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Global Warming Policy and Distributional Effects: A General Equilibrium Analysis[1]

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Abstract

This paper analyzes the impact of carbon taxes on the Japanese economy using an applied/computable general equilibrium model. This analysis sheds light on both the efficiency and the equity issues of these policies. The study shows that some alleviation measures, *e.g.* tax differentiation, might be required to ease the damages caused to energy intensive industries. Moreover, considering the regressivity of the carbon taxes, the tax revenues should be recycled at least to neutralize the adverse distributional effects of these taxes. This paper also analyzes carbon taxes not only as the instruments to internalize externalities, but as those to promote equitable distribution. This analysis reflects the present concerns of Japan. We should consider global warming policies from a broader perspective - as a good opportunity to restructure the Japanese economy and society.

JEL classification numbers: D58, D63, H20, Q40

Key Words: carbon taxes, general equilibrium model, tax differentiation, tax recycling, inequality

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1. Introduction

In December 1997, Japan signed the Kyoto Protocol, committing to a 6% reduction of greenhouse gases (GHGs) from the 1990 emission level in the first commitment period (between 2008 and 2012). The Japanese government ratified the protocol last year. The Kyoto Protocol, despite the U.S. withdrawal and the non-binding targets for developing countries, will pave the way for the long-term commitment to the stabilization of GHGs concentration in the atmosphere. As a matter of fact, countries will discuss the next political issues, including the second period of emission cuts under the protocol; the role of the developing countries; and the prospect of the U.S. return to the negotiations, over the next few years. The long-term aim of the protocol is to curb the artificial warming of the Earth's climate and its possible adverse effects: rising sea levels; melting glaciers; changing rainfall patterns; increasing floods; and more frequent droughts (Houghton et al (2001), McCarthy et al (2001), and Ministry of the Environment (2001a)).

Japan will have to make significant cuts in emissions to reach the reduction target. According to the Ministry of the Environment, the GHGs emissions of Japan increased by 6.8 % to 1,307 million ton (CO_2 equivalent) in 1999 fiscal year from the level in 1990. Therefore, Japan has to cut down about 12.8% from the 1999 level to meet the Kyoto agreement. The Ministry of the Environment (2001b) reported that Japan cannot meet the reduction target without additional policies. Japan, possibly, might manage to achieve the target of the first period without significant domestic emission cuts, by using the so-called Kyoto mechanism. This involves Joint Implementation(JI), Clean Development Mechanism(CDM), Emission Trading(ET) and obtaining credits by properly managing forests and farmlands that absorb carbon dioxide, known as carbon sinks. Nevertheless, Japan must meet much harder targets after the second period (after 2012) under the protocol. Therefore, we must consider more effective policies to cut domestic emissions on a long-term basis.

Reflecting this situation, the Japanese government has started to consider the possibility of introducing carbon taxes. Carbon taxes became more acceptable to Japanese people after COP3 in Kyoto. According to the questionnaire for households carried out by the Environment Agency in 1999 (Survey on Environment Monitor Questionnaire), about 70% of people approve of an introduction of carbon taxes, and the share of approval sharply increased from 45% in 1995. The questionnaire for companies by the Environment Agency (Survey on Environment Friendly Corporate Activities) shows that the number of companies approving of carbon taxes is increasing, although it varies between industries.

Carbon taxes are measures that reduce CO_2 emissions efficiently through price mechanism. However, it is necessary to consider not only economic efficiency, but also distributional issues for equity and political feasibility. Any environmental policies whose prime goals are efficiency have distributional effects and second-best policy analyses cannot be distribution free (Blackorby(1990)). Carbon taxes seriously damage energy-intensive industries; hence, supplementary measures such as tax differentiation will be required for some time to alleviate the pain of structural change. These alleviation measures might also be justified on the basis of political feasibility and equity (Environment Agency (2000)). In addition, burdens of carbon taxes on households are regressive. The net effects of these taxes depend on how tax revenues are recycled or how the revenues are utilized. Most Japanese people, whether they support carbon taxes or not, take great interests in such regressivity (*e.g.*, Environment Agency (2000)). Therefore, the carbon tax revenues should be recycled at least to neutralize adverse distributional effects of these taxes.

Furthermore, carbon taxes should be considered from a broader viewpoint. These taxes are usually understood as incentive taxes for curtailment of CO_2 emissions. Besides that, carbon taxes have another significant role – they can provide a rich source of government revenue.

In Japan, many studies show that the income distribution has become more unequal since the 1980s (*e.g.*, Terasaki and Mizoguchi(1997)) and that the expenditure for social security needs to increase at an incredible pace in the near future because of rapid population aging (*e.g.*, Ministry of Health and Welfare(2000)). Nevertheless, the Japanese government owes a huge debt (about 700 trillion yen), so cannot afford to increase welfare spending. Reflecting on this situation, it would seem practical to use carbon tax revenues for welfare spending. With regard to welfare spending, many studies argue about the limitation of the welfare state, especially in Europe (*e.g.*, Atkinson(1995)); nevertheless, Japan is not in this case, since it is definitely not a welfare state compared with the other developed countries, especially in Europe (*e.g.,*Tachibanaki(1996,2000)). In Japan, the government's role in the public welfare has not been crucial, and groups like families and enterprises have played a prominent role. However, the role of such groups is decreasing. Therefore, from now on, the government will have to be more responsible for the public welfare.

Given the nature of the global warming problem, appropriate policies must not only achieve numerical targets, but also build a sustainable society based on people's value (Metz et al (2001)). For realizing our value, we burden ourselves with "rules" like carbon taxes. Hence, carbon taxes should be considered in the broader context, not only in the context of "Pigouvian tax" or "internalization of externalities." This broader perspective would come to the fore to combat the problems with which Japan would be confronted in the near future.

The purpose of this study is to investigate the economic impact of carbon taxes, distribution of burdens, and equity considerations for the Japanese economy. This study uses a general equilibrium model (GEM). Although there are several studies on impacts of carbon taxes on the Japanese economy, only a few studies use GEMs (Environment Agency (2000)). In particular, there are almost no studies that research distributional impacts of carbon taxes; yet GEMs are useful in analyzing these issues.

The Next Section describes the structure of the model used in this study. Section 3 evaluates the impact of carbon taxes in Japan, and Section 4 discusses sectoral impacts and burden distribution. Section 5 discusses distributional effects on households and appropriate policies from the viewpoint of economic efficiency and equity. The final Section summarizes the main conclusions.

2. Model Structure

Many studies point out that economic impacts cannot be evaluated correctly without GEMs (*e.g.*, Hazilla and Kopp (1990), OECD (1995), Pearce (1999));

nevertheless, there are few studies analyzing impacts of carbon taxes by using GEMs in Japan. Carbon taxes change relative prices, and economic agents would adapt themselves to such circumstances based on their own preferences. The purpose of carbon taxes is to promote such structural changes. If we disregard such adaptation and structural changes, we cannot evaluate the impact correctly.

That is why this study uses an applied/computable general equilibrium (AGE/CGE) model[3]. The model used here is a multi-sector recursive-dynamic applied general equilibrium model named ODIN (Okushima(1999b, 2000a, 2000b))[4]. This model is structured based on Harberger-Scarf-Shoven-Whalley (Shoven and Whalley(1992)), GREEN (Burniaux et al(1992)), EPPA (Yang et al(1996)), and de Melo and Tarr(1992) model. The model structure is as follows (Figure 2.1[5], Table 2.1 and for more details, see Okushima (1999b)). This model is composed of industrial sectors, energy sectors, household sectors, a government sector, an investment sector and foreign sectors. The input-output structure of this model is based on 1995 Input-Output Tables and Energy Balance Tables of Japan. Energy sectors are disaggregated in details in order to distinguish energy goods by carbon intensity. Such disaggregation is important in

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[3] About AGE/CGE models, for example, see Shoven and Whalley (1992), Dixon and Parmenter (1996).
[4] GAMS/CONOPT2 and MINOS5 are used to make calculations for this study.
[5] This model adopts capital-energy separation types (((K,E), L),M) as a model structure although many AGE models adopt value–added types (for example, ((K,L), E,M)). This is because the weak separability of capital-energy is statistically supported in Japan (See, Tokutsu (1994)).

analyzing the impact of carbon taxes. Households are classified into 5 groups according to their income, in order to analyze the distributional effect of carbon taxes. The CES expenditure function is specified for each household group. Each group has its own preference and is endowed with its own capital and labor to finance the purchase of goods and services, savings, or taxes. A transformation matrix is used to translate household demand for consumption goods and services into corresponding demand for production goods and services. Expenditures of the government sector and the investment sector are modeled with fixed coefficient matrices. The government sector collects taxes to redistribute as well as to purchase goods and services for its own purpose. The investment sector collects savings from the households, the government, and the foreign sectors to purchase goods and services for investments.

In spite of the importance of elasticity parameters in AGE Analysis, there are few estimations of elasticities, as many studies indicate (*e.g.*, Shoven and Whalley (1992), OECD (1998)). Therefore, most studies are compelled to "guesstimate" these parameters, although reliability of these kinds of simulation depends on the empirical soundness of the underlying parameters. In this study, the elasticity parameters are based on such reliable literature as Okushima and Goto (2001), Okushima (1999a), and Tokutsu (1994) that estimate the parameters econometrically from Japanese data using the multi-stage Translog or CES functions.

Figure 2.1 Model Structure

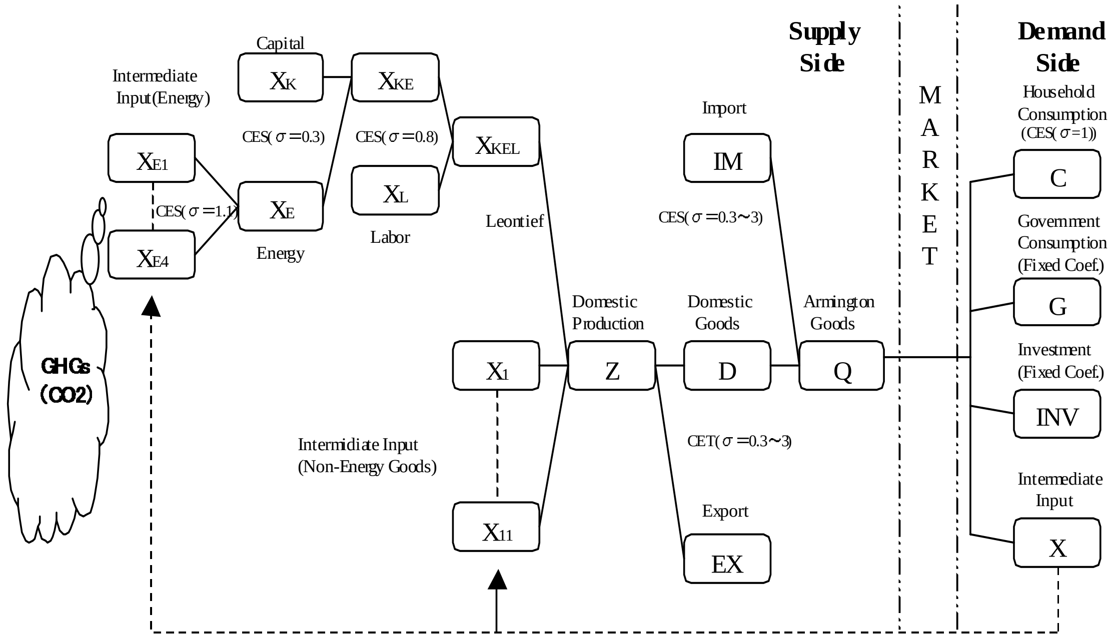


Table 2.1 Industrial Sector, Energy, and Household Group

Industrial Sector

1	Agriculture and Mining (AGM)
2	Food (FOD)
3	Textile (TEX)
4	Paper and Pulp (PAP)
5	Chemical (CHM)
6	Ceramic, Stone and Clay (CSC)
7	Iron and Steel (IAS)
8	Non-ferrous Metal (NFM)
9	Machinery (MAC)
10	Other Manufacturing (OMF)
11	Services and Others (SER)

Energy

E1	Coal (COL)
E2	Oil (OIL)
E3	Electricity (ELC)
E4	Gas (GAS)

Household Group

Yearly Income Quintile Groups (Ten thousand Yen)

I	～482
II	483～625
III	626～781
IV	782～1000
V	1001～

The model's parameters are calibrated to the 1995 base year SAM (Social Account Matrix). The sources to make the 1995 SAM of Japan are mainly 1995 Input-Output Tables, Family Income and Expenditure Survey, Family Saving Survey, Labor Force Survey (Management and Coordination Agency), National Accounts (Economic Planning Agency), Energy Balance Table (Agency of Natural Resources and Energy), National Tax Administration Statistics Report (National Tax Administration), and 1995 Basic Survey on Wage Structure (Ministry of Labor). The RAS method was used for adjustments (See, for example, Bacharach (1971)).

3. Impacts of Carbon Taxes on Japanese Economy[6]

According to the Kyoto Protocol, Japan must cut down CO_2 emissions to 94% of the 1990 level between 2008 and 2012. As already seen, it is not easy to achieve the target without effective measures. Carbon taxes would make it possible to attain the reduction target.

How would carbon taxes affect the Japanese economy? These taxes raise energy prices based on their carbon contents; therefore, in line with the increase of energy prices, the relative prices also change. Corresponding to such price changes, economic agents, such as producers and consumers, change their behavior based on their own preferences. Additionally, tax revenue recycling affects the economy, especially the

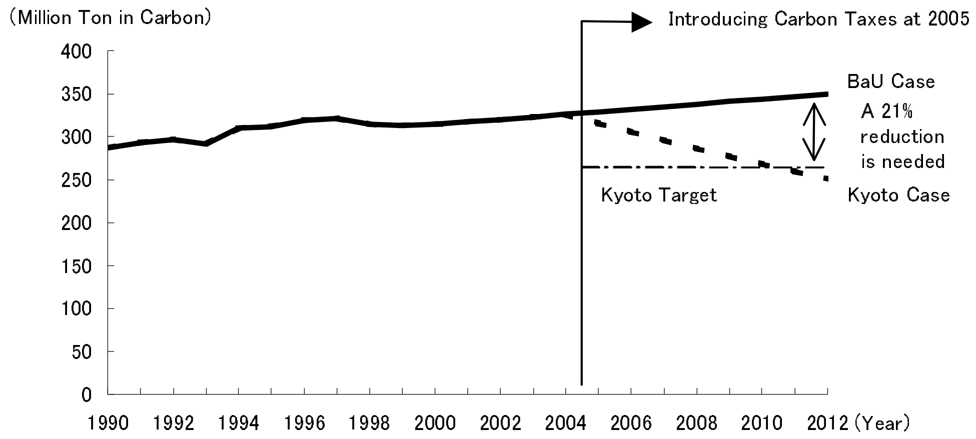
[6] In Japan, CO_2 emissions contribute more than 90% of GHGs emissions, and more than 85% of the CO_2 emissions derive from energy consumption. Therefore, this study focuses on CO_2 emissions from energy consumption. And an adoption of carbon taxes independently in Japan is controversial because it has a negative influence on Japanese international competitiveness. However, this problem is still open to question (See, Jaffe et al (1995), Hoel(2001), Metz et al (2001)). Even if such a negative influence exists, it will be possible to cope with it by alleviation measures such as cutting down tax rates of trade sectors, which are actually carried out in North Europe inducing carbon taxes already.

income distribution of households. GEMs are required to evaluate such effects correctly. Nevertheless, in Japan there are relatively few studies that analyze these issues by GEMs.

This study analyzes how carbon taxes affect on the Japanese economy by using the model. If there is not a notation, carbon tax revenues are assumed to be recycled equally to households by means of income tax reduction, and the government expenditure is fixed to BaU (Business as Usual) Case, i.e. the baseline case. In the BaU Case, the real GDP is simulated to grow by an average of 1.3% per year between 1995 and 2000, and by 2.0% between 2001 and 2012.

Figure 3.1 shows the transition path and the curtailment schedule of CO_2 emissions. In the BaU Case (solid line in the Figure) emission control is not carried out. In the Kyoto Case (dotted line in the Figure) carbon taxes are introduced for meeting the Kyoto agreement after 2005. Several schedules of emission reduction would be possible to attain the target, and the difference between them would affect capital accumulation, for example. This study adopts the schedule of reducing CO_2 emissions by the fixed rate. In order to achieve the target, we must cut down CO_2 emissions by about 21% from the BaU Case around 2010.

Figure 3.1 CO_2 Emissions



(Note) The Figures till 1994 are based on Handbook of Energy & Economic Statistics in Japan (Energy Data and Modelling Center). They are estimated by the model after 1995, reflecting the actual data between 1995 and 2000.

According to the simulation, it is necessary to adopt carbon taxes equivalent to about 18000 yen per ton carbon in 2010 in order to meet the Kyoto target[7]. Table 3.1 shows marginal abatement costs (equivalent to carbon tax rates) in various studies for reaching the Kyoto agreement. The results of Table 3.1 show that the carbon tax rates for attaining the target will be between 77 and 751 dollars in Japan. While there are limitations in comparing various studies, the estimation of this study (192 dollars) is in the middle among the studies.

[7] Japan, surely, needs not attain the Kyoto targets only by carbon taxes, using Kyoto mechanisms (Joint Implementation, Clean Development Mechanism and Emissions Trading) and carbon sinks. However, changes of targets to be reduced by carbon taxes do not affect our implications and conclusions.

Table 3.1 Comparison of Marginal Abatement Costs (Carbon Tax Rates) to Reach the Kyoto Agreement in Japan (2010)

Model	Marginal Abatement Cost (1995US$/tC)	Emission Reduction Rate from BaU (%)
The Model	192	21
G-Cubed	252	29
POLES	240	26
GTEM	751	22
World Scan	87	20
GREEN	77	24
AIM	253	22

Source: OECD (1998)

Note: It should be noted that results of simulations depend on model structures, base scenarios, curtailment schedules and so on (Weyant (1993), Weyant and Hill(1999)), OECD (1998)). Hence, there are limitations in comparing results.

The macro-economic cost for meeting the Kyoto agreement is not high, about 0.1% of the real GDP in 2010 (compared with the BaU Case) in this model. According to OECD (1998), most studies also show that the cost of attaining the target is less than 1% of the real GDP, compared with their baseline scenarios. These results support the efficiency of carbon taxes.

4. Sectoral Impacts and Tax Differentiation

Table 4.1 shows the impact of carbon taxes on each industry by comparing production in the Kyoto and Alleviation cases with BaU. A significant finding in this simulation is that there are large differences in the damages between industries. According to the Kyoto Case (left) in Table 4.1, Energy-Intensive Industries (Paper and

Pulp, Chemical, Ceramics, Stone and Clay, Iron and Steel, and Non-ferrous Metal) are damaged more seriously than other industries. On the other hand, especially in Food, the damages are small.

Table 4.1 Sectoral Impacts (Ratio of production to BaU in 2010, %)

	Kyoto Case	Alleviation Case
Agriculture and Mining	-0.16	-0.19
Food	0.00	-0.02
Textile	-0.26	-0.27
Paper and Pulp	-0.47	-0.42
Chemical	-1.29	-0.93
Ceramic, Stone and Clay	-0.76	-0.69
Iron and Steel	-1.86	-1.42
Non-ferrous Metal	-0.88	-0.84
Machinery	-0.42	-0.39
Other Manufacturing	-0.44	-0.41
Services and Others	-0.23	-0.25
Marginal Abatement Cost (yen)	18000	27000

Next, in the Alleviation Case, the carbon tax rate is half exempted for the five energy-intensive industries to alleviate their damages. Undoubtedly, this weakens the efficiency advantage of carbon taxes. It is based on the "Polluter Pays Principle (PPP)," which accords with the purpose of carbon taxes to promote structural changes of declining carbon intensity of economies. However, many hardships, such as unemployment, would result from this policy. In other words, factor movement is not smooth in the real world, and takes much time and costs for the adjustment. We have to give serious attention to these problems when considering actual policies. From this viewpoint, it is necessary to at least combine alleviation measures for some time with carbon taxes. Implementation of these measures does not mean hindrance to structural changes. There is, however, no great difference between the alleviation and the Kyoto (non-alleviation) case, since both would result in a substantial decline of carbon intensive industries. The difference is whether to achieve these structural changes as rapidly as possible without regard to disruption, or try to achieve them more slowly with regard for people's way of life. These alleviation measures might also be justified for the reason of political feasibility and equity (Environment Agency (2000))[8][9]. European countries, already introducing carbon taxes, adopted alleviation measures for those industries from such viewpoint as equity and international competitiveness.

The Alleviation Case (right) in Table 4.1 shows the following implications. First, in line with adopting alleviation measures, the marginal abatement cost (the carbon tax rate) increases. Given the reduction targets, half-exemptions for those industries with high carbon intensity would increase the burden on other industries. This means that tax differentiation has an adverse effect and there is a trade-off between efficiency and equitable burden distribution. Second, the burden is equalized to some extent by tax differentiation, but the extent of burden equalization is not so great. Alleviation measures raise the carbon tax rate. This damages other industries and households, which consequently cause a decrease in their demand for energy-intensive industries. Therefore, the extent of burden equalization is limited even if alleviation measures are reinforced. These measures can delay the pace of structural changes just a little.

[8] Smith(1789) considered similar problems on the restoration of free trade and said, "(The equitable regard) requires that changes of this kind should never be introduced suddenly, but slowly, gradually, and after a very long warning (IV. ii .44) ". Even so, these alleviation measures should not become protectionist policies for stagnant industries.

[9] On the other hand, Hoel (1996) discusses the conditions on which sectoral differentiation of carbon tax rates would be efficient.

Although the production of energy-intensive industries does not account for much share of the real GDP in Japan, the hardships from weeding out those industries, such as the increase of unemployment, may cause serious social problems. Hence, in addition to the alleviation measures discussed in this section, direct support measures, such as job training programs to give workers new skills, might be needed to promote job-changes more smoothly.

5. Distributional Effects and Equity

This Section investigates the distributive perspectives of carbon taxes. It is considered that carbon taxes are regressive since low-income groups spend a larger fraction of their disposable income on energy goods than middle- or high-income groups (*e.g.*, Poterba(1991), OECD(1995), Cornwall and Creedy(1996)). Although the issue of regressivity is a crucial point in the arguments about introducing carbon taxes in Japan, only a few studies have so far been made of it (Environment Agency (2000)). In a second-best world, we cannot divorce efficiency from equity as we might do when assuming a first-best world (Blackorby(1990)).

In studies about these issues, the evaluation of distributional impact is often carried out in a partial equilibrium framework. However, such evaluations may not be correct unless general equilibrium effects (indirect effects) are taken into account, since these taxes change relative prices and lead to substitution effects of economic agents (See, Poterba(1991), OECD (1995)). In addition, in many studies income data is used as a welfare (well-being) index generally due to data availability. However, it is more suitable for welfare analyses to use consumption than income (See, Poterba(1991), Slesnick (1994,1998), Jorgenson (1998)). Consumption expresses households' preference and substitution effects more correctly than income. Moreover, consumption is more consistent with permanent income hypothesis (Friedman (1957)). Generally, distribution of consumption is flatter than distribution of income and inequality of consumption is much less than inequality of income.

For the reasons mentioned above, this study investigates distributional impacts on households based on consumption changes using the GEM. Table 5.1 shows the impact of carbon taxes on each household group. Household sectors are divided into five groups based on income.

Table 5.1 Consumption Changes in Various Revenue Recycling Schemes (Compared with BaU in 2010, %)

Household Group	No Recycling Case	Fixed Amount Recycling Case	Pro-equality Recycling Case
I	−0.85	0.20	0.73
II	−0.78	0.03	0.14
III	−0.76	−0.09	−0.10
IV	−0.75	−0.16	−0.29
V	−0.78	−0.32	−0.54
Total Consumption	−0.78	−0.11	−0.12
Real GDP	−0.11	−0.10	−0.11

In the No Recycling Case, all tax revenues are used for government expenditure. In this case, total consumption decreases more than in other cases because carbon tax revenues are not returned to households at all. The real GDP of this case does not differ with other cases. The No Recycling Case is the reference case to illustrate the pure effects of carbon taxes on the household distribution of consumption, excluding the influence of revenue recycling.

The No Recycling Case shows that carbon taxes are mildly regressive. Unexpectedly, the consumption of the V class, the class of the highest income, also decreases significantly. The reason is as follows - carbon taxes give serious damages to the energy-intensive industries, which are capital-intensive, and the damages to these industries lead to decline in the demand for capital. The share of capital income is larger in the higher classes than in the lower classes. Therefore, the fall of capital price caused by carbon taxes eases the regressivity. However, even if both effects are taken into account, it turns out that carbon taxes are still regressive.

From the viewpoint of equity and political feasibility, it is necessary to return tax revenues to neutralize the regressivity. The Fixed Amount Recycling Case fulfills such conditions. In this case, the carbon tax revenues are returned equally to households by means of income tax reduction. Since the amount of income and consumption becomes larger with the higher classes, the fixed amount recycling contributes to progressivity. Such effects are shown in Table 5.1. From the viewpoint of equity, the Fixed Amount Recycling Case is more politically feasible than the No Recycling Case.

The last case, the Pro-equality Recycling Case, is when the tax revenues are returned to households inversely proportionate to the ratio of each household group's consumption to the total consumption. This case aims to promote equitable distribution.

This case reflects the following issues - many studies show that, since the 1980s, income distribution has been getting more unequal in Japan (See Terasaki and Mizoguchi(1997), Otake and Saito(1999), and Funaoka(2001)). This is mainly because of rapid population aging. In addtion, the income inequality within each cohort is also getting worse. Moreover, the expenditure for social security is expected to surge in the near future. It is forecasted that the ratio of the working generation (the age between 20-64) to the old generation (the age of more than 65) will be 2 to 1 in 2025, compared with 4 to 1 in 2000. The social security spending for the old generation will soar to more than 100 trillion yen in 2025, compared with 27 trillion in 2000 (Ministry of Health and Welfare (2000)). Because the Japanese government holds a huge debt (about 700 trillion yen), it cannot afford to increase welfare spending so much. Therefore, the carbon tax revenues would be one of the available resources for welfare spending. Although many studies argue about the limitation of a welfare state, especially in Europe (*e.g.*, Atkinson(1995)), Japan is not a welfare state compared with the other developed nations(*e.g.*, Tachibanaki (1996, 2000)). In Japan, the role of groups such as families and enterprises in the public welfare has been important until now. However the role of such groups is decreasing. From now on, the government should be more responsible for the public welfare in Japan.

Carbon taxes could be a rich source of revenues. For example, according to the simulation, they will be no less than five trillion yen (2012), which is about 1% of GDP in Japan. If carbon taxes are introduced as national taxes, they will occupy about 10% of the whole national tax revenues.

The way to use such tax revenues will significantly affect the Japanese economy.

The introduction of carbon taxes may result in the reconstruction of the Japanese tax system as well as the Japanese economy. The Pro-equality Recycling Case in the simulation aims at promoting equitable distribution - not simply neutralizing the adverse distributional effects of carbon taxes. In this case, the carbon taxes are considered as the instruments not only for environmental preservation, but for the promotion of equity. Global warming policies may be enriched when they are consistent with such broader societal objectives (Metz et al (2001)).

As expected, the Pro-equality Recycling Case in Table 5.1 results in more equality than the Fixed Amount Recycling Case. At the same time, in the Pro-equality Recycling Case, both the total consumption and the real GDP decrease a little more than in the Fixed Amount Recycling Case, mainly because the differences of the propensities to savings of households affect capital accumulation. This simulation indicates that there is a bit trade-off relationship between efficiency and equity.

Next, Table 5.2 shows the degree of consumption inequality between households with Atkinson's (1970) Inequality Index[10]. Atkinson's index I_ε is defined by the following formula: where C^h is the consumption of the *h*-th household group, μ is the arithmetic mean consumption, and $f(C^h)$ is the share of the *h*-th household group to the whole households. The parameter ε shows the degree of inequality aversion and $\varepsilon \geqq 0$, for concavity. Its numerical value of ε can take from zero, which means that the society is not interested at all in equality, to ∞, which means that the society only concerns the lowest class, in other words, the society in which so-called Rawlsian

[10] There is vast literature on Inequality Indices. For example, see Cowell(1995), Sen(1997), and Champernowne and Cowell(1998).

Maximin Principle is applied. Thus, Atkinson's index indicates the social value judgment clearly by parameter ε.

$$I_{\varepsilon} = 1 - \left[\sum_{h} \left(\frac{C^{h}}{\mu} \right)^{1-\varepsilon} f\left(C^{h}\right) \right]^{1/(1-\varepsilon)} .$$

Table 5.2 Consumption Inequality (Atkinson's inequality index I, 2010)

ε	BaU	No Recycling Case	Fixed Amount Recycling Case	Pro-equality Recycling Case
0.5	0.0179	0.0179	0.0177	0.0174
1.5	0.0531	0.0532	0.0524	0.0515
2.5	0.0865	0.0867	0.0854	0.0839

Atkinson's index I_{ε} ranges from zero to one, with zero representing no inequality. This index also has the following meanings. According to Table 5.2, in the case of ε = 1.5, Atkinson's index is 0.0531 in the BaU Case. It means that equal social welfare can be attained at the level of 95%(1-0.0531) of the current total consumption, when perfectly equal consumption is performed. That is, I_{ε} is the index of the potential benefits obtained from redistribution, and the amount of the benefits depends on the inequality aversion parameter ε, indicating the social value judgement.

In Table 5.2, compared with the BaU Case, the consumption inequality is a little worse in the No Recycling Case. This shows the regressivity of carbon taxes, as discussed before. However, since the V class is damaged seriously as noted earlier, the degree of deterioration is very small. The consumption inequality gets better as the amount of revenue recycling to the low-income classes increases. The degree of improvement depends on the inequality aversion parameter ε. When the Pro-equality Recycling Case is compared with the No Recycling Case, Atkinson's Index

I_ε improves only 0.0005 (0.0179-0.0174) in the case of $\varepsilon = 0.5$ where the society is hardly interested in the inequality. However, Atkinson's Index I_ε improves no less than 0.0028 (0.0867-0.0839) in the case where the society is more interested in the inequality. Thus, the effect of pro-equality revenue recycling depends on how much society is interested in inequality.

This section analyzed the relation between the recycling schemes of carbon tax revenues and the distributional effects. As the simulation showed, the effects of carbon taxes are regressive. If such regressivity is considered, in line with the introduction of carbon taxes, it is necessary to carry out a tax revenue recycling scheme which would neutralize the adverse distributional effects of these taxes.

The schemes discussed in this study are merely examples. We can consider manifold schemes, such as appropriating carbon tax revenues for pro-employment policies like job training and technological development. Otherwise, we could appropriate the revenues for reducing the government debt. There is room for further investigation.

6. Conclusions

This paper analyzed the impact of carbon taxes on the Japanese economy using the general equilibrium model. According to the simulation, the carbon tax rate of 18000 yen per ton carbon in 2010 is needed to achieve the Kyoto Protocol target. In this case, the real GDP decreases by about 0.1% compared with the BaU Case. Thus, the economic costs are not high, which indicates the efficiency of carbon taxes.

However, the impact of carbon taxes differ between industries. These taxes lead to considerable declines in energy-intensive industries. The uneven burden distribution based on the "Polluter Pays Principle (PPP)" makes the carbon intensity of economies decline. Such structural changes are consistent with the purpose of carbon taxes. If, however, we take into account the tremendous impact of rapid structural adjustments on the economy and society, then, at the very least, alleviation measures should be required for some time. The alleviation measures for energy-intensive industries are effective to some extent in equalization of burdens, discussed in Section 4. However, alleviation measures can delay the pace of structural changes just a little. When implementing carbon taxes, it is also necessary to carry out some direct policies to promote job-changes.

Moreover, carbon taxes are regressive, as shown in Section 5. Considering such regressivity, it is necessary to carry out a recycling scheme of the tax revenues in order to neutralize, if not reverse, the adverse distributional effects of these taxes. In this study, it corresponds to Fixed Amount Recycling Case.

Finally, this study analyzed the carbon taxes not only as instruments of environmental preservation, but also as those of inequality correction from an equity perspective. This point makes the study differ from others that analyze carbon taxes simply as measures to internalize externalities. In this paper, carbon taxes are presented as measures for realizing a sustainable and equitable society. Global warming policies may be enriched when they are consistent with such broader societal objectives. Carbon taxes could bring us rich revenues, which would enable us to reform the Japanese economy. This study shows that the induction of carbon taxes would provide a good opportunity to restructure both the Japanese economy and society.

Unless sound research-based information is available, policy makers are likely, to adopt policies on the basis of ill-perceived conjectures; therefore, a lot of empirical and simulation-based research must be done until actual policies are implemented. In Japan, these kinds of studies are not sufficient for the decision of feasible environmental policies. I hope this study will provide some guidelines for clear thinking about the future environmental policies in Japan.

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