	-0.01	0.03	0.03	0.00	0.00
USA	0.00	0.00	-0.01	-0.01	0.02	0.02	0.01	0.01
EU27	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
OEEx	0.00	0.00	-0.02	-0.02	0.01	0.01	0.01	0.01
EEFSU	0.00	0.00	-0.02	-0.02	0.01	0.01	0.01	0.01
RoA1	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01
ROW	0.00	0.00	-0.01	-0.01	0.01	0.01	0.01	0.01

4.2.1 Macroeconomic Changes

There is little difference between the simulation results of the two models. The change in GDP, for example, is -0.55% for the GTAP-E model and -0.54% for the revised GTAP-E model. The change of CO_2 emissions is -0.77% according to both models.

Tables 17 and 18 show the simulation results using both models for macroeconomic changes in terms of percentage and millions of USD, respectively.

Table 18 Macroeconomic Impacts Due to a 1% Reduction in the Use of Electric Power in Japan (millions, USD)

	Change in GDP		Change in Import		Change in Export		Change in EV		
	GTAP-E model	Revised GTAP-E model	GTAP-E model	Revised GTAP-E model	GTAP-E model	Revised GTAP-E model	GTAP-E model	Revised model	GTAP-E
JPN	-23,863	-23,601	-2,882	-2,849	-5,239	-5,179	-14,617	-14,453	
KOR	8	8	-93	-92	-31	-31	-16	-16	
CHN	-140	-138	-313	-309	-23	-22	-264	-261	
AEEx	-12	-12	-14	-14	44	44	-72	-71	
OASN	-7	-6	-31	-30	3	3	-45	-45	
IND	0	1	-24	-24	62	62	0	0	
USA	17	17	-249	-247	213	211	-47	-48	
EU27	120	120	131	130	590	584	152	151	
OEEx	-26	-26	-187	-183	169	167	-369	-362	
EEFSU	-36	-35	-86	-85	65	64	-134	-132	
RoA1	-25	-24	-41	-40	150	148	-121	-120	
ROW	8	9	-108	-106	104	104	-99	-97	

4.2.2 Change in Industry Output, Private Consumption, and Supply Price across Sectors

Simulation results for industry output, private consumption, and supply price are indicated in Table 19 (percentage change) and Table 20 (change in millions of USD). The results are quite similar across all sectors for both models.

Table 19 Impacts of a 1% Reduction in Electric Supply Usage on Industry Output, Private Consumption, and Supply Price across Sectors in Japan (percentage)

	Change in industry output		Change in private consumption		Change in supply price	
	GTAP-E model	Revised GTAP-E model	GTAP-E model	Revised GTAP-E model	GTAP-E model	Revised GTAP-E model
AGR	-0.33	-0.32	-0.09	-0.09	-0.06	-0.06
Coal	-0.72	-0.72	-0.27	-0.22	-0.06	-0.06
Oil	-0.35	-0.35	-0.26	-0.22	-0.12	-0.12
Gas	-3.50	-3.45	-0.34	-0.31	0.29	0.29
Oil_Pcts	-0.70	-0.69	-0.29	-0.26	-0.01	-0.01
Electricity	-1.00	-1.00	-0.52	-0.55	0.28	0.28
OMN	-0.77	-0.76	-0.32	-0.32	0.04	0.04
PFD	-0.44	-0.43	-0.34	-0.34	0.16	0.16
TXL	-0.53	-0.52	-0.31	-0.30	0.05	0.05
CRP	-0.71	-0.70	-0.38	-0.38	0.13	0.13
NMM	-0.76	-0.75	-0.39	-0.39	0.14	0.13
I_S	-0.74	-0.73	-0.36	-0.35	0.13	0.13
NFM	-0.86	-0.85	-0.31	-0.31	0.09	0.09
FMP	-0.75	-0.75	-0.35	-0.35	0.09	0.09

(Table 19 continued)

MVH	-0.53	-0.52	-0.37	-0.36	0.09	0.09
OTN	-0.55	-0.55	-0.31	-0.30	0.05	0.05
ELE	-0.86	-0.85	-0.39	-0.39	0.12	0.12
OME	-0.81	-0.81	-0.33	-0.33	0.09	0.09
OMF	-0.66	-0.65	-0.36	-0.36	0.12	0.12
CNS	-0.80	-0.79	-0.31	-0.31	0.03	0.03
TRD	-0.50	-0.49	-0.37	-0.36	0.07	0.07
OTP	-0.52	-0.52	-0.37	-0.37	0.10	0.10
WTP	-0.28	-0.27	-0.36	-0.35	0.08	0.08
ATP	-0.40	-0.39	-0.31	-0.31	0.07	0.06
CMN	-0.55	-0.54	-0.48	-0.48	0.25	0.25
OFR	-0.59	-0.58	-0.51	-0.50	0.27	0.27
OSP	-0.63	-0.62	-0.59	-0.58	0.37	0.36
OSG	-0.35	-0.34	-0.33	-0.33	0.03	0.03
TOTAL	-0.60	-0.59	-0.43	-0.43	-	-

Table 20 Impacts of a 1% Reduction in Electric Supply Usage on Industry Output, Private Consumption, and Supply Price across Sectors in Japan (millions, USD)

	Change in industry output		Change in private consumption	
	GTAP-E model	Revised GTAP-E model	GTAP-E model	Revised GTAP-E model
AGR	-310	-306	-28	-28
Coal	0	0	0	0
Oil	-1	-1	0	0
Gas	-48	-48	-8	-8
Oil_Pcts	-1,698	-1,670	-120	-108
Electricity	-1,590	-1,590	-223	-227
OMN	-92	-91	0	0
PFD	-1,395	-1,379	-830	-821
TXL	-327	-324	-124	-123
CRP	-2,748	-2,717	-142	-141
NMM	-539	-533	-13	-13
I_S	-1,285	-1,271	0	0
NFM	-554	-548	-3	-3
FMP	-875	-866	-17	-17
MVH	-2,316	-2,290	-156	-154
OTN	-253	-250	-6	-6
ELE	-3,346	-3,309	-238	-236
OME	-3,289	-3,253	-44	-44
OMF	-1,835	-1,815	-165	-163
CNS	-4,737	-4,687	0	0
TRD	-5,083	-5,028	-2,032	-2,009
OTP	-1,777	-1,758	-411	-407
WTP	-180	-178	-7	-7
ATP	-113	-111	-56	-55
CMN	-983	-972	-316	-313
OFR	-1,888	-1,868	-457	-452
OSP	-10,225	-10,115	-4,319	-4,271
OSG	-3,917	-3,874	-658	-651
TOTAL	-51,405	-50,853	-10,375	-10,265

5. Conclusion

In order to evaluate the impact of the reduced use of electric power caused by electric supply shortage in Japan, this paper considered a scenario in which Japan experiences a 1% reduction in electric supply usage. Scenario simulation was conducted using the GTAP and the GTAP-E models. The latter is an extended version of the GTAP model, which incorporates the energy substitution structure in the GTAP model. To avoid considerable increase in the supply price of electricity, this paper adopted a unique methodology for evaluating the impact of electric supply shortage; to swap qo ("Electricity", "JPN") and qo ("capital", "JPN"), namely the endogenous variable and the exogenous variable respectively, in the basic closure of the GTAP model. This methodology may also be applied to other regions of the GTAP database.

The simulation results revealed that the effect of energy substitution could be significant. A comparison of the simulation results of the GTAP and the GTAP-E models allowed an economic analysis of the effect of energy substitution on electric supply shortage in Japan.

In order to make the GTAP-E model amenable to any type of aggregation, a method is developed to create a database for the GTAP-E model and the revised GTAP-E model released in 2012. Accordingly, the structure of the GTAP-E and the revised GTAP-E model databases is analyzed in detail. Further developments in this area would greatly aid the study of the effects of energy substitution on the economy of a country or a region.

Simulations using both models also allowed an analysis of the effect of investment allocation. The results changed according to the type of investment allocation; the impact of electric supply shortage in Japan becomes more serious when RORDELTA = 0, that is, when investment funds are allocated across regions in order to maintain the existing composition of capital stocks.

There were hardly any differences between the simulation results using the GTAP-E and the revised GTAP-E models. It can thus be concluded that the revised GTAP-E model has introduced many new technical improvements to the GTAP-E model, while maintaining its basic structure and function.

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