Regulatory Interventions for Promoting Investments in Environmentally Benign Energy Technologies

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Revenues and Expenditures of Energy Taxes in Japan (FY 1992)

A. The Tariffs on Imported Crude Oil and Heavy Fuel etc.

Crude Oil	315 yen/kl	=>	The Special Account for Coal	104.3 billion
Gasoline	1,430		Restructuring of Coal Industry	24.8
Kerosene	580		Developments of Coal Producing Regions	11.3
Diesel Oil	1,290		Accidents of Coal Mines	48.3
Heavy Oil	2,520		Labor for Coal Mines	16.2
			Others	3.8

B. The Oil Consumption Tax (*)

Oil	2,040 yen/kl	=>	The Special Account for Oil and its Alternatives	535.4 billion
LPG	670		Measures for Oil	495.6
LNG	720		Resource Developments	101.9
			Reserves of Oil and LPG	349.1
			Restructuring of Oil Industry	40.7
			Others	3.1
			Measures for Alternatives	39.9
			Supply Security	1.3
			Commercialization	8.4
			Technology Developments	28.2
			Others	2.0

C. The Electric Power Development Promotion Tax

0.445 yen/kWh => The Special Account for Electric Power Development Promotion 412.4 billion

The Account for Electric Power Siting	191.8	The Account for Electric Power Diversification	220.6
Electric Power Siting Promotion Funds	82.7	Nuclear	26.9
Nuclear Safety and Other Research Contracts	70.2	Coal Utilization	15.7
Special Grants for Nuclear Plant Siting and Electricity Export	29.0	Hydro	4.8
Hydro Power	6.1	Geothermal	12.6
Others	3.8	Solar	11.8
		Fuel Cell	6.6
		Superconductivity	6.2
		R&D by Science and Technology Agency	106.0
		Others	30.0

(Note)
- Source: MITI (ed.), Sekiyu-Shiryou (1992).
- All the amounts are in Japanese Yen.
- As for the Special Account for Electric Power Development Promotion, the amounts of sources and use do not match due to carry overs from previous years.

(*) Excluding gasoline tax, diesel oil tax and jet fuel tax. The revenue from these taxes is used for transportation infrastructure.

A study on economic measures for CO_2 reduction in Japan

Kenji Yamaji, Ryuji Matsuhashi, Yutaka Nagata and Yoichi Kaya

In this paper, we investigate the costs and effectiveness of two CO_2 emission control policies: a CO_2 tax and a subsidy for CO_2 reduction. CRIEPI's medium-term economic forecasting system is used to analyse the CO_2 tax policy. It is concluded that the national cost of CO_2 reduction by taxation is prohibitively high. For the subsidy we used an integrated approach combining a bottom up model with CRIEPI's model. Although we have shown the usefulness of the integrated approach for analysing the subsidy policy, we need to gather more data to make the results more reliable.

Keywords: CO_2 tax; Subsidy for CO_2 reduction; Macroeconomic cost

Climate change caused by the greenhouse effect is proving a serious threat to the sustainable development of mankind. Since the CO_2 produced by burning fossil fuels is the dominant source of anthropogenic greenhouse gas emissions, world energy systems need to change significantly to cope with the problem of climate change. Fossil fuels now supply almost 90% of world energy requirements and will continue to be principal energy sources for at least several decades. Control of CO_2 emission will involve a strong constraint on energy systems and thus may have a significant negative impact on economic activity and the quality of life.

The costs of CO_2 emission control should be compared with the benefits of emission reduction. There are, however, multiple uncertainties in the sciences on climate change. We do not know the exact relationships between CO_2 emission and atmospheric CO_2 concentration, CO_2 concentration and temperature rise, temperature rise and sea level etc. The damage induced by climate change can only be estimated within a huge range of uncertainty. It is therefore important for us to remain flexible and to bear in mind that our objective is not simply to prevent climate change at whatever cost but to mitigate climate change and still maintain acceptable standards of living.

For identifying phased and flexible response strategies, which consist of policies which involve the minimum sacrifice, it is important to evaluate the national economic costs of measures to control CO_2 emissions. This paper presents a study on the effectiveness of CO_2 emission control strategies in Japan. The analytical framework for the study is an integrated system which combined a modelling approach developed by the Central Research Institute of Electric Power Industry (CRIEPI) and a bottom up approach pursued by the University of Tokyo.[1]

Structural change in Japan's energy system

Tables 1 and 2 show Japan's energy supply–demand structures in 1974 and 1988. Nuclear power and natural gas increased their share nine times and six times respectively during this 15 years; the share of each in total primary energy supply is now 10%. Most of the increase in these two energy supplies is used for electricity generation. On the other hand oil reduced its share from 74% in 1974 to 57% in 1988. Energy consumption in the residential and commercial and transport sectors increased significantly to represent about one-fourth of total energy consump-

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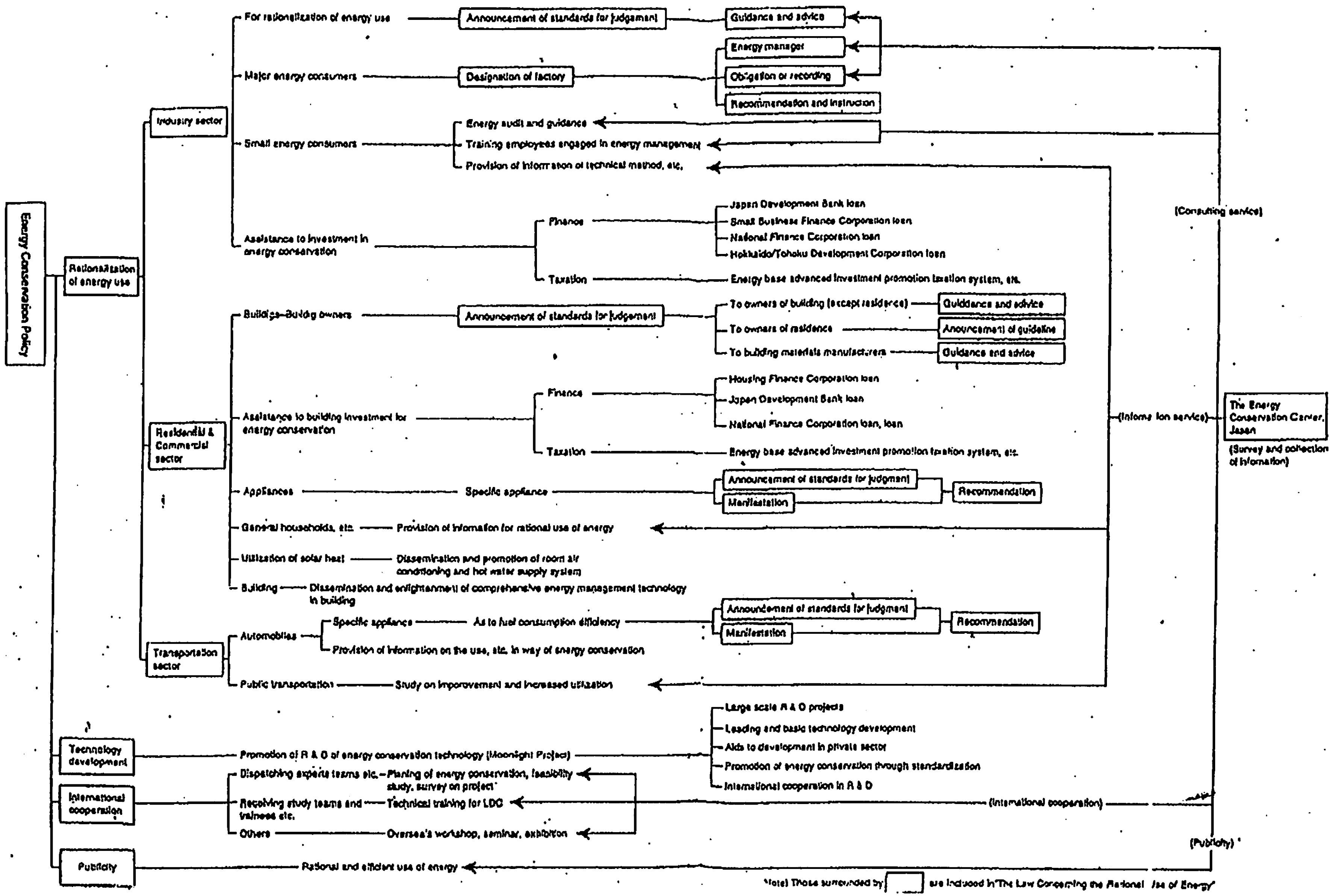
Current Framework of Energy Conservation Policy in Japan



Note) Those surrounded by [ ] are included in "The Law Concerning the Rational Use of Energy"

Table 1. Primary energy requirement in Japan (10^{12} kcal).[a]

	1974		1988		
Nuclear	45.5	(1)	428.4	(10)	
Hydro/geothermal	201.6	(6)	220.3	(5)	
Coal	614.0	(17)	757.1	(18)	
Natural gas	72.2	(2)	430.0	(10)	324 electricity; 100 [illegible]
Oil	2582.5	(74)	2406.3	(57)	
Total	3515.8	(100)	4242.1	(100)	
Electrification (input %)	30		40		
GDP growth 4.4% pa Primary energy 1.4% pa Elasticity 0.31					

Notes: [a] Figures in parentheses are percentages.
[b] 10^{12} kcal = 0.1 Mtoe.

Table 2. Energy consumption by sector (10^{12} kcal).[a]

		1974		1988	
Industry		1575.2	(61)	1403.1	(49)
Residential and commercial		464.7	(18)	710.3	(25)
Transport		456.7	(18)	693.6	(24)
Non-energy use		67.4	(3)	78.2	(3)
Total		2564.0	(100)	2885.2	(100)
Conversion loss (1357)	Electricity generation			1079.3	
	Oil refinery			191.0	
	Town gas etc			86.6	
Total primary energy				4242.1	

Notes: [a] Figures in parentheses are percentages.

tion in 1988. Energy consumption in the industrial sector decreased and its share in total energy consumption was reduced to less than half in 1988.

Figure 1 shows the CO_2/energy/GNP growth rate indicators for the period from 1970 to 1988 divided into three subperiods: 1970–73, 1973–86 and 1986–88. CO_2 emissions in Japan remained constant during the subperiod of high oil prices (1973–86); however, CO_2 emissions had increased more rapidly than the economic growth rate before the first oil crisis and have again been increasing almost in parallel with GNP since 1986. Thus, it would be too optimistic to extrapolate from the performance shown in the period of the oil crises to the future.

CO_2 emission projections in Japan

Figure 2 and Figure 3 show CRIEPI's base case projection of primary energy requirements and associated CO_2 emissions to the year 2005. In this projection, primary energy shares of nuclear power, natural gas, coal and oil in 2005 are 15%, 13%, 20% and 47% respectively; and CO_2 emission in 2005 increases by about 36% from the level of 1988.

The Ministry of International Trade and Industry (MITI) of Japan released the latest official long-term energy outlook in June 1990. In the MITI's outlook, primary energy shares of nuclear power, natural gas, coal and oil in 2010 are 17%, 12%, 15.5% and 46% respectively, and CO_2 emissions are estimated to increase by 16% in 2000 and by 18% in 2010 from the level of 1988.

On the other hand, the Japanese government in October 1990 decided on an action programme to reduce CO_2 emissions, in which the target for CO_2 limitation was stated to be to stabilize emissions of CO_2 on a per capita basis in the year 2000 and beyond at about the same level as in 1990. Since there is an estimated 7% increase in CO_2 emission from 1988 to 1990 and the Japanese population is forecast to increase by about 6% from 1990 to 2000, MITI's projection of CO_2 is very close to the official target stated in the action programme.[2]

As shown in Figure 4, while GNP growth is assumed almost the same in the both projections, MITI's projection of CO_2 emissions is much lower than CRIEPI's. In MITI's energy outlook, utmost efforts to reduce CO_2 emissions such as rapid reduction of energy intensity (−2% pa in terms of primary

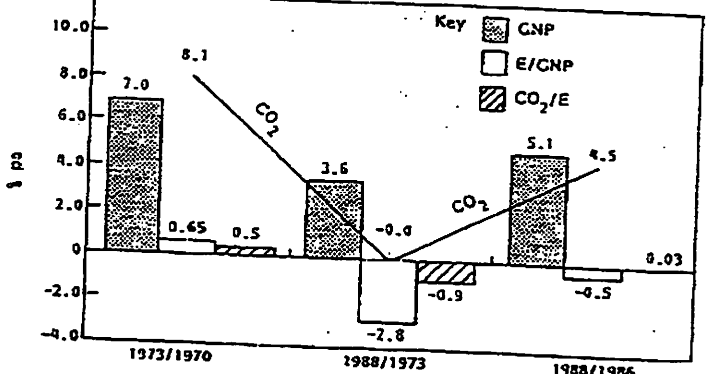


Figure 1. CO_2/energy/GNP growth rate indicators during 1970–88.

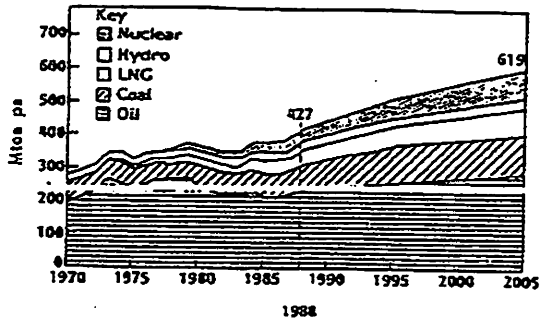


Figure 2. Primary energy requirement in Japan.

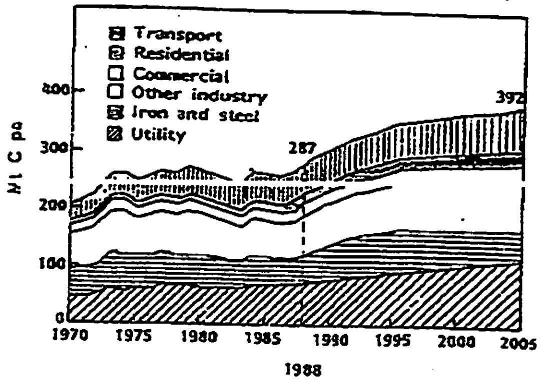


Figure 3. CO_2 emission in Japan.

energy requirement per GNP) and maximum possible nuclear power development (72.5 GWe in 2010) have been already incorporated; thus, CO_2 emissions after 2000 are kept nearly constant at a level about 16% higher than that of 1988. We adopt CRIEPI's projection as a base case in the following sections.

Methods for assessing policy measures to reduce CO_2 emission

There are generally speaking two types of approaches to assessing economic impacts of the measures to reduce CO_2 emission. One is a model based approach which employs macroeconomic models as a key tool to evaluate total impacts of the measures on energy systems and national economy. The other is a so-called bottom up approach which identifies individual technical measures and takes into account individual costs and effects. For the assessment of subsidy policy we apply an integrated system combining the two approaches, while only the model based approach is used for assessing a CO_2 tax policy.

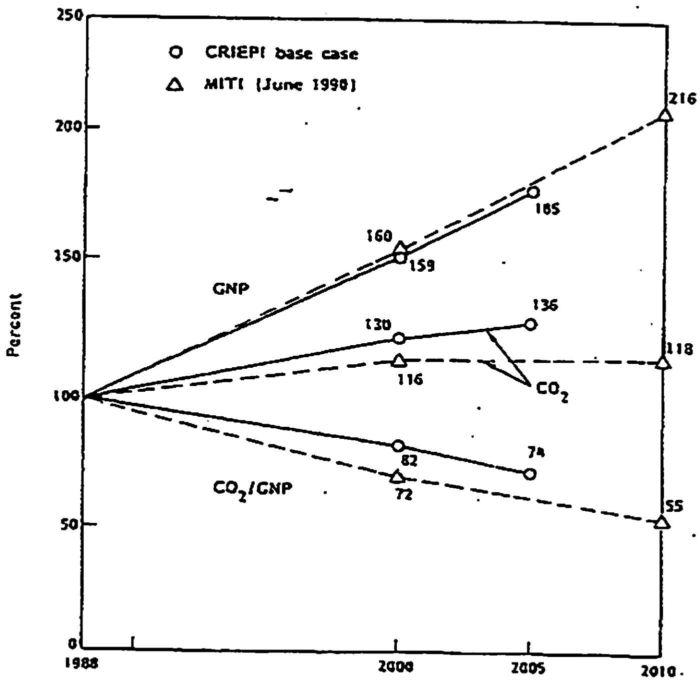


Figure 4. Comparison of CO_2 and GNP projections.

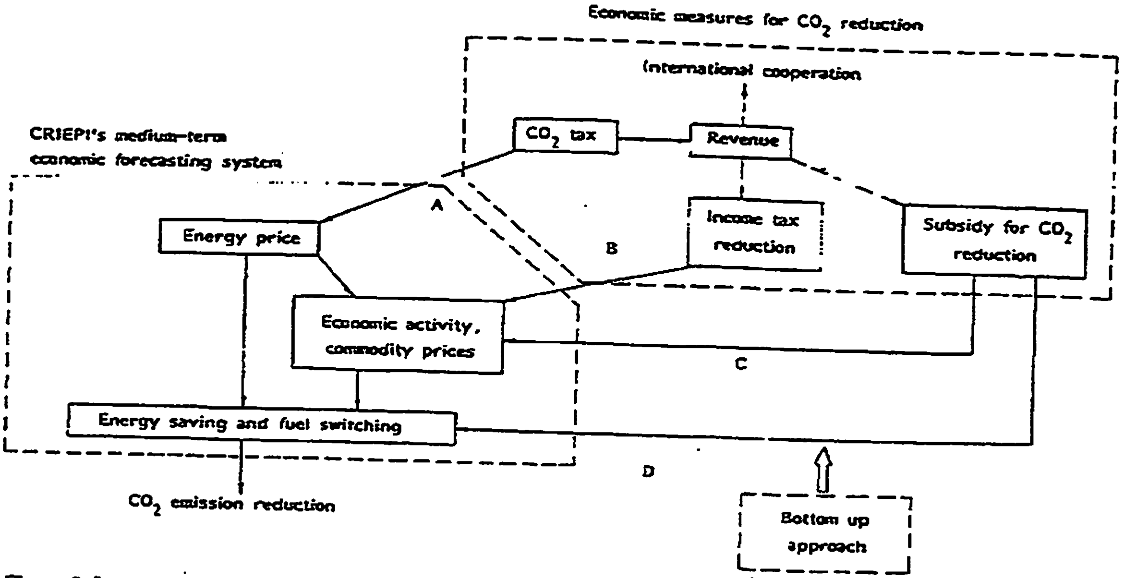


Figure 5. Integrated system for CO_2/energy/GNP analysis

CRIEPI's medium-term economic forecasting system

As the part of model based approach, we adopted CRIEPI's medium-term economic forecasting system.[3] The system consists of four models: a world energy model, a medium-term multisectoral model, an interfuel competition model and a nine-region model.[4] The system was used to make CRIEPI's base case CO_2/energy/GNP projections described in the previous section. The world energy model and nine-region model are not used in the assessment of CO_2 reduction policies because import energy prices are given exogenously and Japan is treated as an aggregate region in the policy analysis.

The multisectoral model is an annual macro input–output linkage model. The model provides more than 4000 pieces of information such as: GNP and its breakdown; outputs, wage/employment, prices etc of the industries with maximum breakdown of 54 sectors (13 sectors in this study); and savings and investment by households, enterprises and governmental sectors. The basic modelling framework follows a general equilibrium tradition, but its equilibrium characteristics are non-Walrasian temporary disequilibrium in the sense that the supply–demand gap, considered as a sign of non-clearing markets, is explicitly introduced and affects the sectoral price–quantity adjustments.[5]

The interfuel competition model determines energy demand by type and by sector with the prices of energy consumed and calculates CO_2 emissions. Major exogenous variables are the levels of economic activity such as output of each industrial sector and disposable income of households, which are provided by the multisector model, and the international prices of energy which are determined by the world energy model. The model consists of two blocks, the end-use energy block and energy conversion block. The end-use energy block is divided into 15 sectors: 9 manufacturing industries, agriculture, mining, construction, services, transport and households. For each sector, energy consumption by type and also by use in the service and household sectors, is determined by the equations estimated from 1970–85 data. In the equations which describe the demand in energy intensive industries, autonomous energy-efficiency improvements, estimated at about 1% pa, are taken into consideration. The energy conversion block determines the prices of secondary energy goods with their effects on energy demands taken into account.[6]

An integrated system

We use an integrated system which combines the bottom up approach developed by Kaya and Matsuhashi with CRIEPI's medium-term economic forecasting system for assessing the effect of subsidy for reducing CO_2 emission.[7] The procedures are schematically shown in Figure 5. It is assumed that the Japanese government gives a subsidy to each enterprise or to each household. The subsidy therefore

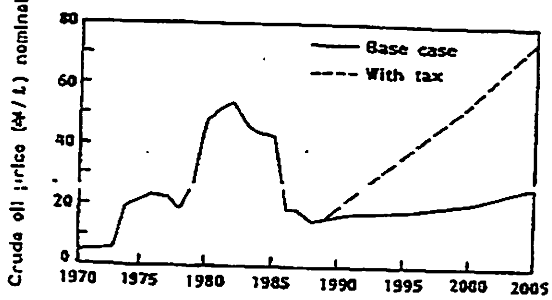


Figure 6. Carbon tax for holding CO_2 emission constant.*
Note: * Introduce in 1990 at a level of ¥ 4000/t C. Increase yearly by ¥ 4000 to give ¥ 64 000/t C in 2005.

leads to investment in the sector to which each energy conservation technology belongs.

As shown in Figure 5, the direct effects of subsidies on energy conservation and fuel switching are evaluated by the bottom up approach (path D in Figure 5); and through CRIEPI's model system the indirect effects of subsidies such as changes of industrial outputs and commodity prices (path C in Figure 5) are analysed. The actual integration procedures are as follows:

- CRIEPI's model produces IIP (Index of Industrial Production) in each sector and CO_2 emission in the base case.
- From the result of CRIEPI's model, we evaluate the subsidy given to each sector and CO_2 reduction arising from the subsidy in the bottom up model.
- The value of the subsidy, which leads to the investment as described above, is taken from the bottom up model to CRIEPI's model. The macroeconomic effect due to the investment is then evaluated in CRIEPI's model.
- From the result of CRIEPI's model, we evaluate the change in net GNP and CO_2 emission.

Analysis of CO_2 tax policies

According to CRIEPI's base case projection of CO_2/energy/GNP, average growth rates of GNP, energy and CO_2 emission for 1988–2005 are 3.7% pa, 2.1% pa and 1.8% pa respectively. Starting from this base case projection, let us assume the introduction of a CO_2 tax to hold CO_2 emissions in 2005 at 1988 levels. The CO_2 tax is to be introduced in 1990 and the level of the tax is increased gradually to maintain its effect.

We assume that the CO_2 tax is imposed on primary energy sources in proportion to theoretically

estimated CO_2 emissions. Both the direct impact of CO_2 tax through increased fossil fuel prices and the indirect impact through changes in economic output and general prices are evaluated by CRIEPI's medium-term economic forcasting system. Depending on how the revenue from the CO_2 tax is used, we have two cases: case 1, tax remove, and case 2, tax offset. In case 1 collected tax revenues are assumed to be removed from the Japanese economy, and, in case 2 the revenue of the tax is offset by an equivalent amount of income tax reduction.

Tax level for CO_2 stabilization

Through several simulation experiments we found a tax schedule to hold CO_2 emissions in 2005 at approximately the level of 1988. As stated in Figure 6, the tax schedule to achieve the target is as follows: CO_2 tax of 4000 yen per tonne of carbon is introduced in 1990, and then increased yearly by 4000 yen until it reaches 64 000 yen per tonne in 2005. As also shown in Figure 6, the CO_2 tax raises crude oil price in 2005 to about 2.8 times higher than in the base case projection. Reduction of CO_2 emissions caused by the tax are illustrated in Figure 7.

Macroeconomic impacts of CO_2 tax policy

The macroeconomic impacts of a CO_2 tax policy to hold CO_2 emissions constant are summarized in Table 3 and illustrated in Figure 8. The results lead to the following findings:

- CO_2 emission stabilization through a CO_2 tax has a serious impact on the national economy: in the tax remove case, the average growth rate of GNP in real terms from 1988 to 2005 reduces by 0.4% pa and GNP in 2005 decreases by 38 trillion (10^{12}) yen (1980), more than 6% down from the base case value.
- Income tax reduction offsetting the CO_2 tax revenue mitigates the adverse macroeconomic impacts: loss of GNP in 2005 in the tax offset case is reduced to 30 trillion (10^{12}) yen (1980), about 5% of the base case value; however, the effect is too small to make CO_2 tax an attractive policy to Japan.[8]
- GNP losses per unit CO_2 reduction range from 250 000 yen per tonne of carbon (cumulative average in the tax offset case) to 360 000 yen per tonne of carbon (2005 year only in tax remove case). The specific CO_2 reduction costs associated with a CO_2 tax in Japan are prohibitively high when compared with the cost estimates of various technical measures to reduce CO_2 emissions, which are mostly less than 50 000 yen per tonne of carbon.

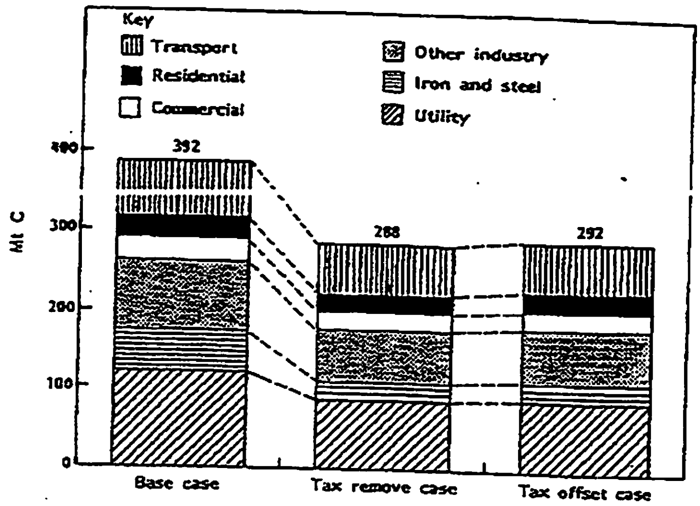


Figure 7. CO_2 emission in 2005.

Analysis of subsidies to reduce CO_2 emissions

In this section we analyse the effect of a subsidy for reducing CO_2 emissions. An integrated system combining the bottom up approach with the top down approach is used to assess the effect of the subsidy. First, we discuss the economic criteria of measures for CO_2 reduction. Then we evaluate CO_2 reductions from the subsidies and their macroeconomic impact.

Economic criteria of measures

We need to introduce some economic incentives to accelerate the implementation of various measures for preventing climate change. Here we introduce the subsidy *Pc* for CO_2 reduction as an economic incentive. We express *Pc* in terms of yen per tonne of carbon reduced. With this subsidy *Pc*, the fundamental condition for economic feasibility is expressed by Equation (1):

$$\text{(savings from reduced energy consumption)} + Pc \times \text{(tonne C reduced)} > \text{(total cost of implementation)} \quad (1)$$

The first term on the left-hand side is applicable primarily for measures which conserve energy. This

Table 3. Costs and effects of tax for CO_2 reduction.

	Tax remove case	Tax offset case
A Real GNP loss (trillion yen)		
in 2005	−37.7 (−6.2%)[b]	−30.0 (−4.9%)
1990–2005 cumulative	−310.6 (−4.0%) (−0.4% annually)	−230.6 (−3.0%) (−0.3% annually)
B CO_2 reduction (Mt C)		
in 2005	104.1 (26.6%)	99.8 (25.5%)
1990–2005 cumulative	985.1 (17.1%)	939.0 (16.3%)
C Tax revenue (trillion yen)[a]		
in 2005	11.9	12.0
1990–2005 cumulative	118.2	119.0
D Specific CO_2 tax revenue (thousand yen/t C)		
1990–2005 nominal	31.4	31.5
1990–2005 real price[a]	23.4	23.3
E National economic cost per CO_2 reduction (thousand yen/t C)		
in 2005	362	301
1990–2005 cumulative	315	246

Notes: [a] Deflated by wholesale price index (real price in 1980).
[b] Difference rate from base case.

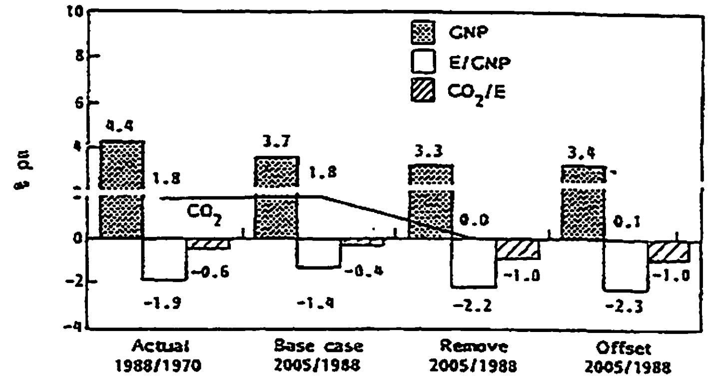


Figure 8. CO_2/energy/GNP growth rate indicators during 1970–2005.

term becomes negative when energy costs are increased by implementing the measures. The total cost of implementation is the sum of both the capital and the operation costs other than the energy costs. It is usually described as $a \times I$ on an annual basis, where a is the annual expense ratio and I is the investment cost. However, the entrepreneur's actual decision on energy conservation measures is not based on this criterion. Since, in the past, energy prices have fluctuated widely, entrepreneurs tend to be rather prudent when they invest in energy conservation. In Japan they typically use a short payback time of around two years.[9] In other words, instead of using an annual expense ratio of a, they use $1/T$ where T is two years.

We can then rewrite the criteria for adopting the measures as follows:

Criterion A (total cost criterion)

$$Pc > \frac{a \times I - (\text{saving from reduced energy consumption})}{(\text{decrease in carbon emissions})}$$

Criterion B (payback time criterion)

$$Pc > \frac{1/T - (\text{saving from reduced energy consumption})}{(\text{decrease in carbon emissions})}$$

where T is two years.

According to the summary report of the energy and industry subgroup in the Working Group 3 of IPCC,[10] we should distinguish marketable technologies from economic technologies. Criterion A and criterion B can be interpreted as the criteria for economic technologies and marketable technologies respectively. Criterion B generally reflects the actual investment pattern of the market. In the next section we will investigate the effect of the subsidy Pc for CO_2 reduction in Japan.

The effects of a subsidy on CO_2 reduction

Two types of measures. Before investigating the measures, we should differentiate between two types of energy conservation measure. One type introduces new facilities so as to reduce energy loss in processes. For example, coke dry quenching systems used in the iron and steel industry belong to this type. For convenience, we call this type the investment type. The other type changes the usage patterns of machines or materials in order to make the system more economical. Typical examples of this type are changes in the usage patterns of automobiles which are caused by changes in fuel prices. We call this type the pattern change type. We assume that measures of the pattern change type are not implemented by introducing the subsidy. On the other hand the subsidy can offer economic incentives for implementing investment type measures. Investment type measures cannot be evaluated without a detailed survey of the engineering–economic characteristics of such measures, which is the essence of the bottom up approach. Therefore the following sections deal only with investment type measures.

Marketability condition. The first step in evaluating measures is to determine the amount of subsidy, Pc, so that these measures can be implemented by actual market incentives. Given the cost data, the Pc necessary for each measure to be marketable can be determined. Here we utilize data gathered mainly by the Japan Energy Conservation Centre; they are not a thorough survey of the results but are the only data presently available. Measures in the data include 57

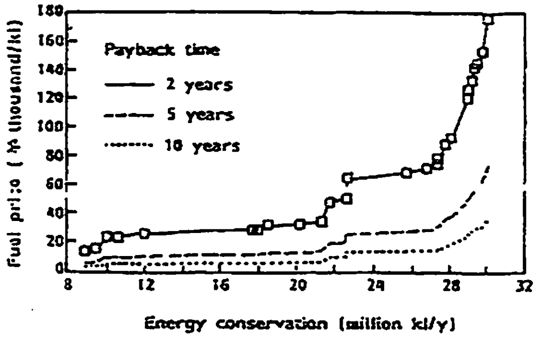


Figure 9. Supply curve of energy conservation.

energy conservation technologies in industry, thermal insulation for houses and buildings and fuel switchings in industrial boilers/furnaces and in electric power stations. As an illustrative example, engineering–economic characteristics of industrial energy conservation technologies are shown in Figure 9. We have made the following assumption about marketability conditions in each sector:

- In the industry sector, we assume that criterion B is adopted, and that the payback period is two years, as described above.
- For thermal insulation in houses and other buildings we assume that criterion B is adopted, but that the payback period is longer than in the industry sector. This is because the lifetime of insulation materials is longer than that of energy conservation technologies in the industry sector. We assume the payback period for thermal insulation to be five years. However, more work is needed to investigate the detailed investment pattern in this sector.
- In the electricity sector the situation is different. Electric power companies in Japan are regulated by the law as public utilities and the price of electricity is based on its cost. We therefore assume that criterion A is adopted in this sector, and that the annual expense ratio is 20%.

Leadtimes for introducing new facilities. Even if the marketability of measures is guaranteed, it takes time for those measures to be effective, due to the time needed for replacing old facilities. Taking this into account we have made the following assumptions about the speed of acceptance of measures:

- The market penetration rate for energy conservation measures is assumed to be 10% pa: in other words an old facility will be fully replaced by a new one in 10 years.
- Taking into account the long lifetime of houses and other buildings, we assume that the market penetration rate of insulation materials for houses is 2.5% pa.
- As for electric power plants, we decide the time needed for replacing each plant on the basis of its vintage, assuming that the average lifetime of plants is 35 years.

Reduction in CO_2 emission versus Pc. On the basis of the above assumptions, we evaluate how much reduction in CO_2 emissions will be attained by the introduction of a *Pc*. Here we should be aware of the fact that only measures of the investment type are considered in the analysis. The results are shown in Figures 10 and 11.

Figure 10 shows how the CO_2 reduction potential will grow with time, with *Pc* staying constant. This result shows how important the time factor is in evaluating the CO_2 reduction potential. Figure 11 shows a cross-sectional result in 2005. This figure shows a trend for the marginal cost of CO_2 reduction to become higher as *Pc* increases.

Macroeconomic impacts of the subsidy

If we introduced a subsidy for CO_2 reduction, it would affect the cost structure of industries and the national economy. The subsidy itself has a positive effect if the cost of financing it is ignored. In this section we will investigate such effects of the subsidy. It is assumed that the subsidy is given from the Japanese government to each enterprise or to each household. The financing of the subsidy is not considered here. The results are summarized in Table 4. The so-called multiplier effect of investment seems to have reasonable values. Since the total amount of the subsidies is much less than GNP, the increase in GNP over the reference case will be less than 1.5%. Due to the small amount of additional GNP which is yielded by the subsidy, there will be

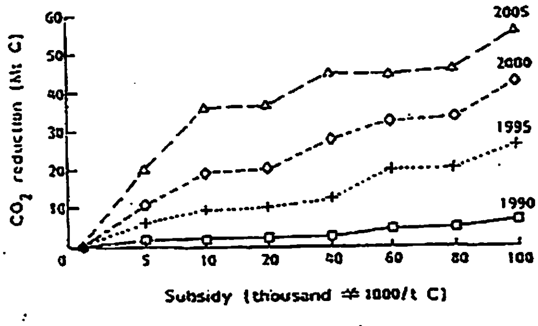


Figure 10. CO_2 reduction by subsidy (direct effect).

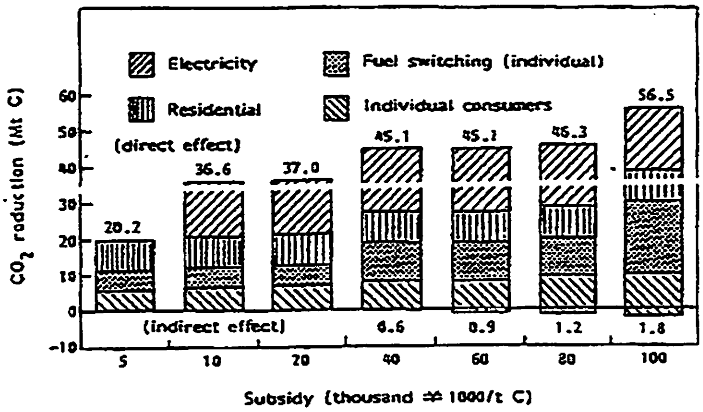


Figure 11. Sectoral CO_2 reduction by subsidy in 2005.

a slight increase in CO_2 emissions. Taking this into account, the total emissions of CO_2 are shown in Figure 12.

Concluding remark

The findings in our study on the economic measures to reduce CO_2 emissions in Japan are summarized as follows:

- Without CO_2 limitation policies, CO_2 emissions from Japan's energy system would increase significantly: by 36% during 1988–2005 according to CRIEPI's medium-term economic forecasting system.
- The level of CO_2 tax rate needed to stabilize Japan's CO_2 emission through price effects only is very high: primary fossil fuel prices should be two to five times higher than those in the base case in 2005.
- The national economic impact of CO_2 emission reduction through a CO_2 tax is significant: GNP in 2005 has decreased more than 6% as a result of holding CO_2 emissions to the 1988 level when the revenue of the CO_2 tax is removed from Japanese economy.
- The national cost of CO_2 reduction by the price signal of a carbon tax is prohibitively high: GNP loss per unit CO_2 reduction is around 300 000 yen per tonne of carbon.
- Income tax reductions offsetting the CO_2 tax revenue mitigate the above adverse impacts; however, the effect is still too small to make CO_2 tax an attractive policy for Japan.
- The level of subsidy required to reduce about 40 million t C of CO_2 emission in 2005 is relatively small: around 20 000 yen per tonne of carbon reduction. But the marginal effect of the subsidy decreases as the level of subsidy

Table 4. Costs and effects of subsidy for CO_2 reduction.

Level of subsidy (thousand yen/t C)	5		20		80	
A Real GNP gain (trillion yen)						
in 2005	0.05	(0.01%)	0.33	(0.05%)	1.66	(0.27%)
1989–2005 cumulative	0.50	(0.01%)	3.50	(0.04%)	22.65	(0.28%)
B CO_2 reduction (Mt C)						
in 2005	20.2	(5.1%)	37.0	(9.4%)	46.3	(11.8%)
1989–2005 cumulative	150.9	(2.5%)	267.3	(4.4%)	426.4	(7.0%)
C CO_2 increase by subsidy (Mt C)						
in 2005	0.03	(0.01%)	0.24	(0.06%)	1.20	(0.31%)
1989–2005 cumulative	0.33	(0.01%)	2.32	(0.04%)	14.96	(0.24%)
D Subsidy (trillion yen)[a]						
in 2005	0.09		0.62		3.11	
1989–2005 cumulative	0.71		5.02		32.42	
E Unit CO_2 reduction cost (thousand yen/t C)						
in 2005	4.2		16.9		68.9	
1989–2005 cumulative	4.7		18.9		78.8	

Note: [a] Deflated by wholesale price index (real price in 1980).

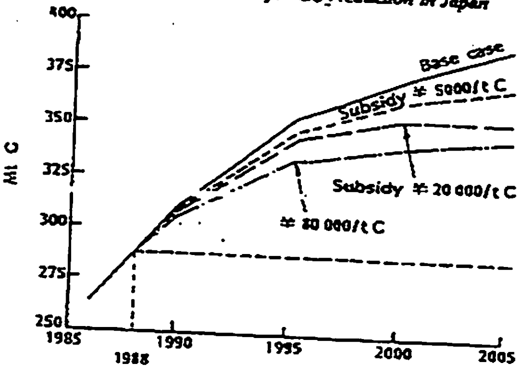


Figure 12. Total emissions of CO_2.

increases; thus CO_2 emission in Japan cannot be stabilized by introducing a subsidy only.

- The national economy is stimulated by introducing the subsidy. But the associated increase in CO_2 emission is small: less than 0.1% for a subsidy level of 20 000 yen per tonne of carbon.

There still remain many issues not analysed in the study. We have not evaluated the effect of using the tax revenue as a subsidy to accelerate the market penetration of specific technical measures for reducing CO_2 emissions. In the study analyses of CO_2 tax and subsidy were carried out separately, and the financing of the subsidy was not taken into account.

Nor have we investigated the influence on global CO_2 emission of the international economic impacts caused by structural changes in the Japanese economy to reduce Japan's CO_2 emissions, or clarified what would happen if many countries introduced a CO_2 tax simultaneously. The advantage that could be achieved through regional and/or global interactions to reduce the global CO_2 emissions more effectively eg technology transfer and international trade of CO_2 emission rights also needs further study.

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[1]K. Yamaji, Y. Nagata, N. Sakurai and T. Hattori, 'Carbon tax simulation analysis', *Economics and Public Utilities*, Vol 27, 1990, pp 85–91 (in Japanese); Y. Kaya and R. Matsuhashi, 'Economic feasibility of CO_2 limitation: Target A, bottom up approach', *London Workshop on Emission Target, Intergovernmental Panel on Climate Change (IPCC)*, June 1991.

[2]The Government of Japan: 'Action Program to Arrest Global Warming', 23 October 1990. Projection of the Japanese population is soon to be revised downwards because of a sharp drop in recent birthrates.

[3]A. Yajima, *A Medium-term Economic Forecasting System*, R-8832, Japan IERE Council, Tokyo, 1989.

[4]In this model Japan is divided into nine regions which correspond to the supply territories of nine major electric utilities.

[5]T. Hattori and N. Sakurai, *The CRIEPI Multisectoral Model of the Japanese Economy*, CRIEPI Report EY90003, 1991.

[6]O. Kumakura, Y. Nagata, Y. Fujii and I. Matsukawa, *Developing the Inter-Fuel competition Model*, CRIEPI Report EY89001, 1989.

[7]*Op cit*, Ref 1, Kaya and Matsuhashi.

[8]The revenue from carbon tax in 2005 is 18.7 trillion (10^{12}) yen in nominal terms, and income tax reduction by the same amount increases GNP by around 33 trillion yen in nominal terms. National demand stimulated by the income tax reduction, however, also increases the price level of general commodities; thus the increment of GNP in terms of constant money value is reduced to around 8 trillion yen (1980).

[9]Y. Kaya, 'Benefits and costs of energy conservation', *Journal of the Japan Society of Mechanical Engineering*, Vol 82, No 725, 1979, pp 313–316.

[10]Intergovernmental Panel on Climate Change Energy and Industry Subgroup Report, May 1990.