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The Deregulation of Japan's Elecctricity Industry

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Abstract

We quantify the impact of deregulation for the Japanese electricity industry with a computable general equilibrium model. Our analysis has two notable features. First, we distinguish three sectors in this industry for analyses of deregulation in detail: power generation, transmission, and distribution. Second, we consider substitution among four energy commodities. Our numerical simulations show a potential for significant welfare improvements and substitution among energy sources from deregulation. Depending on whether deregulation abolishes monopoly rent or x-inefficiency, the effects of deregulation on factor markets would qualitatively differ.

JEL Classification Numbers: L94, L51, C68
Keywords: electricity industry, deregulation, computable general equilibrium

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1. Introduction

1.1 Background

Japan's electricity industry is regulated on the ground that it is a sector in which natural monopoly prevails. The regulatory authority applies rate-of-return (ROR) regulation to the industry, while approving regional monopolies for electricity companies by regulating entry. As a result, the industry suffers from two major problems. First, while ROR regulation can reduce the monopolistic power of electricity companies, it is prone to distort resource allocation. The fair ROR for each electricity company is difficult to determine, and tends to be too lenient. The monopoly rent that the industry produces is distributed among shareholders as a contribution to their dividends and capital gain, and among workers as a contribution to their wages and plentiful fringe benefits. In particular, capital utilization, which is employed as a proxy for production costs in the calculation of electricity charges, tends to be excessive and to distort resource allocation, as Averch and Johnson (1962) have pointed out. Second, ROR regulation guarantees electricity companies a certain level of return and, by regulating entry and preventing competition, weakens the incentive to improve production efficiency or to innovate. This situation leads to so-called x-inefficiency.

Japan has tried mainly to develop second-best regulatory measures—a price capping system and a yardstick system—to overcome these shortcomings of ROR regulation. The Japanese government has not focused on deregulation because natural monopoly has been considered to be inherent in the electricity industry, regardless of the prevailing regulatory regime.

The Japanese have recently formed the view that, because of technical changes, neither the generation sector nor the distribution sector of the electricity industry is any longer a natural monopoly. (In contrast, the transmission sector is still regarded as a natural monopoly.) In these sectors, we can now expect market mechanisms to reduce distortion and x-inefficiency brought about by regulation and the absence of competition. In the US, the UK, and other European countries the removal of barriers to entry into the generation and the distribution sectors has led to remarkable falls in electricity prices.

Following the deregulatory trend in the US and Europe, Japan has, since 1995, pursued reform measures to partially phase out regulation of its electricity industry. The Japanese government has decided to liberalize two major areas.[1] First, independent power producers (IPPs) have been allowed to enter the generation sector. IPPs offer prices that are

[1] Japan also introduced a yardstick method in assessment of ROR. However, we do not consider the issues surrounding the yardstick method in this paper because we cannot distinguish the 10 Japanese electric power companies in our computable general equilibrium analysis.

about 10%–40% lower than those offered by existing companies in competitive bidding on electricity supply.[2] Second, regulation of entry into the distribution sector has been removed for extra-high tension power supply only. Users of extra-high tension power consume as much as 24.5% of total electricity supply in terms of volume (i.e., kWh) and 15.2% in terms of value. However, the number of establishments that can enjoy the benefits of deregulation in the distribution sector is limited by the conditions attached to it.[3] The phasing-out of entry regulation in the generation sector would be of primary importance among these deregulatory measures. In light of the practice of European countries, we can expect Japan to extend the scope of deregulation to the whole of the generation and distribution sectors in

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[2] See MCA (1999, p. 159).

[3] Users of this type of electricity are supposed to use at least 2,000 kW with 20,000 V or higher. This deregulatory measure is to be applied to each establishment: that is, each establishment has to fulfill this condition to enjoy the benefits of the deregulatory measure. Even if a company with multiple establishments consumes 2,000 kW *in total*, the company cannot enjoy the benefits. In addition, this deregulatory measure can work effectively only as long as appropriate measures are successfully established to control wheeling charges from IPPs to the heavy users. This is because the existing electricity companies possess the entire electric power network and retain monopolistic power over wheeling/transmission activity.

future. At that stage, Japan will finally catch up with the advanced nations in deregulation.

1.2 Inefficiency of the Japanese Electricity Industry

Japan has regulated entry into its electricity industry since 1951.[4] The regulators have approved nine (and ten from 1972) vertically integrated electricity companies as regional monopolies.[5] As a result, Japanese companies charge much higher electricity prices than those in the US and Europe (see Table 1). Many controversial points of difference among countries in lifestyle and tariffs, and the variety of conversion factors, make fair international comparison difficult. Nevertheless, we find that prices in Japan are consistently and significantly higher than those in other countries. Deregulation has the potential to significantly lower electricity prices in Japan, which differ from Germany's by at least 17% and, in the extreme case, from those in the US by 68% in 1997.

There is also evidence of cost-inefficiency in Japanese electricity companies.

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[4] Navarro (1996) summarizes the historical development of the Japanese electricity industry.

[5] Strictly speaking, Japan also has two large power producers, established in line with national electricity development policy, and many small producers other than the 10 existing ones. They own neither transmission nor distribution networks, but simply supply the existing electricity companies and/or use it themselves.

Tachibanaki and Ohta (1992) found that the electricity industry pays relatively high wages. Nemoto *et al.* (1993) found inefficiency in the power generation sector, especially because of over-capitalization—the Averch-Johnson (1962) effect. They identified the presence of both monopoly rents (partly distributed to workers as well as shareholders) and the inefficient use of factors. Matsukawa *et al.* (1993) examined the efficiency of electricity price regulation from the standpoint of the Ramsey pricing rule. Owing to the limitations of the partial equilibrium framework, their studies considered neither any deregulatory measures nor the implications of deregulation in the electricity industry for other sectors. Recently, two studies have quantified the effects of a series of deregulatory measures from a macroeconomic or general equilibrium viewpoint. One of them (EPA 1997) evaluates the effects of the deregulatory measures that were actually implemented during 1995–98 with a mid-term multi-sectoral macroeconometric model. The other (ERI 1999) tentatively illustrates the effects of deregulation in various sectors, including the electricity sector, with a computable general equilibrium (CGE) model. However, they take account neither of the differences among power generation, transmission, and distribution, nor of substitution among various energy sources.

1.3 The Plan of this Paper

In this context, we need to quantify the effects of two types of deregulatory measure. One is complete deregulation of entry into both power generation and distribution sectors. The other is ongoing partial deregulation, which liberalizes only the power generation sector. To quantify the effects, we employ a CGE model with 20 sectors (Table 2). CGE models can capture the impacts of resource (re)allocation among the electricity sectors and other sectors, and are suitable for the analysis of efficiency improvements and price distortion. Our analysis has three notable features. First, we distinguish three sub-sectors of the electricity industry—the generation, transmission, and distribution sectors—to quantify both the complete and the partial deregulatory measures in detail. Second, in analyses of energy problems, it is important also to consider substitution between various energy sources, i.e., electricity, gas, petroleum, and coal. Third, the general equilibrium framework can capture the impacts of deregulation in the electricity sectors on other sectors and its overall macroeconomic effects.

This paper proceeds as follows. Section 2 describes the structure of our CGE model and summarizes the expected effects of deregulation. Section 3 gives details of simulation scenarios. Section 4 analyzes the simulation results. Section 5 concludes our paper.

2. The Model

2.1 The General Equilibrium Model for Deregulation

Our CGE model consists of 20 production sectors, one representative household, and the government. The basic model structure is summarized as follows (Figure 1).[6] We assume substitution between capital and labor in value added production with Cobb-Douglas type production functions. We employ Leontief-type functions as production functions for gross output, which is made up of value added, intermediate input, and an energy composite.[7] (The energy composite is discussed later.) Gross output is transformed into domestic goods and exports with constant elasticity of transformation (CET) functions. Composite goods are produced with domestic goods and imports with constant elasticity of substitution (CES) functions. This is called Armington's (1969) assumption; the composite good is called Armington's composite good. Ultimately, Armington's composite (non-energy) goods are used by the household and the government, and for investment and intermediate

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[6] The detailed equation list is available upon request.

[7] We employed only constant-returns-to-scale production functions, following the result of Shinjo (1994), though scale economy is sometimes supposed to prevail in this industry. Shinjo (1994) surveyed recent empirical studies of scale economy in Japanese electricity companies and power plants, and found no definite (or only very weak) evidence of scale economy in this industry.

uses. (If the good is one of the energy goods, it is aggregated into an energy composite and used by the household and [non-energy] production sectors.) The household is assumed to have a Cobb-Douglas type utility function, which is dependent on the consumption of non-energy goods and the energy composite. For simplicity, government consumption and investment uses are fixed.

Government maintains a balanced budget with a lump-sum tax on the household while collecting indirect taxes. Firms' excess profits (i.e., monopoly rents) are transferred to the household as a lump sum. Japan is assumed to have export demand and import supply functions with constant elasticity. Current account deficits are kept constant in US dollar terms with flexible adjustment of the exchange rate.

Primary factors are assumed to be mobile across sectors. Because it would take some time to adjust the capital stock in response to deregulation, it may seem advisable to employ a dynamic model that can describe this adjustment. However, a crucial factor seriously delays adjustment: the reluctance of existing electricity companies to let IPPs use their transmission network. Similar problems actually arose as telecommunications were being deregulated. Unfortunately, as we cannot predict how fast this reluctance will disappear, whether voluntarily or by government decree, we employ a static model with perfect factor mobility for simplicity.

Our CGE model is distinct from usual CGE models in two main ways.[8] First, we take into account substitution between various energy sources. We assume that the non-energy sectors use an energy composite of coal, oil, gas, and electricity.[9] Similarly, we assume that the household consumes an energy composite of oil, electricity, and gas. Aggregation technology of these four/three energy sources is represented by CES functions. We assume that the energy composites are made especially for each user: that is, the share coefficients of each energy input differ according to the technology of the sectors and the household. However, the elasticity of substitution in the aggregation functions is common among all the non-energy sectors due to data limitation.

Second, we distinguish three sectors in the electricity industry: generation, transmission, and distribution. We assume that the entire output of the generation sector is used by the transmission sector as an intermediate input. Similarly, we assume that the entire output of the transmission sector is used by the distribution sector. The output of the distribution sector is used for the aggregation of energy composites for intermediate uses and

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[8] Devarajan *et al.* (1990) present a standard CGE model for static analyses. Our model is based on theirs.

[9] On the other hand, we assume that the energy sectors demand energy goods with the fixed coefficient technology in a usual manner.

household consumption, as discussed above.

We estimate the model with a so-called calibration method by setting 1997 as the base year. Our main data sources are input–output tables for 1995 by MCA (1997) (Table 3). Because we find little difference in the magnitude of economic activities during 1995–97, we do not carry out any special matrix adjustments to update the input-output tables from 1995 to 1997. Elasticity of substitution/transformation in trade-related CES/CET functions is obtained from the GTAP database version 3.[10] Elasticity of substitution in the energy composite aggregation functions is obtained from Matsukawa *et al.* (1993).[11] In separating the electricity industry reported in the input–output tables into its three sub-sectors, we utilize financial statements for the 10 Japanese electricity companies from MOF (1998).

2.2 Expected Effects of Deregulation

We expect deregulation to eliminate two sources of inefficiency in the electricity industry: monopoly rent and so-called x-inefficiency. Abolition of monopoly rent lowers demand prices from Pd to P* and increases quantity from Q0 to Q1 (Figure 2). The net benefits of deregulation flow from removing the deadweight loss. The loss is measured by

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[10] On the Global Trade Analysis Project (GTAP) database, see Hertel (1997).

[11] However, elasticity of substitution for the energy sectors is set at zero.

the size of the triangle between the vertical lines on Q0 and Q1. In our CGE model, this type of efficiency improvement can be described by incorporating monopoly rent as markups over marginal costs in an indirect-tax equivalent manner in the status quo and by phasing out the rent in counterfactual situations.

The productivity improvements shift the supply curve downward from S to S′ to lower prices from P0 to P1 with increases in quantity from Q0 to Q1 (Figure 3). The net benefits of deregulation come from increases in the surplus. The degree of improvement is measured by the size of a trapezoid between the two supply curves of S and S′. In our CGE model, this type of efficiency improvement can be described as a decrease of the minimum input requirements of value added in production functions. (Recall that we assume Leontief-type production functions for gross output.)

Comparison between these two figures leads to a following result. Even if deregulation causes the same degree of price fall and quantity increase, the net benefits from productivity improvements are greater than those from the abolition of monopoly rent. We can easily confirm this point graphically by setting the anticipated decline of demand price in Figure 2 (Pd-P*) equal to that in Figure 3 (P0-P1). The difference in net benefits between these two cases is shown by the parallelogram enclosed by the two supply curves and the vertical lines on the origin and Q0 in Figure 3.

The above discussion occurs in a partial equilibrium framework. In a general equilibrium framework, we have to consider many more factors. In production activity, the fall in the price of electricity would lower prices in other sectors that use electricity intensively as an intermediate input. We also need to consider substitution between electricity and other energy commodities. Efficiency improvements in the electricity industry would reallocate primary factors to the other sectors.

3. Simulation Scenarios

3.1 The Complete and the Partial Deregulation Scenarios

To evaluate quantitatively the impact of deregulation, we prepare two scenarios. One is the complete deregulation scenario, which assumes a phase-out of entry regulations in the electricity generation and distribution sectors. The other is the partial deregulation scenario, which assumes deregulation only for the generation sector.

As discussed in Section 2.2, we assume that in each scenario deregulation would affect the electricity industry particularly in the following two ways. On the one hand, deregulation would remove the monopoly rent that accrues to the electricity industry under ROR regulation. On the other hand, deregulation would force the electricity companies to improve their productivity by reducing x-inefficiency.

We expect the price of electricity in Japan to fall to the levels in other countries on completion of the deregulation in the electricity generation and distribution sectors. The expected price falls are simply set at 10%, 20%, 30%, or 40%, following Table 1. In our empirical implementation, however, we have no data about either the amount of monopoly rent or potential productivity improvements, but only about the price differentials shown in Table 1.[12] To overcome the hidden data problem, we consider two extreme cases where the price differentials derive solely from either the monopoly rent or the x-inefficiency. In sum, we consider 16 cases (with two types of coverage of deregulation, two sources of inefficiency, and four cases of a price fall).

Our numerical simulations take the following three steps. First, before counterfactual simulations of deregulation, we estimate (a) the amount of monopoly rent whose abolition would achieve these expected price falls by complete deregulation, and (b) the degree of productivity improvement that would likewise achieve these price falls by complete deregulation. They describe the current situation, which cause inefficiency under regulation. Second, we quantify the welfare gains that would flow separately from the

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[12] We cannot calibrate the amount of monopoly rent by using the conventional relationship between marginal revenues and marginal costs, as the existing price regulation does not allow this relationship to hold.

abolition of monopoly rent and productivity improvements in these two electricity sectors, and how complete deregulation in these two sectors would affect the other sectors and the household in the Japanese economy. Third, we quantify the effect of partial deregulation, which it was decided to implement mainly for the power generation sector in 1995.

In contrast to the complete deregulation scenario, the partial deregulation scenario assumes either the abolition of monopoly rent or the reduction of the minimum requirements of value added for the electricity generation sector only. Although the deregulation program adopted in 1995 covers a phase-out of entry regulation in the field of the extra-high tension power distribution, we do not include this measure in our partial deregulation scenarios. This is because we expect that the number of beneficiaries would be limited (as discussed in footnote 3) and because it is difficult to distinguish between the various types of electricity supply in our CGE model.

3.2 The Magnitude of Monopoly Rent and Productivity Improvements

Before the counterfactual simulations, the amount of monopoly rent and productivity improvement is estimated (Table 4). The first column of Table 4 shows that if we achieve, for example, a 10% price fall (i.e., an output price decline in the electricity distribution sector) through the abolition of monopoly rent under complete deregulation, monopoly rent has to account for 21.7% of value added before deregulation. In this estimation, we assume that monopoly rent is included in the value added reported in the original input–output tables, that the share of monopoly rent in value added is the same in the three electricity sectors, and that the share of monopoly rent in wages and operating surplus is also the same in them. Because value added-output ratios are different among the three electricity sectors, the rent-output ratios are different among them: 12.6%, 3.0%, and 2.6%. In the monopoly-rent abolition simulations, we include these markup rates (i.e., the rent–output ratios) in an indirect-tax-equivalent manner and simulate their abolition in the generation and/or the distribution sectors.

We describe the productivity improvements with smaller coefficients for minimum input requirements of value added in the Leontief-type production functions. The second column of Table 4 shows that if we achieve, for example, a 10% price fall through productivity improvements under complete deregulation, we must have a redundant input of value added of as much as 22.0% of the value added employed by the generation and distribution sectors before deregulation.[13]

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[13] Whiteman (1999) found the x-inefficiency of the three largest Japanese electricity companies to be as much as 0-39% of hydro- and thermal-plant capacity and labor uses. The case of a 10% price fall shown in Table 4 seems consistent with his estimation results.

4. Simulation Results

4.1 The Complete Deregulation Scenario

First, we quantify the impact of complete deregulation. In this complete deregulation scenario, we assume that deregulation occurs in both the generation and the distribution sectors. When Japan phases out entry regulation in these two sectors, we can regard the Japanese electricity industry as equally liberalized as those in the US and European countries. We assume that complete deregulation either eliminates exclusively monopoly rent or improves productivity in these two sectors.

4.1.1 The Monopoly Rent Abolition Case

We evaluate the effects of deregulation by assuming that these measures abolish monopoly rent in the two sectors of the electricity industry. In this case, we would have remarkable increases in the output of the three electricity sectors (Figure 4). These increases would affect all the energy sectors most significantly. There would be sharp differences among changes in the output of the four/three energy commodities that are aggregated into an energy composite good. Coal and gas output would decrease while electricity and oil output would increase.[14] On the one hand, the household would increase consumption of all of the three energy commodities (Figure 5). (Note that the household is assumed to consume an energy composite made up from only three energy commodities—oil, electricity, and gas—and not coal.) On the other hand, we have sharp declines in all kinds of intermediate energy uses except electricity (Figure 6). The increases in household demand for oil and gas would make up for the decline in intermediate demand for them. The difference in energy consumption behavior between the household and intermediate uses would be mainly attributable to the differences of elasticity of substitution in their energy composite aggregation functions. Following Matsukawa *et al.* (1993), we assume higher

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[14] We expect that our assumption about the elasticity of substitution in the energy composite aggregation function would affect our simulation results very significantly. We conduct a sensitivity analysis with respect to that elasticity by perturbing it by 30% upward and downward from the central case with the elasticity originally reported by Matsukawa *et al.* (1993). The results of our sensitivity analysis suggest, in sum, that welfare effects could differ marginally whereas the sectoral output of the four energy goods could differ significantly. Among these energy goods, gas and oil output seems particularly sensitive to the elasticity assumption. Changes in their output would be positive in the 30% less elastic case but negative in the 30% more elastic case.

elasticity for the intermediate users (0.63) than for the household (0.37).[15] Thus, substitution effects tend to dominate expansion effects in the energy composite aggregation for intermediate uses, whereas expansion effects tend to dominate substitution effects for household uses.

The electricity price falls would cause falls in output prices mainly in industrial sectors, but marginal rises in output prices in agriculture and service sectors (Figure 7).[16] The falls would be much less than 2% even in the case of a 40% fall in electricity prices (not shown in the text).

Because of complete deregulation, the rental price of capital would rise by as much as the wage rate. Welfare improvements would be as much as 77 billion yen in the 10% case. The welfare effects would be intensified according to the magnitude of expected price falls (Table 5).

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[15] Note that the elasticity of substitution in the CES functions is approximately equal to the own-price elasticity of demand functions derived from the CES functions.

[16] Note that we choose a wholesale price index as a numéraire. This is a Laspeyres index and covers 17 non-electricity commodity prices. Even when we employ a consumer price index as a numéraire instead, the result is barely affected.

4.1.2 The Productivity Improvement Case

In the second case, we assume that deregulation would force electricity companies to improve productivity, especially in minimum requirements of value added input. In output, we would have significant increases in the three electricity sectors (Figure 4). We find that deregulation with productivity improvement would bring about larger increases (or smaller declines) in the output of all sectors than deregulation with the abolition of monopoly rent. This is because the productivity improvement would release factors originally employed by the generation and distribution sectors without reducing their output and would stimulate the output of other sectors.

In welfare, there would also be larger gains in the productivity improvement case, say 1,528 billion yen following a 10% price fall, than in the rent abolition case, say 77 billion yen following the same price fall (Table 5). This significant difference of welfare effects corresponds to the difference between the size of the triangle in Figure 2 and that of the trapezoid in Figure 3.

The falls in the price of electricity following productivity improvement would bring about similar changes to the prices of the other commodities, in both size and sign, in comparison with those brought about by the abolition of monopoly rent (Figure 7). However, the changes in factor prices would occur in a different manner as between these two cases

(Table 5). Although the abolition of monopoly rent would raise both factor prices almost equally, the productivity improvements would cause a much larger rise in the wage rate than in the rental price of capital. This is explained as follows. The productivity improvement from deregulation would reduce the minimum requirements of factor use and induce the electricity sectors to release a large proportion of the factors initially employed by them. The electricity sectors employ capital intensively (Table 3); therefore, they release a larger amount of capital than of labor. Thus, the rental price of capital would become cheaper than the wage rate.

4.2 The Partial Deregulation Scenarios

Next, we quantify the effectiveness of the currently ongoing partial deregulation, which is applied only to the generation sector. We assume that partial deregulation causes exclusively either the abolition of monopoly rent or a productivity improvement in this sector. Indeed, the anticipated welfare gains would be smaller than those in the complete deregulation cases, but would be still sizable (Table 5). This is because the value added in the generation sector is much larger than that in the other two electricity sectors (Table 3). Thus, even without reforms in the distribution sector, we can expect that partial deregulation only of the generation sector would be worthwhile as the first of a series of deregulatory measures in the near future.

In other respects, we find similar results in quality but smaller ones in quantity. For example, changes of gross output from partial deregulation would be a little smaller than those from complete deregulation but similar in sign (Figure 8).

5. Concluding Remarks

We have analyzed the impacts of deregulation in the Japanese electricity industry with a general equilibrium framework. The highlights are as follows. (1) We found that electricity and oil would be substituted for coal and gas because of lower electricity prices from deregulation. The substitution effects would be significant, more so in intermediate uses than in household consumption. (2) We can expect a larger welfare effect from deregulation through productivity improvements than through the abolition of monopoly rent. Although welfare improvements induced by partial deregulation would be smaller than those induced by complete deregulation, the former would be still sizable and worthwhile as the first step in future deregulation programs. (3) Finally, depending on whether the deregulation leads to productivity improvements or abolition of monopoly rent, effects on factor markets would differ qualitatively. The electricity industry employs a large amount of capital intensively. The impact of deregulation in this industry would significantly affect the capital market in Japan.

Table 4 suggests a large amount of monopoly rent and/or a significant degree of inefficiency in the status quo. In the largest case for 40% price falls, there would be either as much as 71.5% of markups over output prices or inefficiency in production of as much as 87.7% of unnecessary value added inputs. The markup ratio and the degree of inefficiency may seem very large. We simulated two extreme cases, each of which takes into account only one source of inefficiency. The reality would be mid-way between these two extremes; that is, the abolition of monopoly rent and the productivity improvement would occur simultaneously to a relatively smaller degree than we assumed for each.

Our empirical investigations could be improved on some points as an analysis of the electricity industry. We assume simple price contracts and consider only two types of users, but in the real world we have various price contracts and will have more as a result of deregulation. Price discrimination between users can be another important issue in electricity services. In view of recent concerns about the prevention of global warming, we will have to seek policies to counteract increases of energy use brought about by deregulation. We will need to extend our model and analyses in these respects.

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Table 1: International Comparison of Average Electricity Prices

(Average Charges per kWh in Japan = 1.00, in 1997)

Conversion Factors	The US	The UK	France	Germany	Japan
w/Purchasing Power Parity					
Residential Uses (Low Voltage)	0.57	0.71	0.63	0.83	1.00
Industry Uses (High Voltage)	0.44	0.59	0.48	0.68	1.00
w/Exchange Rates					
Residential Uses (Low Voltage)	0.41	0.60	0.55	0.73	1.00
Industry Uses (High Voltage)	0.32	0.49	0.42	0.60	1.00

Source: Purchasing power parity: OECD (1999)

Electric power charges: Kaigai Denryoku Chosakai (1999)

Table 2: Sectors and Their Abbreviations Included in the CGE Model

Sectors	Abbreviations
Agriculture	AGR
Mining	MIN
Food	FOD
Coal and Its Products #	COL
Oil and Its Products #	OIL
Chemical	CHM
Steel and Other Metal Products	STL
Machinery	MCH
Other Manufacturing	OMN
Construction	CST
Power Generation ** #	PGN
Electricity Transmission ** #	ETR
Electricity Distribution ** #	EDS
Gas Supply #	GAS
Water Supply and Waste	WAT
Commerce	CMC
Finance and Insurance	FIN
Transportation	TRN
Communication	COM
Other Services	OSR

Note: ** denotes electric power sectors.

# denotes energy sectors.

Table 3: The Aggregated Input–output Table

(unit: billion Japanese yen)

	COL	OIL	PGN	ETR	EDS	GAS	OTH	Subtotal	Household Consumption	Other Final Demand	Gross Output
COL	506	0	522	0	0	-12	1,048	2,064	3	-646	1,421
OIL	107	3,520	1,351	0	0	320	6,684	11,982	3,083	-5,343	9,721
PGN	0	0	0	10,264	0	0	0	10,264	0	0	10,264
ETR	0	0	0	0	12,653	0	0	12,653	0	0	12,653
EDS	30	83	0	0	0	33	10,817	10,963	4,820	25	15,809
GAS	0	0	0	0	0	19	1,045	1,065	1,101	-1	2,166
OTH	388	856	2,693	592	1,160	633	417,228	423,551	295,326	229,636	948,513
Subtotal	1,031	4,460	4,566	10,856	13,813	993	436,823				
Capital	193	598	4,031	1,255	960	577	181,024				
Labor	178	318	928	326	801	514	302,693				
Indirect Tax	19	4,346	738	215	235	82	27,972				
Gross Input	1,421	9,721	10,264	12,653	15,809	2,166	948,513				

Note: The 'other final demand' includes government consumption, investment, and net exports. Sectors other than the energy sectors are merged into one column/row, named OTH, for simplicity in this table. The other abbreviations are those shown in Table 2.

Source: Compiled from MCA (1997).

Table 4: Estimated Magnitude of Monopoly Rent and Productivity Improvements

(%)

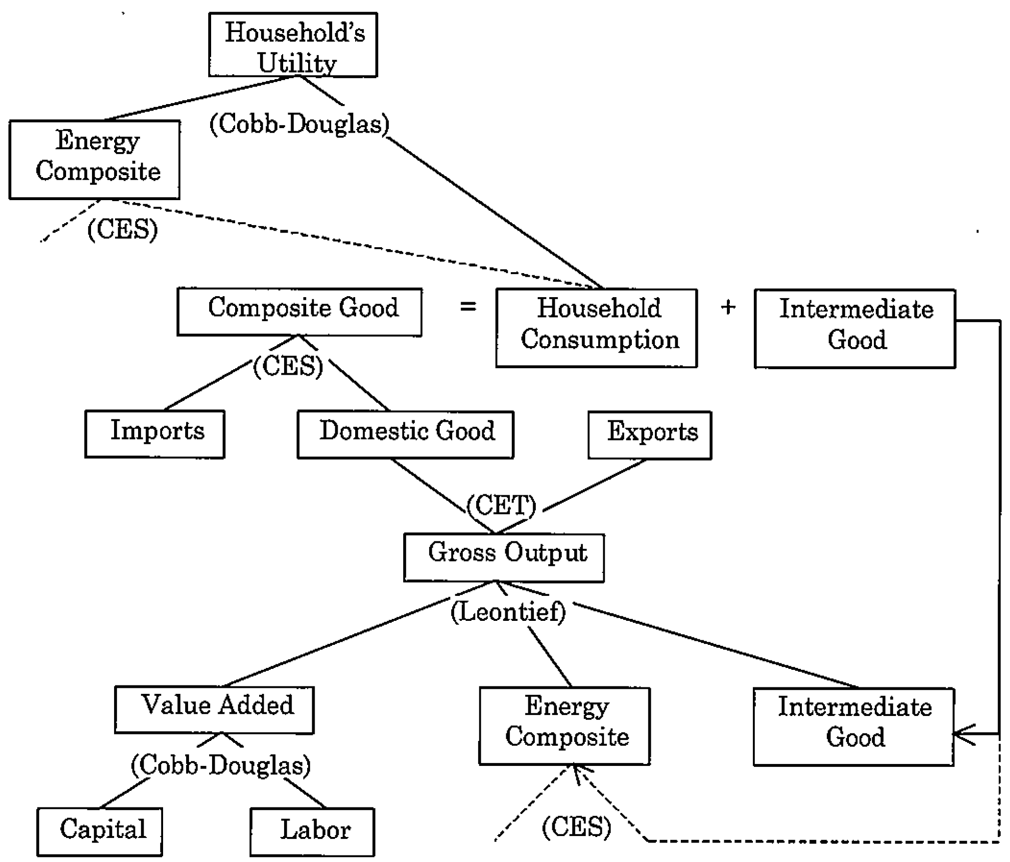
Charge Declines	Monopoly Rent to be Abolished: Rent/Value Added Ratios	Monopoly Rent to be Abolished: Rent/Output Ratios PWG	ETR	EDS	Reduced Minimum Requirements of Value Added by Productivity Improvements
10%	21.7	12.6	3.0	2.6	22.0
20%	42.2	28.0	6.0	5.3	43.9
30%	61.9	47.1	9.1	7.9	65.9
40%	80.5	71.5	12.2	10.5	87.7

Table 5: Simulation Results

Deregulation Measures				Price Falls			
				10%	20%	30%	40%
Complete Deregulation	Monopoly Rent Abolition	Factor Prices (%)	Capital	0.3	0.6	0.9	1.2
			Labor	0.2	0.5	0.8	1.1
		Welfare	(billion yen)	77	243	511	896
	Productivity Improvements	Factor Prices (%)	Capital	0.0	0.1	0.1	0.1
			Labor	0.4	0.8	1.2	1.7
		Welfare	(billion yen)	1,528	3,130	4,819	6,617
Partial Deregulation	Monopoly Rent Abolition	Factor Prices (%)	Capital	0.2	0.5	0.7	1.0
			Labor	0.2	0.4	0.6	0.9
		Welfare	(billion yen)	63	207	446	798
	Productivity Improvements	Factor Prices (%)	Capital	0.0	0.0	–0.1	–0.1
			Labor	0.3	0.7	1.0	1.3
		Welfare	(billion yen)	1,100	2,235	3,410	4,632

Note: Welfare impacts are measured by equivalent variations with the household's utility function.

Figure 1: The CGE Model Structure



Note: If the intermediate or the (Armington's) composite good is an energy good, it follows the broken lines. Government consumption and investment uses, which are also demand components of the composite good, are omitted to save space.

Figure 2: Effects of Abolition of Monopoly Rent

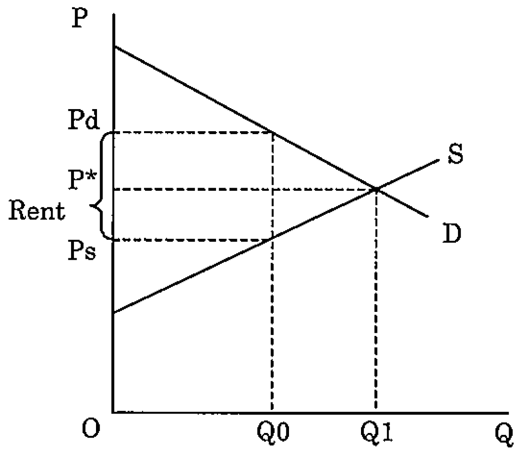


Figure 3: Effects of Productivity Improvements

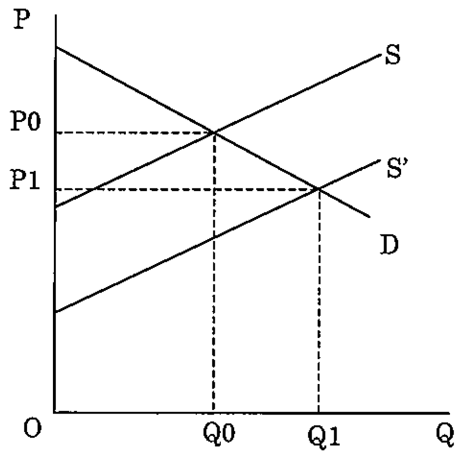


Figure 4: Changes of Output by the 10% Price Falls in the Complete Deregulation Cases

(%)

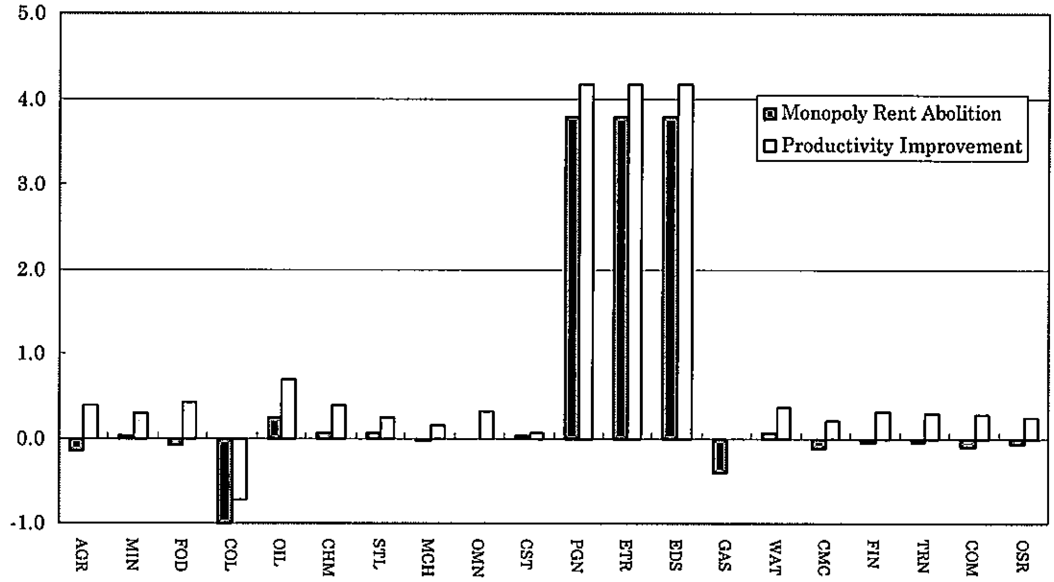


Figure 5: Changes of Household Consumption by the 10% Price Fall in the Complete Deregulation Cases

(%)

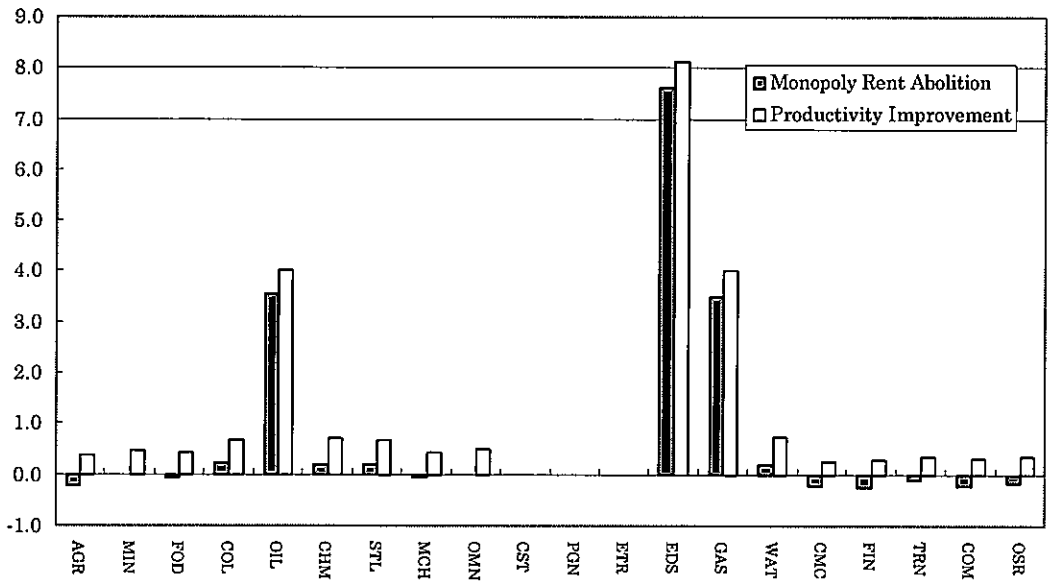


Figure 6: Changes of Total Supply of Intermediate Good by the 10% Price Fall in the Complete Deregulation Cases

(%)

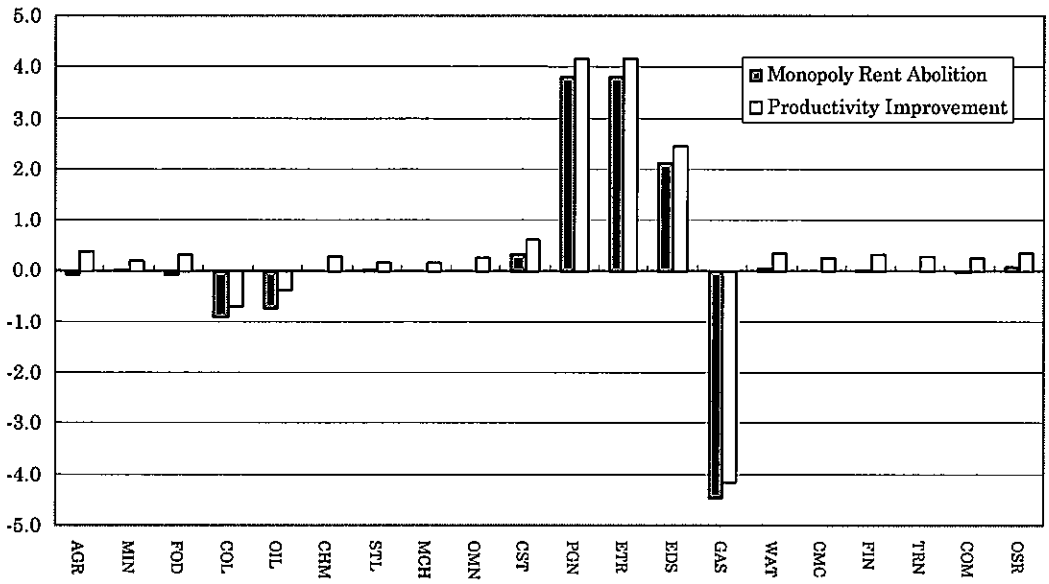


Figure 7: Changes of Output Prices by the 10% Price Fall in the Complete Deregulation Cases

(%)

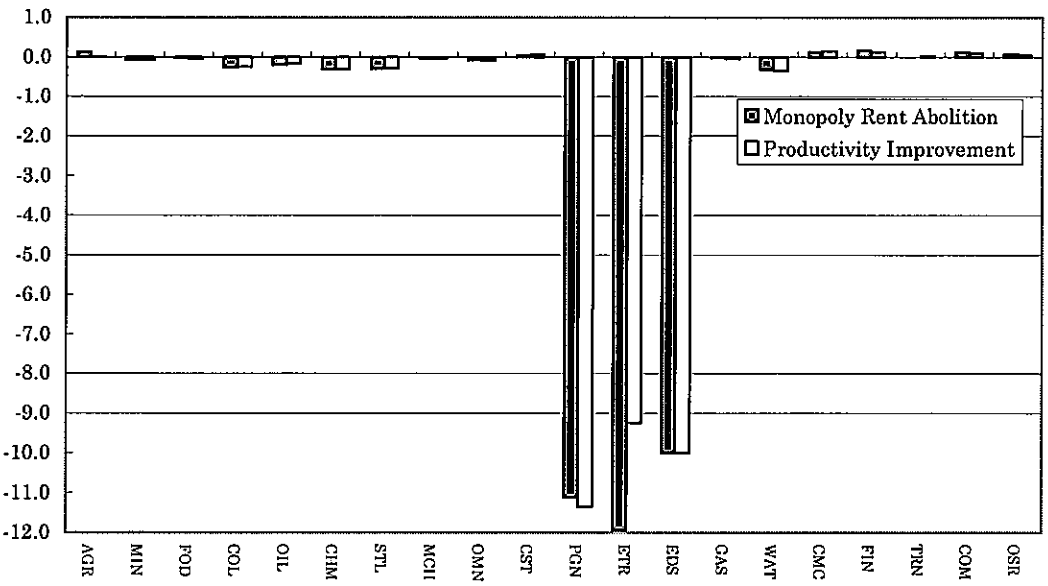
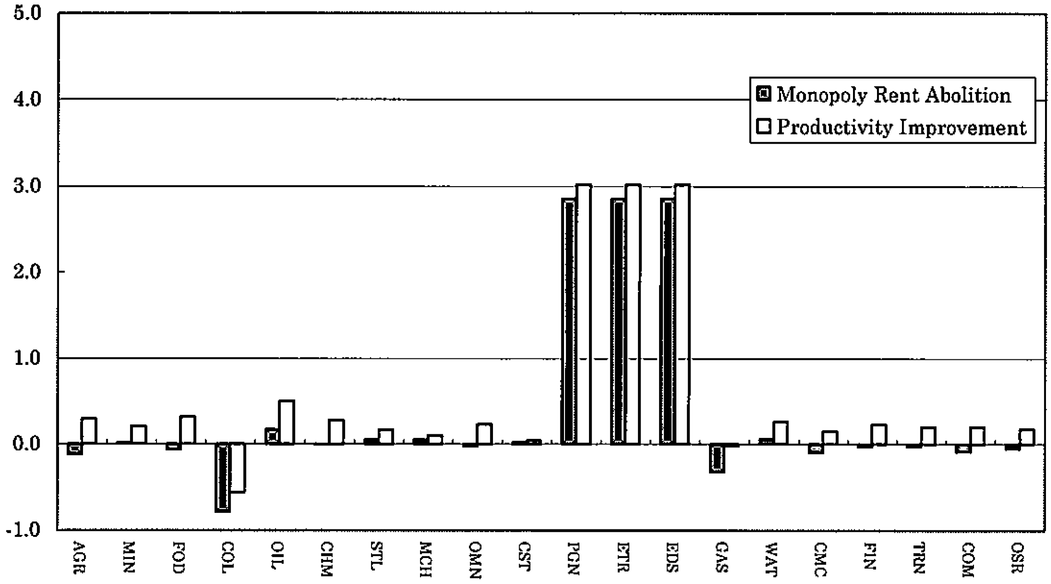


Figure 8: Changes of Output by the 10% Price Fall in the Partial Deregulation Cases

(%)



The Deregulation of Japan's Electricity Industry
Attachments

[Not to be published]

October 4, 2000

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Contents:

Appendix I: The Detailed Equation List

[The Household Consumption[1]]

- The demand function for non-energy goods

$$X^p_{ni2} = \alpha_{ni2}\left(\sum_{h,j} p^f_h F_{h,j} - S - T^d + \sum_j \omega_j p^z_j z_j\right) / p^q_{ni2}$$

- The demand function for the energy composite

$$X^{pEn} = \alpha^{En}\left(\sum_{h,j} p^f_h F_{h,j} - S - T^d + \sum_j \omega_j p^z_j z_j\right) / p^{xpEn}$$

[The Energy Composite Aggregation for the Household]

- The energy composite aggregation function for the household

$$X^{pEn} = o^p\left(\sum_{ei2} \psi^p_{ei2} {X^p_{ei2}}^{\chi^p}\right)^{1/\chi^p}$$

- The energy goods demand function

$$X^p_{ei2} = \left(\frac{{o^p}^{\chi^p} \psi^p_{ei2} p^{xpEn}}{p^q_{ei2}}\right)^{1/(1-\chi^p)} X^{pEn}$$

[The Domestic Production]

- The value added aggregation function

---

[1] In their background, we assume the following household utility function:

$$U = \left(X^{pEn}\right)^{\alpha^{En}} \prod_{ni2} {X^p_{ni2}}^{\alpha_{ni2}},$$

where U denotes utility.

$$Y_j = b_j \prod_h F_{h,j}{}^{\beta_{h,j}}$$

- The fixed-coefficient value added demand function

$$Y_j = ay_j Z_j$$

- The fixed-coefficient non-energy intermediate demand function by the non-energy sectors

$$X_{ni,nj} = ax_{ni,nj} Z_j$$

- The fixed-coefficient energy composite demand function by the non-energy sectors

$$X_{nj}^{En} = \sum_{ei} ax_{ei,nj} Z_{nj}$$

- The fixed-coefficient intermediate demand function by the energy sectors

$$X_{i,ej} = ax_{i,ej} Z_{ej}$$

- The primary factor demand function

$$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_h^f} Y_j$$

- The unit cost function for the non-energy sectors

$$p_{nj}^z = ay_{nj} p_{nj}^y + \sum_{ni} ax_{ni,nj} p_{ni}^q + \sum_{ei} ax_{ei,nj} p_{nj}^{xEn}$$

- The unit cost function for the energy sectors

$$p_{ej}^z = ay_{ej} p_{ej}^y + \sum_i ax_{i,ej} p_i^q$$

[The Energy Composite Aggregation for Production Sectors]

- The energy composite aggregation function for the non-energy sectors

$$X_{nj}^{En} = o_{nj}\left(\sum_{ei}\psi_{ei,nj} X_{ei,nj}^{\ \chi}\right)^{1/\chi}$$

- The energy good demand function

$$X_{ei,nj} = \left(\frac{o_{nj}^{\ \chi}\psi_{ei,nj} p_{nj}^{xEn}}{p_{ei}^{q}}\right)^{1/(1-\chi)} X_{nj}^{En}$$

[The Government Behavior]

- The government budget constraint

$$T^{d} = \sum_{i} p_{i}^{q} X_{i}^{g} - \sum_{i} T_{i}^{m} - \sum_{j} T_{j}$$

- The government consumption

$$X_{i}^{g} = X_{i}^{g0}$$

- The indirect tax revenue function

$$T_{i} = \tau_{i}(1+\omega_{i}) p_{i}^{z} Z_{i}$$

- The import tariff revenue function

$$T_{i}^{m} = \tau_{i}^{m} p_{i}^{m} M_{i}$$

[Investment Behavior]

$$X_{i}^{v} = X_{i}^{v0}$$

[International Trade]

- Price conversion functions between prices in JPY and in USD

$$p_{i}^{e} = \varepsilon\, p_{i}^{We}$$

$$p_i^m = \varepsilon\, p_i^{Wm}$$

- The BOP constraint (redundant)

$$\sum_i p_i^{We} E_i + S^f = \sum_i p_i^{Wm} M_i$$

- The import good supply function of the non-electricity goods

$$\left(\frac{p_{nl}^{Wm}}{p_{nl}^{Wm0}}\right)^{\sigma_{nl}} = \frac{M_{nl}}{M_{nl}^0}$$

- The export good demand function of the non-electricity goods

$$\left(\frac{p_{nl}^{We}}{p_{nl}^{We0}}\right)^{-\sigma_{nl}} = \frac{E_{nl}}{E_{nl}^0}$$

- The import and export of the electricity goods

$$M_{el} = M_{el}^0$$

$$E_{el} = E_{el}^0$$

[Armington's Composite Good Aggregation[2]]

- The Armington's aggregation function

$$Q_{nl} = \gamma_{nl}\left(\delta^m_{nl} M_{nl}{}^{\eta_{nl}} + \delta^d_{nl} D_{nl}{}^{\eta_{nl}}\right)^{1/\eta_{nl}}$$

- The import demand function of the non-electric goods

$$M_{nl} = \left(\frac{\gamma_{nl}{}^{\eta_{nl}} \delta^m_{nl} p^q_{nl}}{(1+\tau^m_{nl}) p^m_{nl}}\right)^{1/(1-\eta_{nl})} Q_{nl}$$

- The domestic good demand function of the non-electric goods

$$D_{nl} = \left(\frac{\gamma_{nl}{}^{\eta_{nl}} \delta^d_{nl} p^q_{nl}}{p^d_{nl}}\right)^{1/(1-\eta_{nl})} Q_{nl}$$

- The market clearing conditions of the electric good

---

[2] In addition, we have one treatment different from usual CGE models. We do not employ the Armington (1969) structure in international trade of electricity while we assume this structure for the other commodities. This special treatment is made for the following reason. Input-output tables, which are our main data source, report international trade of such a non-tradable good as electricity. They show a small amount of uses of electricity by foreign people who live/travel in Japan and by Japanese people who travel/live abroad. We do not want such minor uses of electricity to crucially affect our empirical results; we fix these uses in quantity and assume common prices for both domestically used and (seemingly) internationally traded electricity.

$$Q_{el} = D_{el} + M_{el}$$

$$(1+\tau_{el}^{m})p_{el}^{m} = p_{el}^{q}$$

$$p_{el}^{d} = p_{el}^{q}$$

[Transformation Functions]

- The transformation function among exports and domestic supply

$$Z_{nl} = \theta_{nl}\left(\xi_{nl}^{e} E_{nl}{}^{\phi_{nl}} + \xi_{nl}^{d} D_{nl}{}^{\phi_{nl}}\right)^{1/\phi_{nl}}$$

- The export supply function

$$E_{nl} = \left(\frac{\theta_{nl}{}^{\phi_{nl}} \xi_{nl}^{e} (1+\tau_{nl})(1+\omega_{nl}) p_{nl}^{z}}{p_{nl}^{e}}\right)^{1/(1-\phi_{nl})} Z_{nl}$$

- The domestic good supply function

$$D_{nl} = \left(\frac{\theta_{nl}{}^{\phi_{nl}} \xi_{nl}^{d} (1+\tau_{nl})(1+\omega_{nl}) p_{nl}^{z}}{p_{nl}^{d}}\right)^{1/(1-\phi_{nl})} Z_{nl}$$

- The market clearing conditions for the electric good

$$Z_{el} = E_{el} + D_{el}$$

$$p_{el}^{e} = (1+\tau_{el})(1+\omega_{el}) p_{el}^{z}$$

$$p_{el}^{q} = (1+\tau_{el})(1+\omega_{el}) p_{el}^{z}$$

$$p_{el}^{d} = (1+\tau_{el})(1+\omega_{el}) p_{el}^{z}$$

[The Market Clearing Conditions]

- Usual goods

$$Q_i = X_i^p + X_i^g + X_i^v + \sum_j X_{i,j}$$

- Primary factors

$$FF_h = \sum_j F_{h,j}$$

[The Private Saving]

$$S = \sum_i p_i^q X_i^v - \left(S^g + \varepsilon S^f\right)$$

[The Numéraire]

$$\sum_{nl} p_{nl}^z Z_{nl}^0 = \sum_{nl} p_{nl}^{z0} Z_{nl}^0$$

[Notations]

<u>Sets</u>

i, j:	Goods and sectors (listed in Table 2),
ei, ej:	Energy goods and sectors {COL, OIL, PGN, ETR, EDS, GAS},
ni, nj:	Non-energy goods and sectors,
$ei2$	Energy goods and sectors other than coal {OIL, PGN, ETR, EDS, GAS},
$ni2$:	Non-energy goods and sectors including coal,
el:	Electric power goods and sectors {PGN, ETR, EDS},
nl:	Non-electric goods and sectors, and
h:	Factors {Capital and Labor}.

Endogenous variables

X_i^p: Quantity of private consumption of the *i*-th good,

X^{pEn}, p^{xpEn}: Quantity and price of private consumption of the energy composite,

$F_{h,j}$, p_h^f: Quantity of the *h*-th factor employed by the *j*-th sector and the *h*-th factor price,

$X_{i,j}$: Quantity of the *i*-th intermediate good used by the *j*-th sector,

X_j^{En}, p_j^{pEn}: Quantity of the intermediate energy composite used by the *j*-th sector and its price,

Y_j, p_j^y: Quantity of value added produced by the *j*-th sector and its price,

Z_j, p_j^z: Quantity and price of the *j*-th gross output,

E_i, p_i^e: Quantity of the *i*-th good export and its price in local currency terms,

M_i, p_i^m: Quantity of the *i*-th good import and its price in local currency terms,

Q_i, p_i^q: Quantity of the *i*-th Armington's composite good and its price,

D_i, p_i^d: Quantity of the *i*-th domestic good and its price,

ε: Exchange rate,

T_j: Amount of domestic production tax imposed on the *j*-th sector,

T^d: Amount of (lump-sum) direct tax,

T_i^m: Amount of import tariff imposed on the *i*-th imported good, and

S, S^g: Amount of private and government saving.

X_i^g: Quantity of government consumption of the *i*-th good,

X_i^v: Quantity of investment uses of the *i*-th good,

Exogenous variables

FF_h: Endowment of the *h*-th factor,

S^f: Amount of foreign saving in the US dollar terms.

p_{nl}^{Wm}, p_{nl}^{We}: Price of the non-electricity import and export in the US dollar terms,

and variables with a superscript zero, which represent the initial values.

τ_j, τ_i^m: Rates of domestic production tax on the *j*-th sector and import tariffs on the *i*-th good, and

ω_{el}: Markup rates caused by monopoly ($\omega_{el} > 0$, only in the monopoly rent abolition cases).

Appendix II: Figures Omitted in the Main Text

Figure II.1: Changes of Output by Monopoly Rent Abolition under Complete Deregulation

(%)

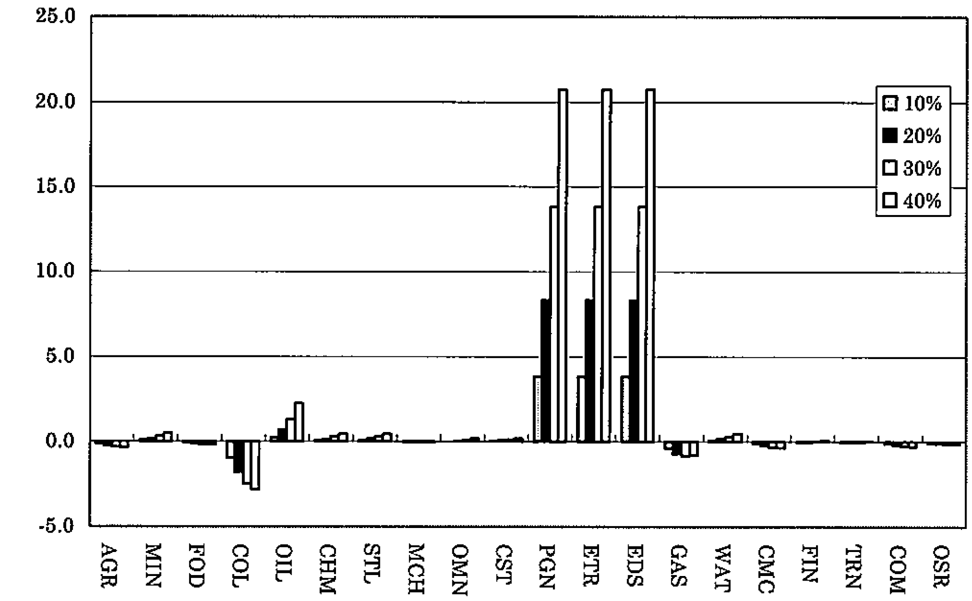


Figure II.2: Changes of Household Consumption by Monopoly Rent Abolition under Complete Deregulation

(%)

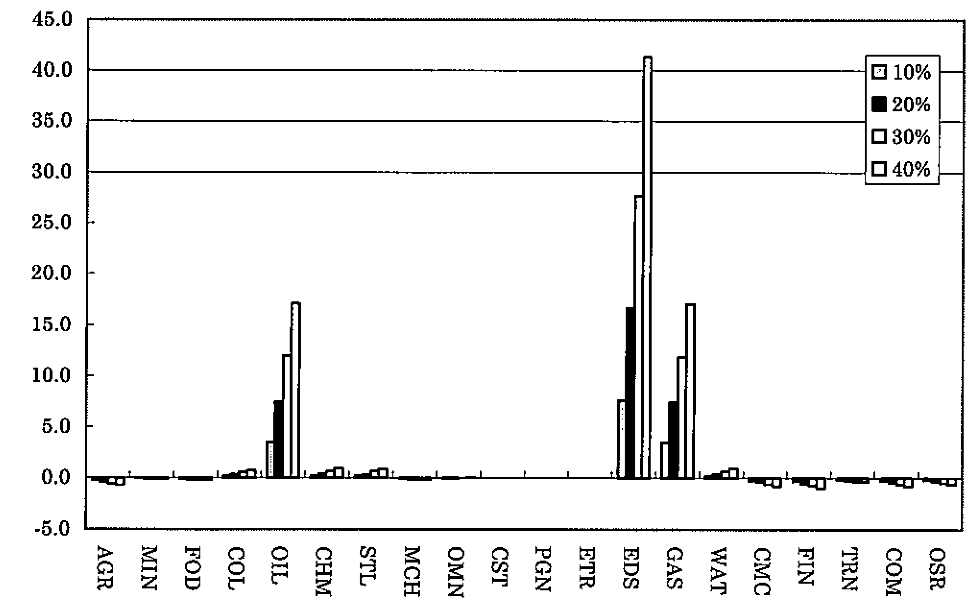


Figure II.3: Changes of Total Supply of Intermediate Good by Monopoly Rent Abolition under Complete Deregulation

(%)

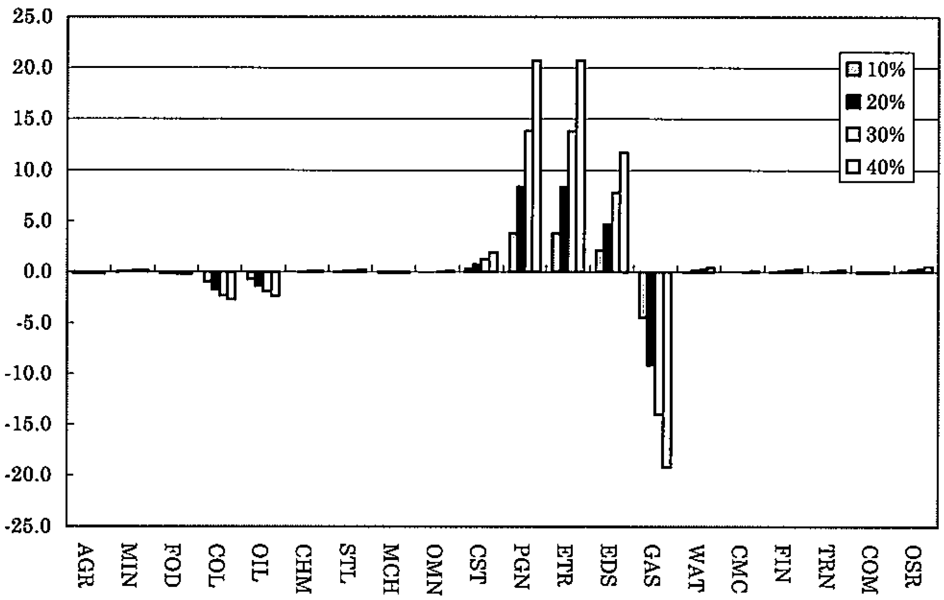


Figure II.4: Changes of Output Prices by Monopoly Rent Abolition under Complete Deregulation

(%)

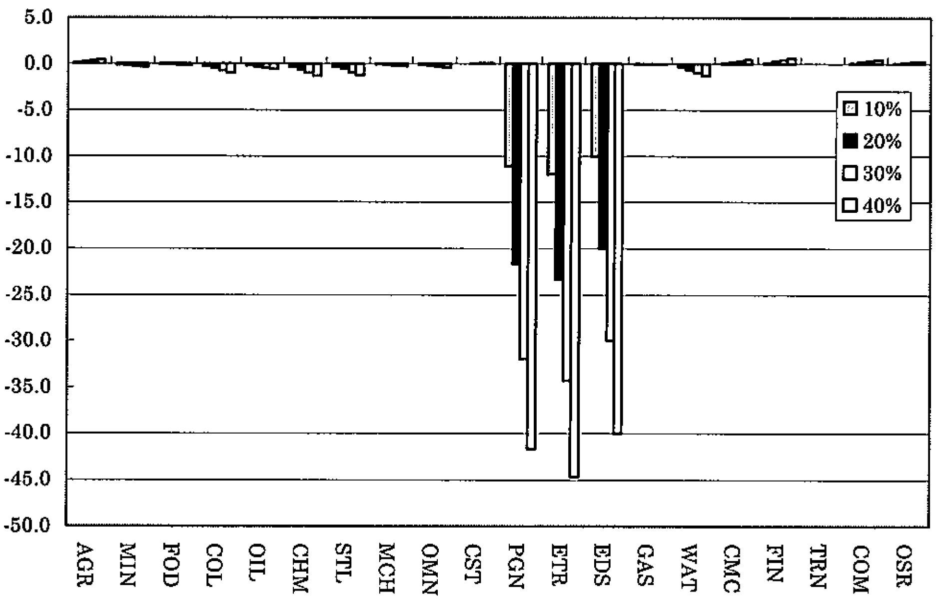


Figure II.5: Changes of Output by Productivity Improvements under Complete Deregulation

(%)

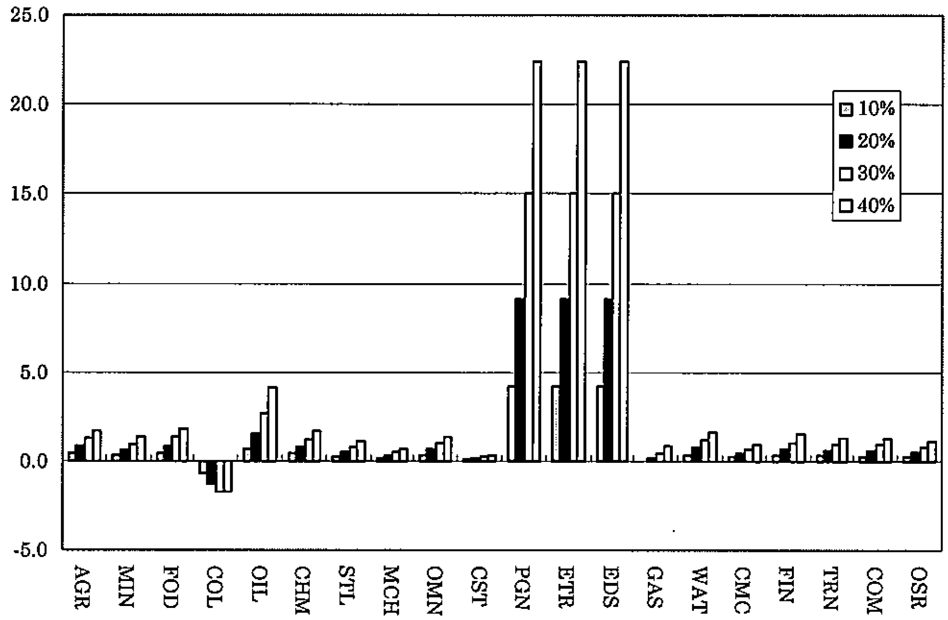


Figure II.6: Changes of Household Consumption by Productivity Improvements under Complete Deregulation

(%)

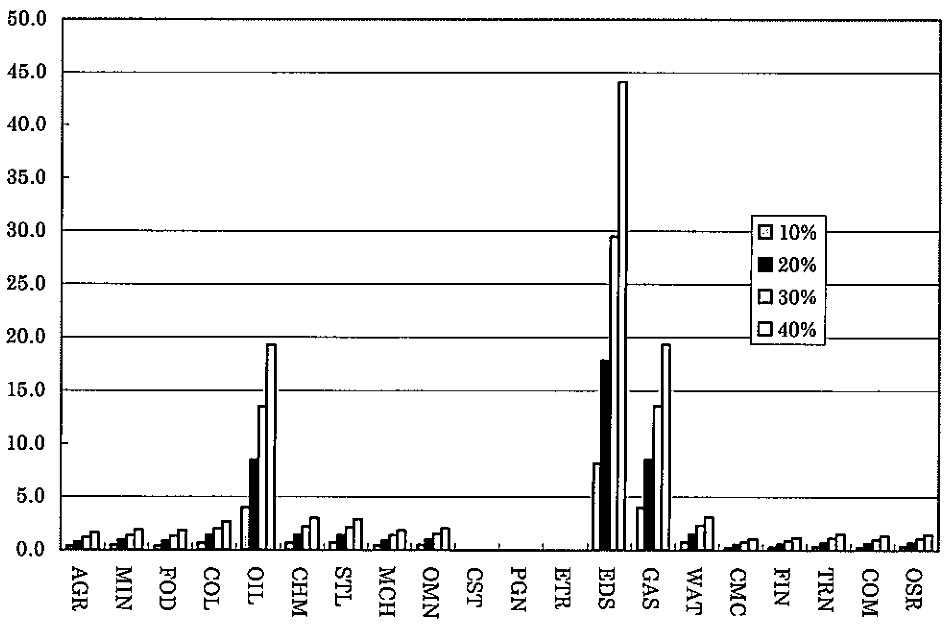


Figure II.7: Changes of Total Supply of Intermediate Good by Productivity Improvements under Complete Deregulation

(%)

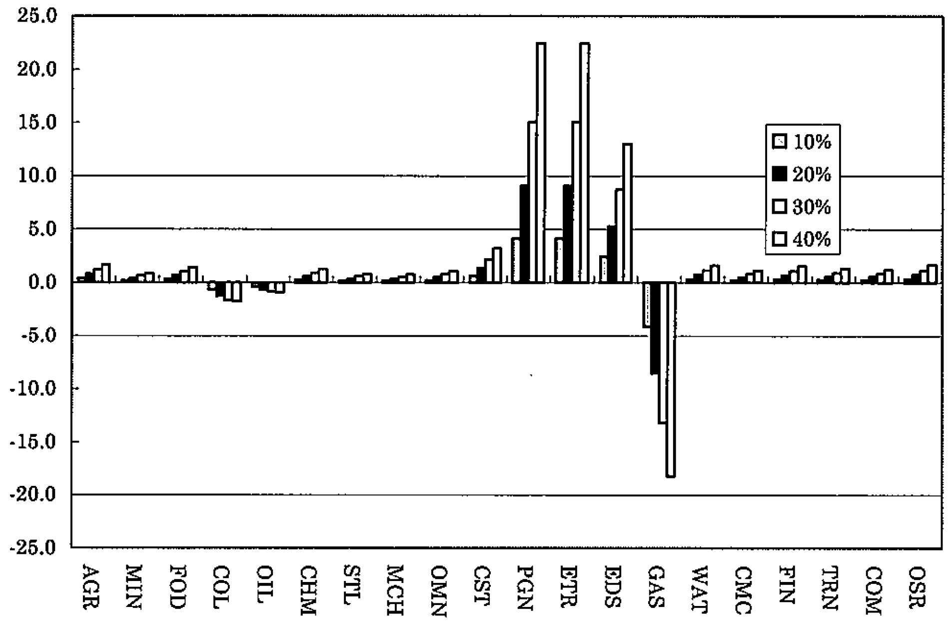


Figure II.8: Changes of Output Prices by Productivity Improvements under Complete Deregulation

(%)

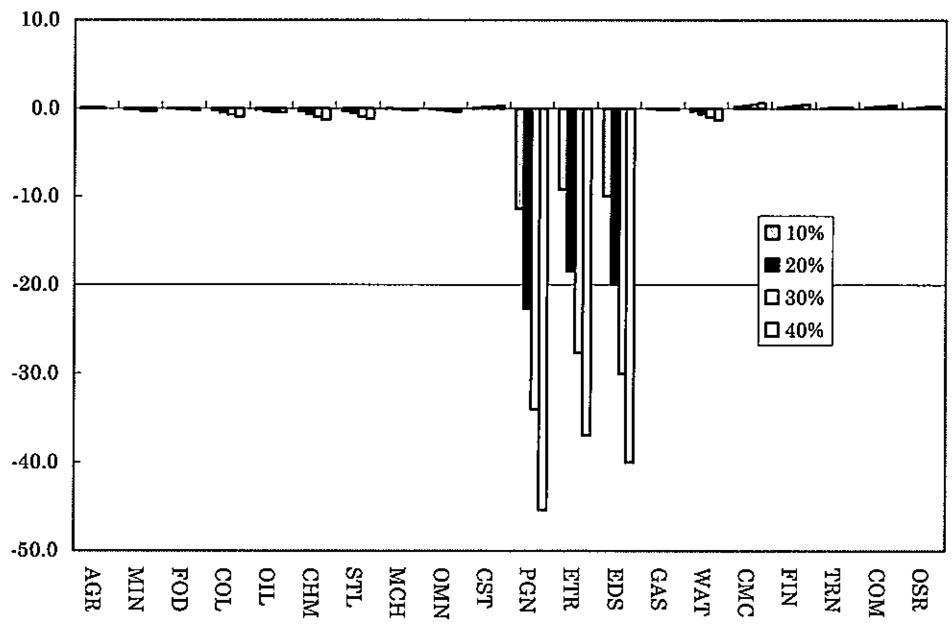


Figure II.9: Changes of Output by Monopoly Rent Abolition under Partial Deregulation

(%)

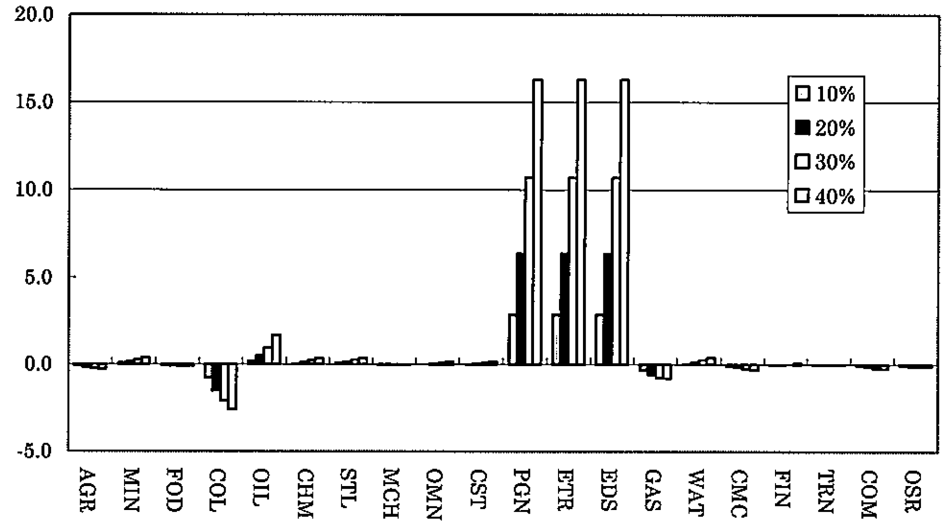
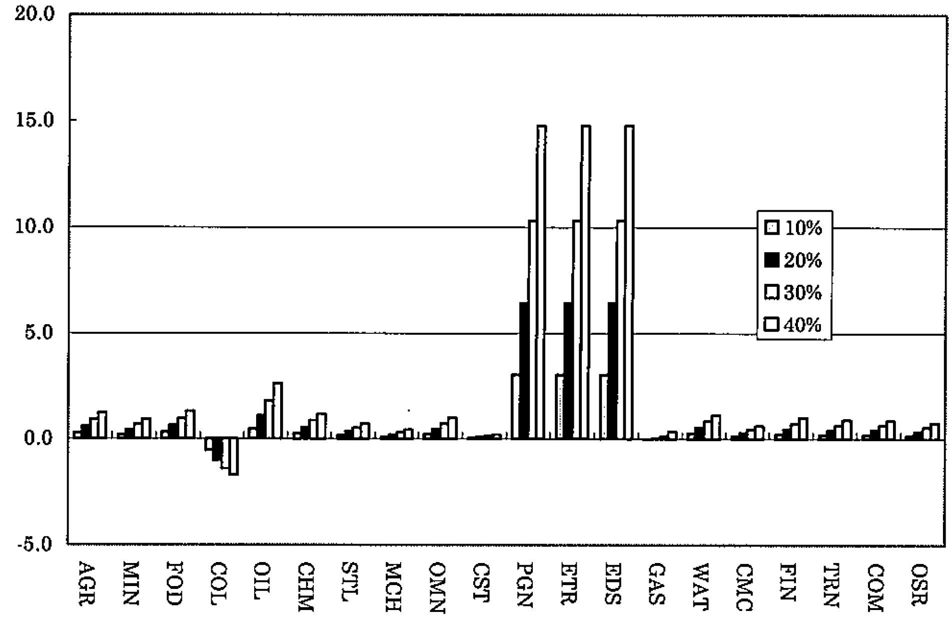


Figure II.10: Changes of Output by Productivity Improvements under Partial Deregulation

(%)



Appendix III: Sensitivity Analysis

We expect that our assumption about the elasticity of substitution in the energy composite aggregation functions would be one of the key parameters for our simulation results. We conduct a sensitivity analysis with respect to that elasticity by perturbing it by 30% upward and downward from the central case reported by Matsukawa *et al.* (1993). The results of our sensitivity analysis suggest that welfare impacts would differ marginally (Table III.1) while output of the four energy sectors seems sensitive to the elasticity (Figures III.1 and III.2). Among these four, changes of gas and oil output would be particularly sensitive to the elasticity and be positive in the less elastic case but negative in the more elastic case. Though figures included here are only for the complete deregulation scenarios, a similar discussion can be made for the results of the sensitivity analysis about the partial deregulation scenarios.

. Table III.1: Results of the Sensitivity Analysis about Welfare Impacts

(Units: billion yen)

		Elasticity of Substitution		
		Lower Case (x0.7)	Central Case (x1.0)	Upper Case (x1.3)
Complete Deregulation	Monopoly Rent Abolition	78	77	75
	Productivity Improvements	1,534	1,528	1,523
Partial Deregulation	Monopoly Rent Abolition	64	63	62
	Productivity Improvements	1,105	1,100	1,095

Figure III.1: Sensitivity Analysis with respect to Elasticity of Substitution for Energy Composite:

Changes of Output by Monopoly Rent Abolition under Complete Deregulation

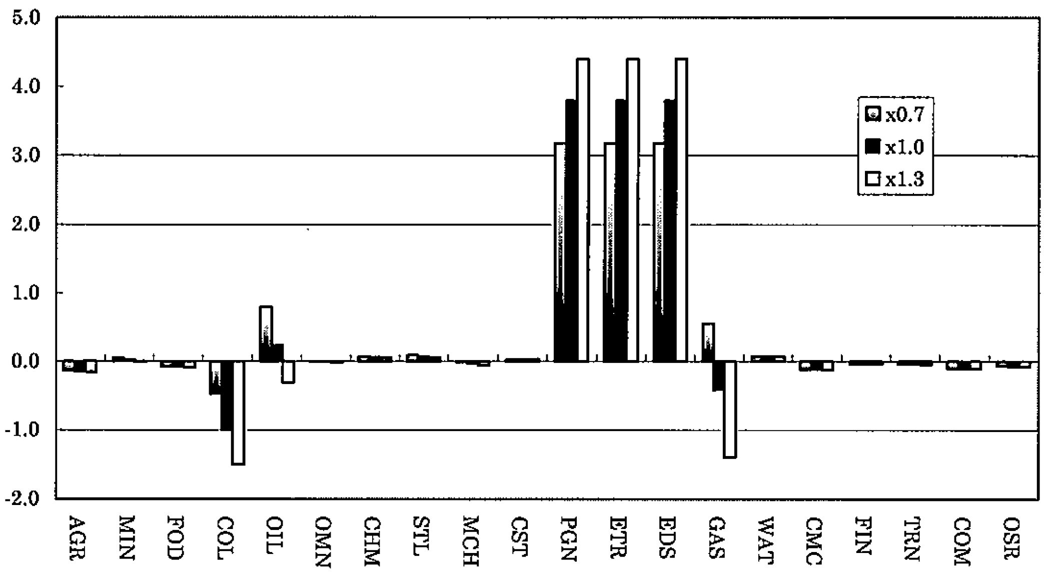


Figure III.2: Sensitivity Analysis with respect to Elasticity of Substitution for Energy Composite:

Changes of Output by Productivity Improvements under Complete Deregulation