2.3 HOW TO ACCESS THE ECONOMIC EFFECTS OF STEPS TO REDUCE CO2 EMISSIONS IN MACRO-ECONOMIC MODELS AND EXAMPLES OF TRIAL CALCULATIONS

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Described below are the findings of a study on how steps taken to reduce CO2 emissions will affect the macro-economy and energy demand-supply. Used in the study is a linkage of a macro-economic model and an energy model.

1. BASIC STRUCTURE OF THE MODEL

The impact of different measures is thought to have influence on in macro-economic activities and the demand for energy basically through the market mechanism (the price effect resulting from an energy price rise among others). The effect of the energy price increase on energy consumption and CO2 reduction can be summarized as follows (Ito (1990)):

- Energy price increase
  - Energy conservation resulting from price increase
  - Accelerated advances of energy-saving technology
  - Expansion of energy-saving equipment investment
  - Inter-fuel substitution
  - Reduction of energy consumption
  - Market penetration of new energy
- Transformation in economic and industrial structure
- Changes in living pattern

Considered here as likely impact of the reduction of CO2 emissions are energy price increases, energy-saving equipment investments, introduction of new energy sources, adjustment of the industrial structure.

(1) Fossil Fuel Taxation (Impact to Raise energy Price)

A major problem confronting energy conservation is economic efficiency (cost). Very often a given proposal is rejected on the grounds of cost efficiency, although it is technologically feasible. The incentive for energy conservation is not strong when energy prices are low as they are today but it is desirable that energy prices are kept at somewhat higher levels in terms of the protecting limited resources and environmental preservation. The environmental cost is an exogenous non-economic effect. One way to promote the conservation of resources, help save energy, and encourage the introduction of new energy sources is to levy a tax on fossil fuels to share the environment cost, and earmark the revenues collected for various measures.

Tax revenues can be put to the following two uses:

1) Global funds: assistance to the developing countries in economic development, energy-saving equipment and technology, and the development of clean energy. In this case, the assistance amounts to the overseas transfer of income for Japan's macro-economy, and accordingly causes a slight decrease in its national income.

2) Funding of a variety of domestic programs including energy conservation and technology. The worldwide availability of these technologies will prove beneficial.

(2) Promotion of Investment in Energy-Saving Equipment

Investment in energy conservation equipment has a two-fold impact in macro-economic terms. One is a reduction of fossil fuel consumption and a cutback in energy costs as a result of energy conservation. The other is a shrinkage of the potential economic growth capacity, when investment to augment production capacity is diverted for energy conservation, as investment in energy conservation equipment does not lead to the expansion of production capacity.

(3) Concept of Introducing New Energy

The fuel cost of a new energy source might be zero or low as compared with existing ones, but its capital cost is high enough to impede its introduction. This capital cost can be expected to fall as a result of the effect of mass-production, as with other products. The extent of such a decrease is believed to follow the learning curve governed by cumulative output (The Energy Data and Modeling Center (1988) and Tsuchiya *et al* (1989)). In the meantime, the market penetration of new energy sources can very often be explained by a logistic curve, which seems to apply to the introduction of a new energy technology. The scenario showing the introduction of a new energy source is illustrated by both the learning curve and the logistic curve. In this scenario the rising prices for the traditional energy sources accelerate the introduction of new energy. It is assumed that the new source, however, has a low energy density and is dependent of the natural conditions and the location and that introduction of a new energy will be limited to specified areas.

Figure 1 shows the basic structure of a model that analyzes the effects of restrictions on CO2 emissions on the macro-economy. The dotted line-surrounded part is a general macro-economic model of the effective demand deciding type (Keynesian) (Murota *et al* (1991)). With production functions, an energy model as shown by Box 1, the model makes it possible to assess the effects on the macro-economy of a CO2 reduction (The size of the model is 152 formulas and the macro-economic sector 87 formulas, while the energy sector is 65 formulas.)

2. SIMULATION OF A REDUCTION OF CO2 EMISSIONS

Let us make a simulation for the period up to 2010 using the above model and look at the way the reduction in CO2 emissions affects the macro-economy and the demand-supply structure of energy. The following four scenarios are considered.

(1) Base Scenario

This scenario is devised to serve as the base for a comparison and does not incorporate any special CO2 controls. Its main premise is that oil prices will remain at 30 dollars per barrel (real 1991 price) and rise to 40 dollars in 2010, with LNG prices linked to the oil prices, while coal prices will grow at a slightly lower rate. The exchange rate is assumed to be 110 yen to the dollar in 2000 and 100 yen in 2010, with a tight money policy kept in place, as public investments will steadily increase as part of the program of domestic demand expansion.

(2) Fossil Fuel Taxation Scenario (Case 1 and Case 2)

Taxation is assumed to be applied, according to CO2 emissions by calorie. Two tax rates are assumed for the primary energy sources:

Case 1: 50% for coal, 40% for oil, 30% for LNG

Case 2: 100% for coal, 80% for oil, 60% for LNG

In the above two cases, carbon tax revenues are assumed to be earmarked for domestic purposes. The quantity of new energy introduced is the same as in the base scenario.

(3) Scenario for energy-saving Equipment Investment, encouraging the Use of New Energy and overseas Assistance (Case 3)

This scenario envisages the implementation of policies relating to earth environmental issues, such as energy conservation, new energy, and overseas assistance (overseas transfer of income), and is predicated based on the following assumptions:

- Besides the premise for case 1 (50% taxation), about two percent of private-sector equipment investment (annually some two trillion yen) goes to energy conservation equipment (industrial sectors). However, funds for energy-saving equipment are assumed not to meet additional demand, but they are to be diverted from the budget for increased production. In other words, energy conservation equipment spending is not viewed as generating additional effective demand. The goals for public welfare life and transport systems are to produce more efficient appliances for people's lives and improve the fuel efficiency of cars. Energy conservation is estimated to proceed at a yearly rate of 0.5% for public welfare and transport systems as against the base scenario (the figures deemed attainable in view of present-day technology).
- Half of the carbon tax revenues will be put aside for overseas assistance funds (overseas transfer of income).
- The supply of new energy is projected to grow by about 10 million KL in terms of oil in 2010 against the base scenario,
- In addition to the above premises, it is assumed that the economy will significantly cut back its energy consumption (with part of the heavy industry transferred to developing countries and import substitution underway (Murota (1983)). This will lead to reduced energy demand in the developed countries and go a long way toward supporting the economic growth of developing countries. The assumption here is the transfer from the developed to developing countries in 2010 of 10 million tons of steel, 8 million tons of cement, 500,000 tons of paper pulp and 800,000 tons of ethylene (decreases in exports or replacement with imports). The figures represent the transfer of about 10% of output in 2010. Industry transfer will not do anything to reduce CO2 emissions worldwide, but will do a great deal to rectify the income gap between North and South.

3. RESULTS OF SIMULATIONS AND THEIR IMPLICATIONS

Tabulated on Table 1 are the results of simulations.

<Base Scenario>

The base scenario projects an annual economic growth rate of 3.3% until 2010, while the demand for primary energy will grow at a yearly rate of 1.8% and will total 650 million tons of oil in 2010 in terms of calorific value (GNP elastic modules of 0.54). CO2 emissions will amount to 370 million tons (in terms of carbon) in 2000 and rise to 420 million tons in 2010, up 19% and 36% respectively from 1990.

<Case 1 and Case 2 >

Next, turning to taxation, in Case 1 with 50% taxation, the economy will register an annual growth rate of 3.6% until 2010, down 0.2 points from the base scenario. With a 10% taxation (Case 2), the economic growth rate will fall to 3.4%, down 0.4 points from the base scenario. Whether these figures are high or not is a matter on which opinions may differ. If the figures represent a two-year lag in attaining the desired level of GNP (namely, approximately the same level as in 2008 in the base scenario), the cost to be borne for protecting the global environment will not be so high. CO2 emissions for 2010 will be put at 380 million tons in Case 1, a decease of about 13% from the base scenario, while Case 2 projects 360 million tons of emissions, a fall of about 15% from the base scenario.

<Case 3>

In the case of a scenario that promotes energy, conservation and the introduction

of new energy sources reduces the industry's excessive dependence on energy and diverts one half of carbon tax revenues for overseas assistance (Case 3), CO2 emissions for 2010 will remain at 306 million tons, virtually at the 1990 level, while GNP will be almost the same as in Case 1. To view decreases in CO2 emissions and GNP as the total cost of environmental protection, the cost of reducing CO2 emissions will be 220,000 yen per ton. Carbon tax revenues will run to 3,900 billion yen in 3000 and 5,600 billion yen in 2010, an amount sufficient to finance CO2 emission reduction and overseas aid (one half of tax revenues will be earmarked). I terms of total tax revenues including general tax revenues, Case 3 will see a slight decrease from the base scenario. In other words, an increase in carbon tax revenues will be offset by a decrease in general tax revenues, and so it will be more important to efficiently use tax revenues including general taxes.

The supply of new energy will grow by about 10 million KL in terms of oil in 2010 as against the base scenario. The supply after 2020 will increase by 40 million KL at an accelerating rate. In short, 2010 can be viewed as the initial stage for the full-scale adoption of new energy. It will take a long time to introduce new energy, which will prove to be a very important long-term energy source. In this sense it is desirable to undertake aggressive technological development and encourage the adoption of new energy as soon as possible.

The above consideration leads to the following conclusion:

The key to the successful restriction of CO2 emissions with growth maintained lies in the promotion of energy conservation and an expansion of the use of renewable energy sources. To encourage these using market forces, it is necessary to get existing energy sources to take over their due share of the external economy cost (environmental cost). CO2 taxation is one means, but the question is how to use it effectively.

Per capita GNP consumption of energy for developing countries is twice the figure for the advanced countries (1980), that is, a very low efficient use of energy. True, developing countries cannot but expand demand for energy if they are to develop their economies, but if they positively introduce technologies from the developed countries, they can afford to slow down the tempo of energy demand expansion while attaining the desired level of economic growth. The developing countries exploit energy poorly partly because of their low economic levels. To break the cycle of poverty -> population increase -> environmental destruction, it is essential to help the developing countries achieve economic growth. The biggest challenge in solving those problems is raising of the needed funds, for which assistance from the developed countries is of extreme importance in terms of technology and capital. The international adjustment of the industrial structure (industry transfer) will become increasingly important.

This model analysis has focused on a CO2 tax as one example of how developed countries can raise assistance funds while implementing their own domestic energy conservation. As far as the macro-economic effects are concerned, the model shows that it is quite possible at a lower cost for this country to reduce CO2 emissions and provide assistance to developing countries if an appropriate policy is implemented while using market forces. Development of the exhaustible resources might contribute only for a limited period, but energy conservation technology and the technology of tapping renewable energy sources will remain as lasting sources. Assuming economics is "one branch of science that deals with the optimum distribution of resources, that is, seeks a solution that will produce affluence with all the limited resources and constraints," energy economics is one of its applied divisions. The optimum distribution of resources is making it increasingly necessary to consider factors not within one country but a global scale and from a supra-generation viewpoint. In one way the issue provides a golden opportunity for developing countries and the rest of the world to remedy the income gap.

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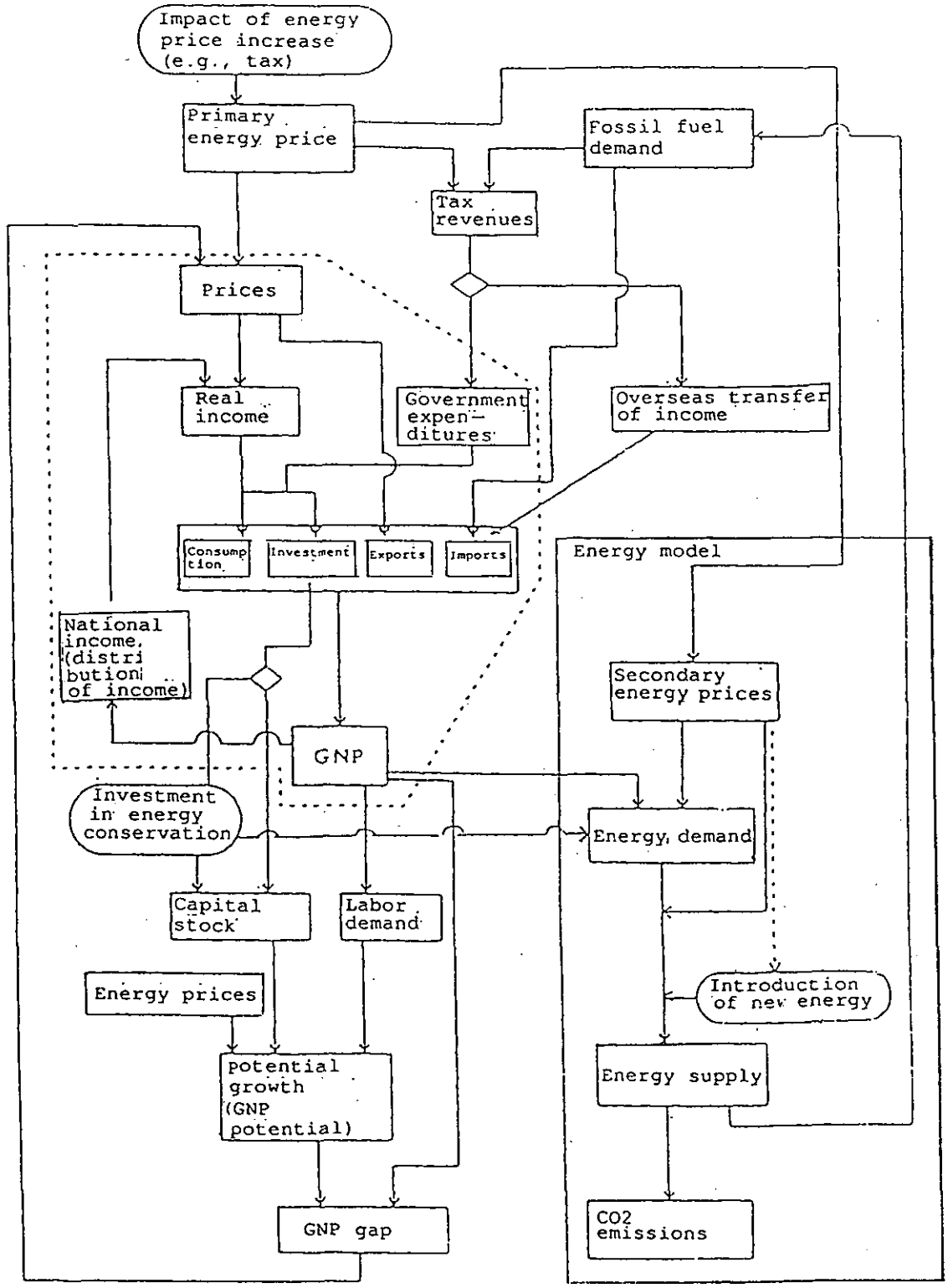

Figure 1 Outline of Model

Box 1 Base Formula Attached to Macroeconomic Model

Energy price

PEj = PEMj* (1+RTAXj)

PEMj: Import prices for primary energy

RTAXj: CO2 control tax revenues

(j: Oil, coal, gas)

RE = f (weighted average price of PEJ)

Potential GNP

GNP* = f (L, K*, PE) K* = K-KENE

L = labor, K: total capital stock

KENE: energy conservation capital stock

As the rate of energy conservation capital stock to total capital stock grows, the supply capacity shrinks. Define the demand-supply gap as GAP-GNP/GNP* from actual GNP and potential GNP*, and the widening of this gap will raise prices and lower real income.

P = f(W, PE, GAP)

P: prices, W: wages, GAP: GNP gap

Energy Demand

E = f (GNP, PE, KENE)

Incorporate energy conservation equipment stock in the traditional demand functions derived from income and price effects. With KENE not taken into account, the resulting effect will find its way in price effects (PE coefficient). However, the effect is separated here. Distribution by Energy Source

Ej = Sj·E (E=>Eji)

Su = f (PEi, PEj) .. relative price

CO2 = SRj·Ej

Sj: share by energy source CO2: CO2 emissions

Ri: original emission unit

Inter-energy competition can be expressed as functions based on relative prices between fuels, shown above. However, the above formula does not apply to materials for steel, petrochemicals, and car oil, which do to compete with other types of fuels or are not to be substituted by them.

Table 1 Comparison of Results of Simulations

		Base Case	Case 1 50% taxation	Case 2 100% taxation	Case 3 50%taxation promoted case
Real economic growth rate					
2000/1990		3.8%	3.6%	3.4%	3.6%
2010/2000		2.8%	2.7%	2.7%	2.7%
Average	2010/1990	3.3%	3.1%	3.0%	3.1%
Supply of primary energy (MTOE)					
	1990	486	486	486	486
	2000	596	573	556	521
	2010	593	647	620	568
2000/1990		2.1%	1.7%	1.3%	0.7%
2010/2000		1.5%	1.2%	1.1%	0.9%
Average	2010/1990	1.8%	1.4%	1.2%	0.8%
Ultimate energy demand					
2000/1990		1.8%	1.4%	1.0%	0.3%
2010/2000		1.1%	0.8%	0.7%	0.4%
Average	2010/1990	1.4%	1.1%	0.8%	0.3%
Energy/GNP elasticity modules					
2000/1990		0.54	0.47	0.40	0.20
Average	2010/2000	0.54	0.44	0.41	0.31
CO2 emissions (million ton)					
	1990	308	308	308	308
	2000	367	348	333	303
	2010	420	379	357	306
Index 90=100					
	2000	119	113	108	98
	2010	136	123	116	99
Energy/GNPVariation rate					
2000/1990		-1.7%	-1.8%	-2.0%	-2.8%
2010/2000		-1.3%	-1.5%	-15.0%	-1.8%
CO2/energy Variation rate					
2000/1990		-0.3%	-0.4%	-0.5%	-0.9%
2010/2000		-0.2%	-0.3%	-0.4%	-0.8%
Ultimate energy price					
2000/1990		3.9%	5.3%	6.3%	5.3%
2010/2000		3.3%	3.3%	3.3%	3.4%
Average	2010/1990	3.6%	4.3%	4.8%	4.4%
Wholesale price index					
2000/1990		0.5%	1.0%	1.4%	1.1%
2010/2000		0.4%	0.5%	0.6%	0.5%
Average	2010/1990	0.5%	0.8%	1.0%	0.8%
Total tax revenues (nominal, trillion yen)					
	2000	168.1	165.9	166.1	163.2
	2010	248.3	243.4	240.6	240.6
Carbon tax revenues (nominal, trillion yen)					
	2000	0.0	4.4	8.6	3.9
	2010	0.0	5,8	13.0	5.6
Cost of reduction (1,000 yen per ton)Period average					
			584	597	222

Note: GNP decrease/CO2 emission reduction