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A GENERAL EQUILIBRIUM ANALYSIS OF WASTE MANAGEMENT POLICY IN JAPAN*

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Abstract

This paper examines the possible impact of waste management policy on the Japanese economy by using an applied general equilibrium model. The analysis sheds light on the price substitution effect following the introduction of a nationwide industrial waste tax, and considers the impact on each industry and recyclable resource in detail. The results show that the policy can reduce the amount of final waste disposal without high costs promoting the growth of secondary industries and recycling activity. It is found that the reduction of final waste disposal can be achieved more efficiently through the price substitution effect between primary and secondary (recycled) goods than that between primary goods.

Key Words: General Equilibrium Model, Japan, Recycling, Waste, Waste Tax
JEL Classification: D58, H23, Q53

I. *Introduction*

The waste problem is serious. It represents an imminent threat to economic growth rather than resource availability (Schmidt-Bleek (1994)). Agenda 21 (Chap.21) states that unsustainable patterns of production and consumption are causing an increase in the quantity and

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variety of waste at unprecedented rates. It also refers to an urgent need for 'environmentally sound waste management' to change the trend. In Japan, where land is scarce and where the population is mostly concentrated in the cities, it is more difficult than in other countries to find waste disposal sites.[1] Reducing waste discharge and final disposal is an emerging issue.

In this context, the Japanese government has begun to consider the possibility of introducing economic instruments for waste management (Environment Agency (2000)).[2] Such economic instruments are intended to promote dematerialization of the economy through price substitution effects (Schmidt-Bleek (1994)). It is expected that taxation on waste discharge will reduce the amount of final waste disposal through price incentives. At the same time, the tax revenue can be appropriated for the construction cost of waste treatment or disposal facilities, which is soaring in recent years to deal with hazardous substances such as dioxins. In the UK, since October 1, 1996, a landfill tax has been imposed on waste disposed of at the licensed landfill sites (OECD (2001), Porter (2002)).[3] In addition, in Japan after the Comprehensive Decentralization Law came into force in April 2000, 21 local governments introduced industrial waste taxes, ahead of the national government.[4]

However, problems will arise when local governments introduce industrial waste taxes at their convenience. The main one is the leakage problem that waste is transferred to areas with no or lower taxation (Ministry of the Environment (2002)). Moreover, an industrial waste tax should be imposed nationally at a uniform rate because industrial waste is treated at levels beyond the prefecture level. The tax scheme should be integrated over as wide an area as possible to maximize the effect of the tax.

Waste management policy was implemented from the perspective of how to treat generated waste and, in that sense, was implemented symptomatically. To achieve a 'sound material-cycle society', it is necessary to change the economic structure of mass production, mass consumption and mass disposal, as well as our behavioral patterns. That is, it is necessary to promote economic restructuring; it is not sufficient to simply strengthen the 'end-of-the-pipe' treatment of generated waste. In this regard, economic instruments such as a waste tax are considered effective measures for changing people's behavioral patterns by generating price incentives and for dematerializing the Japanese economy.

It is essential to examine the effects of policies that have substantial and complicated effects on the economy before they are introduced. How much could the policy reduce the amount of final waste disposal? How much is recycling promoted? What should the tax rate be? To what degree is each industry affected? To achieve the reduction target, what type of economic structure (in terms of economic and material flows) is needed? Since all societies generate waste, waste management policy must focus on managing economic and material flows, rather than on assigning blame for waste generation. For this, economic instruments

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[1] According to the Fundamental Plan for Establishing a Sound Material-Cycle Society, the remaining landfill capacity at final disposal sites for industrial waste is four years in the whole country and a year in the metropolitan areas. See also Chap. 4 of OECD (2002).

[2] Economic instruments are prescribed in Article 23.2 of the Fundamental Law for Establishing a Sound Material-Cycle Society. Moreover, the Fundamental Plan for Establishing a Sound Material-Cycle Society also states clearly that "the State will examine the effectiveness of economic instruments" (Sec. 3, Chap.4).

[3] OECD(2001) reports that the landfill tax in the UK is by and large effective.

[4] In fact, these industrial waste taxes were introduced to raise revenues for waste disposal, rather than to internalize externalities.

using price incentives are effective measures. Before such a policy is introduced, quantitative analysis is essential.

Nevertheless, there have been few quantitative studies of waste problems because of data availability and other limitations. Although data availability has recently improved, few quantitative studies of this issue exist.[5] Most research focuses on a single good (such as used paper or construction waste), and is purely theoretical or descriptive. To justify the practical use of economic instruments in the conduct of waste management policy, quantitative, as well as qualitative, research is needed.

Hence, in this paper, we construct an applied/computable general equilibrium model, the ODIN-WR model, and quantitatively evaluate the effect of a nationwide industrial waste tax on the Japanese economy. Some studies of this issue use applied general equilibrium models. Masui et al. (2000, 2001) and Masui (2003) evaluate the impact of environment policy in tackling both global warming and waste problems.[6] Washida (2004, Chap.6) also estimates the effect of an industrial waste tax.[7] The distinguishing feature of our study is that it explicitly models and considers the price substitution effect between competitive primary and secondary goods.[8] In other words, this analysis focuses on how the price-incentive policy affects the economic and material flows of the Japanese economy.

In section 2, we explain the ODIN-WR model. In section 3, we evaluate the impact of waste management policy on the Japanese economy from the viewpoint of interdependence between primary and secondary industries (primary and secondary goods). We also consider how the policy affects flows of recyclable resources. The final section presents concluding remarks.

II. *The Model*

In a market economy, material flow circulates in connection with economic flow. Even if there is value in use, it will become waste without demand. By contrast, waste with demand can be reused or recycled. Market demand and supply determine whether recyclables are recycled or thrown away for final disposal. Material flow decisively depends on economic flow.

In this context, it is necessary to consider economic flow in order to analyze waste problems. Furthermore, economic instruments affect the economy through price substitution effects, for instance. To evaluate these effects, a general equilibrium model that describes the

[5] Of these studies for the Japanese economy, Nakamura (2000), and Nakamura and Kondo (2002) analyze the effects of alternative waste management scenarios using their waste input-output model. Yoshioka et al. (2003) also examines waste problems by using input-output analysis.

[6] These studies differ from ours in that they evaluate the effect of the policy by setting the constraint to both carbon dioxide emission and final waste disposal. In addition, their model simplifies the government sector and seems not to be suited to an analysis of price-incentive (tax) policy. Moreover, their studies do not focus on the price substitution effect.

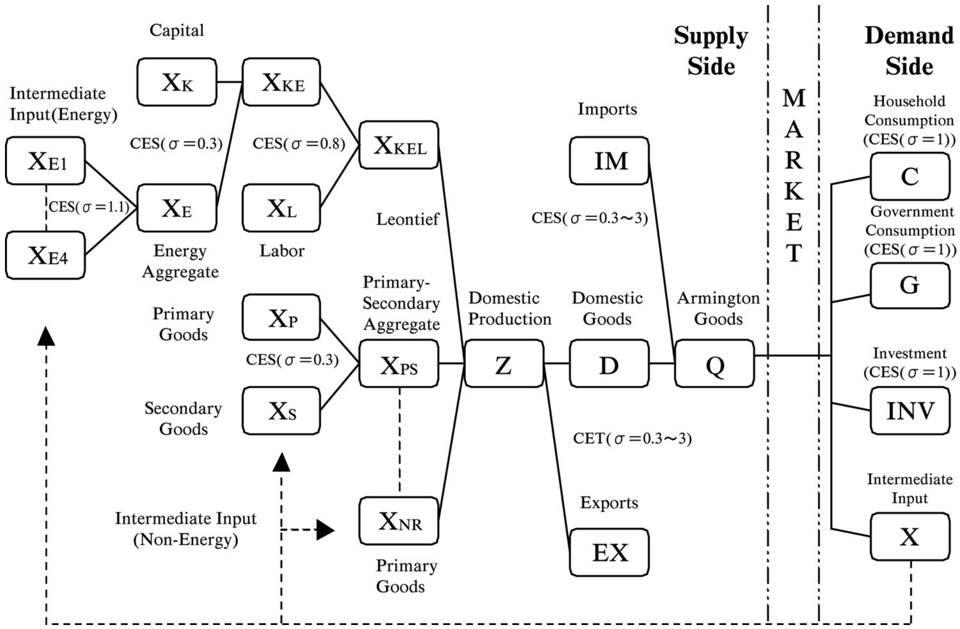
[7] Washida (2004)'s model (EPAM) is different from ours, especially in the treatment of recycling. In the EPAM, the final waste disposal service substitutes for energy and value-added. The amount of recycling is given by the difference between waste discharge and final waste disposal. Recycled goods are homogeneous with primary goods.

[8] In what follows, industries producing primary goods are referred to as primary industries, and industries producing secondary (recycled) goods from recyclable resources are termed secondary industries.

economic structure in detail — that is, production and consumption structures, and the interdependence between industries — is needed. Much literature points out that economic effects cannot be evaluated correctly without using general equilibrium models (e.g., Hazilla and Kopp (1990), Pearce (1991)). Moreover, few studies have analyzed the effects of economic instruments in the context of waste problems by using general equilibrium models. Such a policy affects relative prices, and economic agents adapt to the changed circumstances based on their own preferences. The objective of using instruments is the promotion of such structural changes. If such adaptation and structural change is disregarded, policy effects cannot be appropriately evaluated.

That is why this study constructs and uses an applied/computable general equilibrium (AGE/CGE) model.[9] The model used is a multi-sector applied general equilibrium model named ODIN-WR. The model is structured based on the Harberger-Scarf-Shoven-Whalley model (Shoven and Whalley (1984, 1992)), the GREEN model (Burniaux et al. (1992)), the EPPA model (Yang et al. (1996)) and de Melo and Tarr's (1992) model. The model structure is described by Figure 1 and Table 1 and is explained in the Appendix. For more details, see Yamashita (2003) and Okushima (2004).

FIG. 1. STRUCTURE OF ODIN-WR MODEL



[9] For AGE/CGE models, see, e.g., Shoven and Whalley (1984, 1992).

TABLE 1. INDUSTRIAL AND ENERGY SECTOR IN ODIN-WR MODEL

Primary Industry or Goods	Secondary Industry or Goods	Energy
Agriculture (AGRP)	Agriculture (AGRS)	Coal (COL)
Mining (MINP)	Mining (MINS)	Oil (OIL)
Food (FODP)	Food (FODS)	Electricity (ELC)
Textile (TEX)	Paper and Pulp (PAPS)	Gas (GAS)
Paper and Pulp (PAPP)	Ceramic, Stone and Clay (CSCS)	
Chemical (CHM)	Iron and Steel (IASS)	
Ceramic, Stone and Clay (CSCP)	Non-Ferrous Metal (NFMS)	
Iron and Steel (IASP)		
Non-Ferrous Metal (NFMP)		
Machinery (MAC)		
Other Manufacturing (OMF)		
Construction (CON)		
Water and Heat Supply (WAH)		
Services and Others (SER)		

The model adopts capital-energy separation types (((K, E), L), M) as a model structure, although most AGE models adopt value-added types (such as ((K, L), E, M)). This is because the weak separability of capital-energy is statistically supported in Japan (see, e.g., Tokutsu (1994)).

Despite the importance of elasticity parameters in AGE analysis, there are few estimates of elasticities in the literature: see, e.g., Shoven and Whalley (1984, 1992). Therefore, in most studies, these parameters are 'guesstimated'. However, the reliability of these kinds of analyses depends on the empirical validity of the underlying parameters. In this study, the elasticity parameters are based on reliable literature such as Okushima and Goto (2001) and Tokutsu (1994), who estimate these parameters econometrically from Japanese data by using multi-stage translog and CES functions.

The distinguishing feature of the ODIN-WR model is that it explicitly includes secondary industries; that is, it incorporates recycling activity. The ODIN-WR model includes as secondary goods nine types of recyclable resources on which data are available from the Table on Scrap and By-products in the Input-Output Tables. In addition, a substitution relationship between competitive primary and secondary goods is explicitly modeled in the ODIN-WR model.

The production sector of the ODIN-WR model comprises 21 industrial sectors and four energy sectors. These sectors are price takers and are assumed to maximize profits in a competitive market. The model has both primary and secondary industries for seven goods (AGR, MIN, FOD, PAP, CSC, IAS and NFM). These primary and secondary industries compete with, or substitute for, each other. The production structure is described by nested constant returns-to-scale CES functions, as Figure 1 illustrates.

The model also has a household sector, a government sector, an investment sector and a foreign sector. Expenditures in the household sector, the government sector and the investment sector are represented by CES functions. Households own all primary factors (labor and capital). They sell these factors and purchase goods and services on the basis of their own preferences. The government collects revenues from income taxes, output taxes, import taxes and from a waste tax, which it redistributes and uses to purchase goods and services for its own purpose. The investment sector collects savings from households, the government and the foreign sector to purchase goods and services for investment. The model is a small open-economy model and makes the Armington (1969) assumption. For more details, see the Appendix.

The model's parameters are calibrated to the 1995 Social Accounting Matrix (SAM): see, e.g., Pyatt and Round (1985). The main sources for Japan's 1995 SAM are as follows: 1995 Input-Output Tables, Family Income and Expenditure Survey, Family Saving Survey, Labor Force Survey (Management and Coordination Agency); National Accounts (Economic Planning Agency); 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, e.g., Bacharach (1970)).

For information on waste and recyclable resources, in this paper, we mainly used the Input-Output Tables (Management and Coordination Agency) and the Discharge and Disposal Situation of Industrial Waste (Ministry of Health and Welfare). The model considers all industrial waste included in the Discharge and Disposal Situation of Industrial Waste for analysis, and deals with nine types of recyclable resources in the Table on Scrap and By-products of the Input-Output Tables (Table 2). These are waste textile; slag; fly ash; cullet; animal and plant residue; used paper; glass bottle; iron scraps; and non-ferrous metal scraps.[10] Although there are recyclable resources besides these items, in this analysis, we focus on these nine items reported by the Table on Scrap and By-products because the reliability of the value data is important.[11]

Table 2 lists the recyclable resources, their output sectors, input sectors and their competitive or substitutive sectors. Figure 2 illustrates these relationships conceptually. The figure shows that recyclable resources are discharged as waste by the output sectors, which are primary industries in the ODIN-WR model. Secondary industries then re-commercialize these recyclable resources. That is, secondary industries reproduce recyclables on a commercial basis with costs, and then sell them as secondary goods in the market. The input sectors use these secondary goods as intermediate inputs. In the model, all input sectors are primary industries. The input sectors use secondary goods to make profits; that is, secondary goods compete with substitute primary goods. For example, used paper is discharged from Paper and Pulp (PAPP) and Other Manufacturing (OMF) in which publishing is the main contributor. The discharged material is collected from the firms, sorted by type of used paper and then baled by secondary-Paper and Pulp (PAPS), which comprises collectors and hauliers of used paper. Used paper that has been sorted and baled by type and is ready for shipment is 'secondary' paper. In the ODIN-WR model, these processes are known as re-commercializing. Secondary paper is used as an intermediate input by Paper and Pulp (PAPP).

[10] Of these recyclable resources, glass bottles are reused as glass bottles and others are recycled. In the analysis, however, both reusing and recycling are treated as re-commercializing. Moreover, these are not rigorously distinguished and 'recycling' sometimes includes 'reusing'.

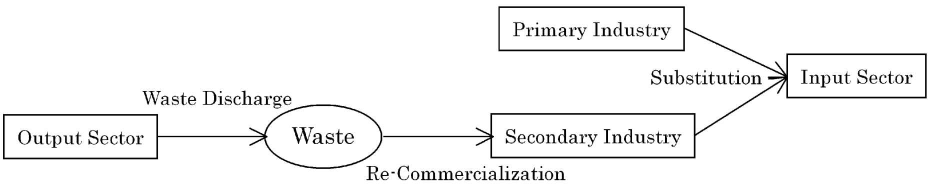
[11] In addition to the nine types in Table 2, steel vessels are reported by the Input-Output Tables. Their output is valued at only 6 million yen and they are generated from fixed capital formation and are exported. Hence, they are ignored in our analysis.

TABLE 2. OUTPUT, INPUT AND COMPETITIVe SECTORS FOR RECYCLABLE RESOURCES

Recyclable Resources (Secondary Industry)	Output Sector	Input Sector	Competitive Sector (Primary Industry)
Waste Textile (AGRS)	TEX	TEX	AGRP
Slag (MINS)	IASP	CSCP, CON	MINP
Fly Ash (MINS)	ELC	CSCP	MINP
Cullet (MINS)	CSCP, CON	CSCP	MINP
Animal & Plant Residue (FODS)	FODP	FODP	FODP
Used Paper (PAPS)	PAPP, OMF	PAPP	PAPP
Glass Bottle (CSCS)	SER	FODP	CSCP
Iron Scraps (IASS)	IASP, MAC, OMF, CON	CHM, IASP	IASP
Non-Ferrous Metal Scraps (NFMS)	IASP, MAC, OMF	CHM, CSCP, IASP, NFMP	NFMP

Note: Please see Table 1 for abbreviations.

FIG. 2. OUTPUT, SUBSTITUTION AND INPUT OF RECYCLABLE RESOURCES



The classification of items for the Discharge and Disposal Situation of Industrial Waste (Ministry of Health and Welfare) corresponds most closely to that of Table 2.[12] However, the statistics only report the amounts of waste generation by industry and item, and the data about waste treatment and disposal by item. Hence, we must estimate the amounts of recycling and final disposal by industry and item. We do so by using the ratio of the amounts of recycling, reduction and final disposal for each item to the amounts of waste generation by industry and item. From this procedure, value data on recyclables can be obtained from the Input-Output Tables. Quantity data on these items can be obtained from the Discharge and Disposal Situation of Industrial Waste.[13]

Table 3 shows the amounts of waste discharge, recycling and final disposal and the material balance of recyclable resources. The amount of waste discharge in the analysis is

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[12] Iron scraps and non-ferrous metal scraps are aggregated as metal scraps in the Discharge and Disposal Situation of Industrial Waste. In this analysis, metal scraps are divided into iron scraps and non-ferrous metal scraps by distributing proportionally by their amount of generation in the Input-Output Tables.

[13] However, in the Discharge and Disposal Situation of Industrial Waste, there is the case in which recyclable resources are discharged or recycled in the sectors that are not reported in the Input-Output Tables. Since the reliability of the value data in the Input-Output Tables is important, the recycling activities that are not reported by the Tables are not taken into account in the analysis. In addition, there are no data on the cost of recycling activity by item. Thus, the costs are estimated from data such as Koshi Oroshiurigyo Jittai Chosa Hokokusho by Zenkoku Seishi Genryo Shoko Kumiai Rengokai.

different from the amount of waste generation in the Discharge and Disposal Situation of Industrial Waste. However, the amounts of final disposal are the same. This is because the process of intermediate treatment (reduction) is not explicitly taken into account in this research. The amount of waste generation in the Discharge and Disposal Situation of Industrial Waste includes the amount of waste that is to be reduced in the process of intermediate treatment. By contrast, the amount of waste discharge in the analysis ((A) in Table 3) only includes the amount of recyclable resources ((B) in Table 3) and non-recyclable waste that has already been reduced in the process of intermediate treatment ((C) in Table 3). Recyclables that are not used and non-recyclable waste are thrown away for final disposal ((D) in Table 3). The difference between the amount of recyclable resources in the waste (the potential amount of recycling, given by (E) in Table 3) and the actual amount of recycling ((F) in Table 3) is the potential amount of additionally recyclable material indicated by the material balance. In the ODIN-WR model, the amount of recycling for each recyclable

TABLE 3. AMOUNTS OF WASTE DISCHARGE, RECYCLING AND FINAL DISPOSAL AND MATERIAL BALANCE OF RECYCLABLE RESOURCES

(ten-thousand ton)

Output Sector	Amount of Waste Discharge												Amount of Final Disposal (D)
	Total (A)	Amount of Recyclable Resources in Waste										Amount of Non-Recyclables (C)	
		Total (B)	Waste Textile	Slag	Fly Ash	Cullet	Animal & Plant Residue	Used Paper	Glass Bottle	Iron Scraps	Non-Ferrous Metal Scraps		
AGRP	394											394	394
MINP	471											471	471
FODP	504	282					282					222	272
TEX	35	4	4									31	33
PAPP	500	77						77				423	435
CHM	334											334	334
CSCP	402	170				170						232	340
IASP	1,919	1,717		1,660						48	8	202	561
NFMP	59											59	59
MAC	347	185								90	95	162	198
OMF	300	86						29		10	48	214	229
CON	2,221	318				173				145		1,903	2,042
WAH	1,114											1,114	1,114
SER	342	169							169			173	281
COL	3											3	3
OIL	14											14	14
ELC	353	262			262							91	146
GAS	1											1	1
Total (E)	9,310	3,270	4	1,660	262	344	282	106	169	293	151	6,043	6,926
Actual Amount of Recycling (F)		2,384	2	1,312	206	125	232	90	61	235	121		

Note: 1. The figures are estimated from the Discharge and Disposal Situation of Industrial Waste and other sources.

2. Please see Table 1 for abbreviations.

resource ((F) in Table 3) cannot exceed the amount generated ((E) in Table 3). For example, Table 3 shows that 40,000 tons of waste textile was discharged by TEX (the output sector). This amount is the most that that could be used by TEX (the input sector) from the material balance.

Table 4 reports waste discharge and recovery coefficients from the ODIN-WR model. The discharge (recovery) coefficient of each industry is the ratio of the amount of waste discharge (recovery) to the sum of intermediate inputs in the 1995 SAM. That is, the total amounts of waste discharge are equal to the amounts of final disposal and recovery.

TABLE 4. WASTE DISCHARGE AND RECOVERY COEFFICIENTS FROM ODIN-WR MODEL

	Discharge Coef. (ton/0.1 billion yen)		Recovery Coef. (ton/0.1 billion yen)
AGRP	57	Waste Textile (AGRS)	−1,586
MINP	599	Secondary Minerals (MINS)	−135,021
FODP	20	Animal&Plant Residue (FODS)	−58,800
TEX	5	Used Paper (PAPS)	−87,575
PAPP	81	Glass Bottle (CSCS)	−3,129
CHM	19	Iron Scraps (IASS)	−2,097
CSCP	71	Non-Ferrous Metal Scraps (NFMS)	−1,291
IASP	130		
NFMP	13		
MAC	4		
OMF	9		
CON	45		
WAH	617		
SER	2		
COL	3		
OIL	3		
ELC	45		
GAS	1		

Note: 1. Secondary minerals consist of slag, fly ash and cullet.
2. Please see Table 1 for abbreviations.

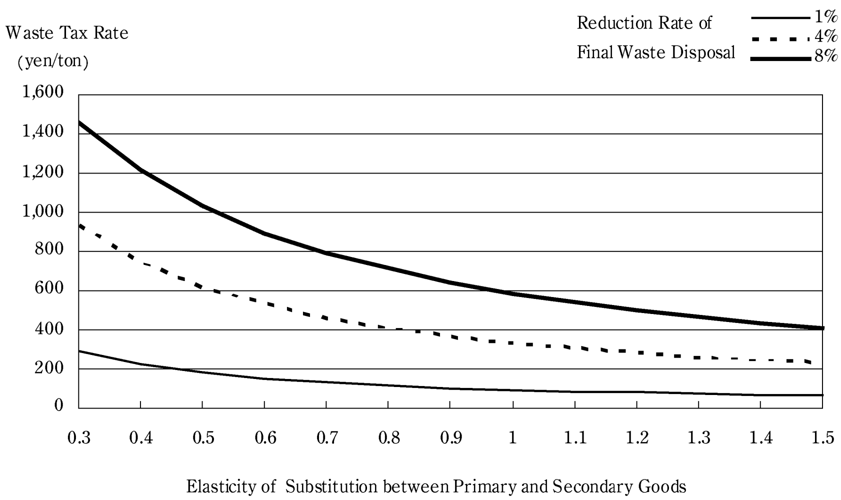
III. *Influence of Waste Management Policy on the Japanese Economy*

In this section, we analyze the influence of waste management policy on the Japanese economy by using the ODIN-WR model. This analysis considers the introduction of a nationwide industrial waste tax that serves to promote waste reduction and recycling. As mentioned previously, the waste analyzed is industrial waste. The tax revenue is assumed to be recycled to the government expenditure. To evaluate the effect, we compare all cases with the Business-as-Usual (BaU) case, which is the before-policy case. The BaU Case represents the situation of the Japanese economy in the base year, 1995.

We explain the industrial waste tax that is considered in the analysis. The tax is imposed on industries in proportion to their waste discharge (recovery) per unit. Note that, in the ODIN-WR model, secondary industries collect waste in the production. In other words, for primary industries, lower production leads to reduced waste discharge, but for secondary industries, increased production contributes to increased waste recovery (negative waste discharge). Hence, production has opposite effects on waste discharge in primary and secondary industries. Then, the policy is efficient if the waste tax is levied on primary industries (primary goods) in proportion to their waste discharge per unit and if the recycling subsidy (negative tax) is given to secondary industries (secondary goods) in proportion to their waste recovery (negative waste discharge) per unit. We define such a policy mix of taxes and subsidies as the waste tax.

In what follows, we evaluate the effect of the waste tax on the Japanese economy by using the ODIN-WR model. Figure 3 shows the relationship between the tax rate, the elasticity of substitution between primary and secondary goods and the rate of reduction of final waste disposal. Figure 3 indicates that, for a fixed elasticity, the higher is the reduction rate, the higher the tax rate needed. For example, given an elasticity of 0.3, the tax rate needed to achieve a 1% reduction in final waste disposal is 290 yen. For reductions of 4% and 8%, respectively, tax rates of 940 yen and 1,460 yen are needed.[14]

FIG. 3. RELATIONSHIP BETWEEN THE WASTE TAX RATE, THE ELASTICITY OF SUBSTITUTION AND THE FINAL WASTE DISPOSAL REDUCTION RATE



It is important to note that the waste tax (the price-incentive policy) could reduce the amount of final waste disposal by a maximum of 10%. That is, given the model and data, the price substitution effect causes a 10% reduction in final waste disposal at most. The reason is as follows. The policy reduces the amount of final disposal because it increases the price differentials between primary and secondary goods. These increased differentials lead to substitution between primary and secondary goods. The greater the target reduction, the

[14] In our study, the waste tax can reduce the amount of final waste disposal more effectively than implied by other studies such as Washida (2004). This is possibly due to the difference in model structures, especially with regard to recycling, and the data. Additionally, in Washida (2004), the tax is levied on final waste disposal, not on waste discharge.

higher the tax rate needed. Note that revenues must at least match production costs for all primary and secondary industries. The imposition of the tax increases the prices of primary goods, which leads to increased production costs. Were the production costs of secondary industries to exceed revenues, secondary industries would shut down. In general equilibrium analyses such as ours, all industries must at least break even.

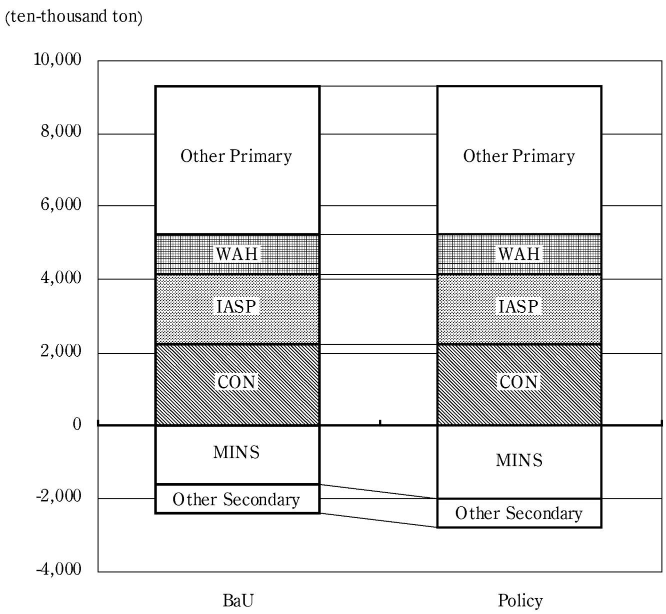
There has been much progress in production, intermediate treatment and recycling technology. Given these advances, the economy could reduce the amount of final waste disposal by more than the amount implied by the model. A limitation of our model is that it does not consider these technological innovations. However, the advantage of policy analysis using general equilibrium models is that one can evaluate the price substitution effect that is due to policy; hence, this analysis focuses on the price substitution effect.

We examine the elasticity of substitution between primary and secondary goods. The elasticity of substitution is:

$$\sigma = \frac{d(x_2/x_1)}{(x_2/x_1)} \Big/ \frac{d(p_1/p_2)}{(p_1/p_2)},$$

where x_1 is demand for the primary good, x_2 is demand for the competitive secondary good, p_1 is the price of the primary good and p_2 is the price of the secondary good. The elasticity parameter measures to what degree changes in relative prices affect relative demands. The parameter value determines how much changes in relative prices, caused by the policy, increase the demand for secondary goods.

FIG. 4. WASTE DISCHARGE AND RECOVERY BEFORE AND AFTER POLICY



Note: Please see Table 1 for abbreviations.

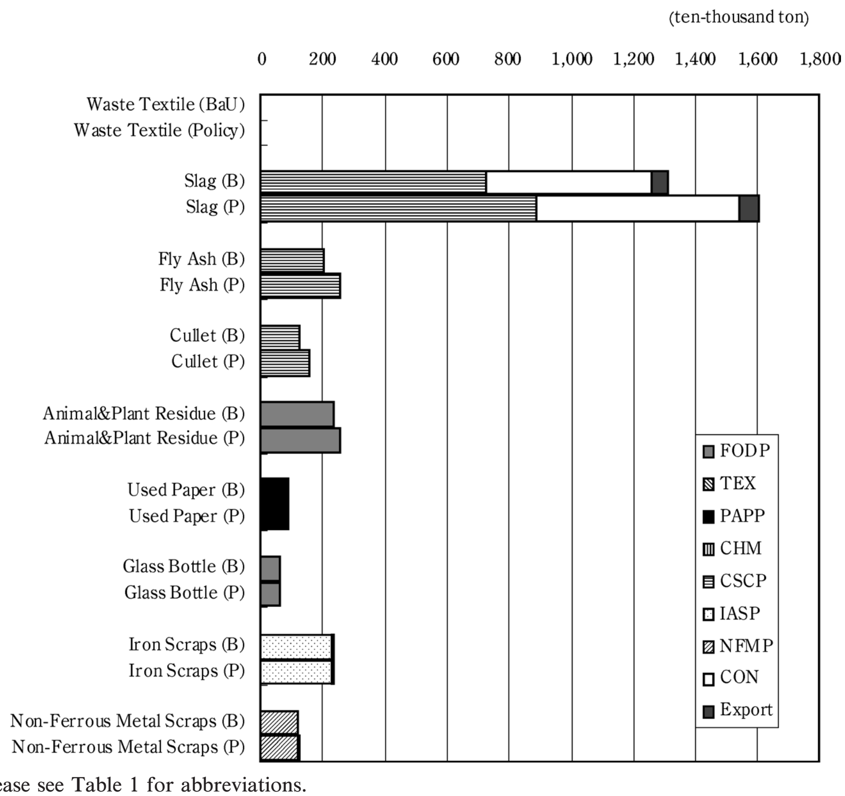
Figure 3 shows that the larger the elasticity, the easier price substitution is between primary and secondary goods, and hence, the lower the tax rate needed to achieve a given waste reduction. For example, an 8% reduction in final waste disposal requires a tax rate of 1,460 yen given an elasticity of 0.3. Corresponding tax rates at elasticities of 0.5 and 1, respectively, are 1,030 yen and 590 yen.

From now on, we fix the elasticity at 0.3, given the results from the existing literature.[15] We fix the waste tax rate at 1,200 yen. These settings define the Policy Case. In the Policy Case, the amount of final waste disposal is 65.28 million tons, which represents a 6% reduction compared to the BaU Case.

Figure 4 compares the amounts of waste discharge and recovery in the Policy Case and those in the BaU Case by industry. In this Figure, points above zero represent waste discharge and those below zero represent waste recovery. Industries are arranged in Figure 4 for clarity.

In the BaU Case and the Policy Case, Construction (CON), Iron and Steel (IASP) and Water and Heat Supply (WAH) are the main contributors to waste discharge, whereas secondary-Mining (MINS) is the largest contributor to waste recovery. Moreover, as shown

FIG. 5. AMOUNT OF RECOVERY BEFORE AND AFTER POLICY



Note: Please see Table 1 for abbreviations.

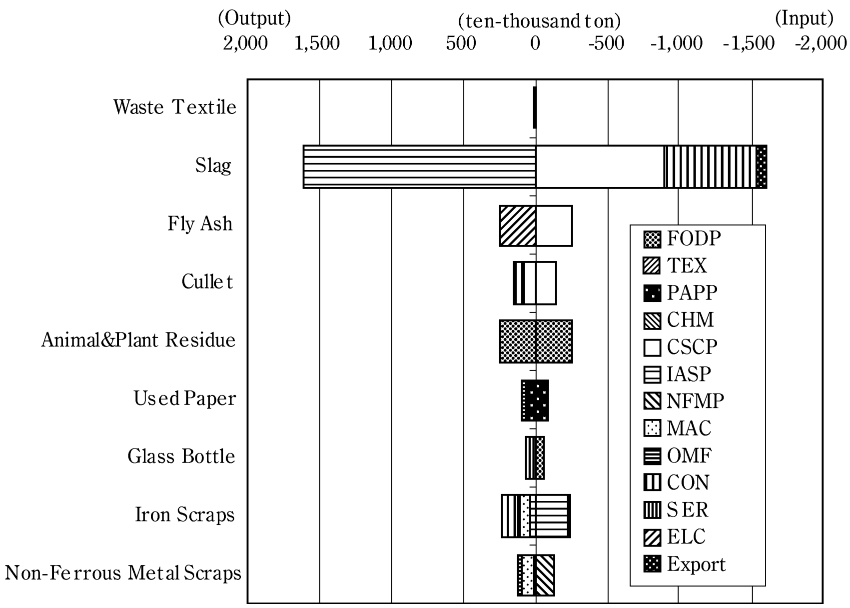
[15] For example, Washida (1995) estimates the elasticity parameter for paper.

in Figure 4, the total amount of waste discharged by primary industries is about 93 million tons in the Policy Case, which is similar to the BaU Case. On the other hand, the amount of waste recovery by secondary industries, especially by secondary-Mining (MINS), is much higher. This result indicates that it is much more efficient for reduction in final waste disposal to increase recycling activity by secondary industries than to reduce production in primary industries to reduce waste discharge. According to this analysis, which aims to reduce the amount of final waste disposal by weight, it is efficient to promote the activity of secondary-Mining (MINS) to recycle resources such as slag, fly ash and cullet, which are heavy and bulky.

We examine the change in the amounts of waste recovery and discharge for each recyclable resource. Figure 5 shows the change in the amount of recovery for each recyclable resource before and after the policy. The recycled resources are used by primary industry or exported. After the policy is introduced, the amounts of recovery increase for all items, but particularly slag. Figure 5 also shows the input sectors of recycled resources. For example, recycled slag is used in Ceramic, Stone and Clay (CSCP) and Construction (CON). On the other hand, there is only one input sector for recycled resources such as fly ash, cullet, animal and plant residue and used paper.

Figure 6 illustrates the output sectors for recyclable resources on the left-hand graph and the input sectors on the right-hand graph by resource. All output and input sectors are primary industries and the values are the amounts of recycling after the policy. The values on the left and right graphs are the same for each recyclable resource.

FIG. 6. OUTPUT AND INPUT SECTORS FOR RECYCLABLE RESOURCES

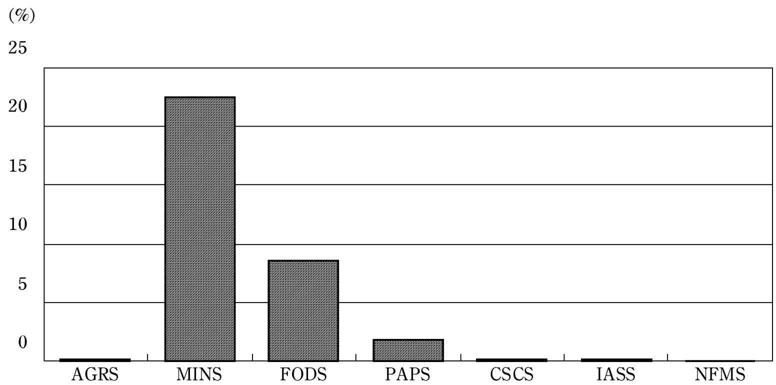


Note: Please see Table 1 for abbreviations.

It is important to note that, for resources such as used paper and animal and plant residue, the sectors that discharge recyclable resources use the resources themselves. Note also that animal and plant residue is discharged only by Food (FODP) and is used only by that industry. For the output and input sectors of recyclable resources, see Table 2.

Next, we examine the effect of the policy on each industry. Figure 7 shows the effects of the policy on secondary industries. The policy causes a substantial increase in the production of secondary industries due to substitution from primary to secondary goods. The increases in secondary-Mining (MINS), secondary-Food (FODS) and secondary-Paper and Pulp (PAPS) are particularly large. These correspond to increases in the amounts of recycling of secondary minerals (slag, fly ash and cullet), animal and plant residue and used paper, respectively.

FIG. 7. PRODUCTION CHANGES IN SECONDARY INDUSTRIES BEFORE AND AFTER POLICY



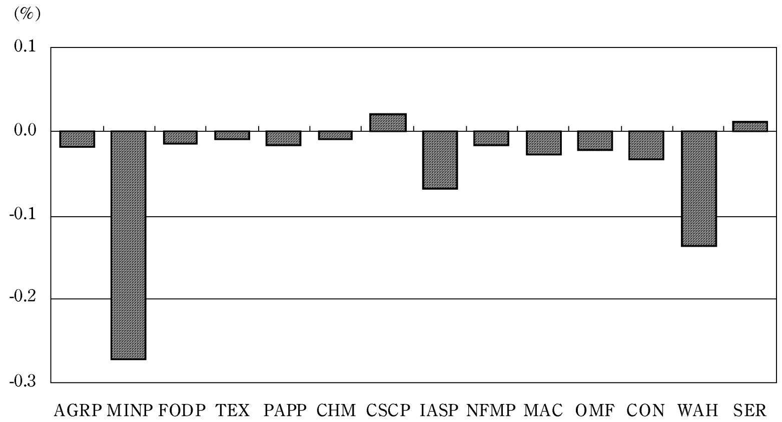
Note: Please see Table 1 for abbreviations.

As seen above, the policy promotes the growth of secondary industries and recycling activity. However, it is not only the growth of secondary industry, but also structural change in primary industries, that is needed to achieve dematerialization of the economy. These changes are strongly related since the growth of secondary industries depends on the demand for secondary goods by primary industries as well as the price of competitive primary goods. The demand for secondary goods depends totally on the activity of primary industry. Put another way, the growth of secondary industries is closely related to change in the production structure of primary industry. Therefore, when considering the impact of waste management policy, it is necessary to take into account the interdependence between primary and secondary industries.

Figure 8 shows the effect of the policy on primary industry. The policy has a slight negative effect, which is illustrated in Figure 4. This means that the policy would not do much damage to the economy; that is, it would reduce GDP by less 0.1%.

In Figure 8, the damage stands out in such sectors as Mining (MINP), Iron and Steel (IASP) and Water and Heat Supply (WAH), in which industries waste discharge per unit is high. In addition, the policy increases price differentials between primary and secondary goods. Hence, industries such as Mining (MINP) and Iron and Steel (IASP) engage in increased competition with substitute secondary industries, which reduce demand for their goods. By

FIG. 8. PRODUCTION CHANGES IN PRIMARY INDUSTRIES BEFORE AND AFTER POLICY



Note: Please see Table 1 for abbreviations.

contrast, Ceramic, Stone and Clay (CSCP) and Services and Others (SER) increase production after the policy. The reason is that Services and Others (SER) discharge little waste per unit, and so the price substitution effect from other primary goods leads to an increase in the demand for their goods.

For Ceramic, Stone and Clay (CSCP), further explanation is required. Generally, raw-material industries such as Paper and Pulp, Ceramic, Stone and Clay, Iron and Steel and Non-Ferrous Metal, play an important role in recycling activities. Of these industries, the cement industry, which is included in Ceramic, Stone and Clay (CSCP) in the model, is important as an input sector of recyclable resources (see, e.g., Development Bank of Japan (2003)). The cement industry could use recyclable resources in large quantities as an intermediate input. According to the Japan Cement Association, 30% of cement by weight is currently made from recyclable resources. Furthermore, in the production process, waste virtually becomes non-hazardous and little secondary waste is generated. These advantages indicate the importance of the cement industry for recycling activity. The cement industry, that is, Ceramic, Stone and Clay (CSCP), play a significant role in reduction of final waste disposal in the economy.

Our results confirm the importance of this sector. According to Table 2, slag, fly ash, cullet and non-ferrous metal scraps are used by Ceramic, Stone and Clay (CSCP). Of these resources, slag and fly ash are used by the cement industry. As Figure 6 shows, slag is generated from Iron and Steel (IASP) and fly ash from Electricity (ELC) (including thermal power-generation plants). Figure 5 shows that after the policy is introduced, recycling of these resources greatly increases. These recycled resources are used by Ceramic, Stone and Clay (CSCP). In other words, after the policy is introduced, Ceramic, Stone and Clay (CSCP) uses the recycled resources that the policy makes cheaper. This helps the industry to compete on price. Consequently, production increases.

These results show that we must take into consideration not only the recycling activity of secondary industries (secondary goods) but also the activity of primary industries that use secondary goods (the 'outlets') in order to promote the growth of secondary industries and recycling activity following the implementation of the policy. We must also consider the activities of primary industries that substitute, or compete with, secondary goods. If policy is expected to have a marked effect in reducing the amount of final waste disposal, it is important to examine this from the perspective of managing the flow of recyclable resources systematically so that recyclable resources may smoothly circulate from secondary to primary industry. The promotion of recycling needs to expand markets for secondary goods, that is, to increase the demand for goods that use secondary goods in their production, in addition to price incentives.

We summarize the effect of the policy on primary industries. If the interdependence between primary and secondary industries is considered, the following three characteristics are important:

1. Industries that discharge a lot of waste per unit production;
2. Industries that are in fierce competition with secondary goods;
3. Industries that use large amounts of recycled resources in production.

The implementation of waste management policy, as has been studied in this paper, is considered to generate negative effects in industries with characteristics 1 and 2, and positive effects in those with characteristic 3. Table 5 classifies the primary industries in the model on the basis of these characteristics.

TABLE 5. CHARACTERISTICS OF PRIMARY INDUSTRIES

	Characteristics		
	1	2	3
AGRP			
MINP	○	○	
FODP		○	○
TEX			
PAPP		○	○
CHM			
CSCP			○
IASP	○	○	○
NFMP		○	○
MAC			
OMF			
CON			
WAH	○		
SER			

Note: Please see Table 1 for abbreviations.

We gain a deeper insight into the effect of the policy on primary industries by examining the result illustrated in Figure 8 by using Table 5. The policy damages industries with characteristic 1 because of taxation. In addition, the policy also has negative effects on industries with characteristic 2, which include Mining (MINP) and Iron and Steel (IASP), because of intensified competition with secondary goods. Hence, the aggregate negative effect causes relatively much damage to industries with both characteristics 1 and 2.

On the other hand, the policy hardly damages industries such as Food (FODP), Paper and Pulp (PAPP) and Non-Ferrous Metal (NFMP), which exhibit characteristics 2 and 3. Although these industries face intensified competition from secondary goods, they can use cheaper secondary goods in production. Consequently, the reduction in production costs from using secondary goods mitigates the negative effect. This advantage applies particularly to industries such as Food (FODP) and Paper and Pulp (PAPP), which, in the model, use their own discharged recyclable resources. If primary and secondary industries are considered as one sector, that sector reduces the amount of waste discharge by circulating recyclable resources within the sector.

As explained above, Ceramic, Stone and Clay (CSCP) is an industry that exhibits characteristic 3. After the policy is introduced, this industry could use cheaper secondary goods. Consequently, as shown by Figure 8, the industry is positively affected by the policy, although it is a primary industry.

The policy affects the economy and industries because of the interdependence between industries. Hence, to evaluate this effect, a model that can consider inter-industry relationships between primary and secondary industries is needed. The advantage of our applied general equilibrium model is that it can quantitatively and comprehensively.

Since general equilibrium models also have limitations, they must be complemented by other models. For example, general equilibrium models often assume that labor or capital moves smoothly. This means that transition costs are small. Our results show that the policy promotes dematerialization of the economy without generating high costs. However, changing the economic structure is not easy, and high transition costs often prevent policy implementation. When such policies are introduced, direct support measures, such as job training programs that provide workers with new skills, might be needed to smooth the transition process.

IV. *Conclusion*

This paper, by using the ODIN-WR model, has examined the potential impact on the Japanese economy of a nationwide industrial waste tax, which is a policy mix that imposes a tax on primary goods and provides a recycling subsidy (a negative tax) to secondary goods. We considered the price substitution effect following the introduction of the policy, and what price structure and economic flows are needed to achieve a 'sound material-cycle society', or a dematerialized economy.

We conclude that it is possible to achieve an efficient reduction in final waste disposal by implementing the policy. It stimulates the growth of secondary industries as well as recycling activity, and does little damage to production in primary industries. The results indicate that the reduction of final waste disposal can be achieved much more efficiently through the price substitution effect between primary and secondary goods than through price substitution between primary goods. Although a limited number of types and amounts of recyclable resources have been considered, the results suggest that the policy could efficiently promote recycling activity.

This analysis examined the impact of the policy on industries while considering interdependence between them. Hence, the effects on primary industries are determined not only by the waste intensiveness of their goods but also by their relationships with competitive secondary industries and the availability of secondary goods. It is also clear that the growth of secondary industries depends on the primary industries that use secondary goods and that compete with them. When analyzing the impact of waste management policy, one must not lose sight of such complex relationships between primary industries or those between primary and secondary industries. In this sense, it is necessary to look at the economy comprehensively when considering such policies. The overall effect on the economy is best analyzed and explained by using a general equilibrium model such as ours.

It is important to identify the limitations of our analysis. First, there are data limitations. As indicated by Turner et al. (1994), there are insufficient data to effectively analyze waste problems. An applied general equilibrium analysis, as undertaken in this paper, needs price and cost data as well as quantity data. In this study, we limited our analysis to the nine types of recyclable resources appearing in the Input-Output Tables because of data availability and reliability. The data used are not sufficient and our analysis is not comprehensive.

Moreover, in practice, policies that regulate or tax waste discharge may increase the illegal disposal of waste. Our model does not consider this possibility. When and if such a policy is implemented, these illegal activities would have to be taken into account (Ministry of the Environment (2002)). However, data limitations make illegal dumping difficult to analyze quantitatively. The inherent difficulty in this kind of study is that excessively strong assumptions may be needed.

Our analysis does not explicitly consider intermediate treatment, as already mentioned. Nor have we considered technological innovations such as those in production, intermediate treatment or recycling. In practice, these innovations will contribute significantly to reducing the quantity of final waste disposal in future. By not considering such significant factors, our study might underestimate the economy's potential for waste reduction.

To repeat, the main advantage of policy analysis using general equilibrium models is that the price substitution effect generated by price-incentive policy can be appropriately evaluated. Therefore, it is reasonable to have limited our analysis to the price substitution effect of the tax. Models are not perfect and all models involve compromises (Johansen (1960)). It would be churlish for policy scientists to overcome these limitations by adding further assumptions in an attempt to 'paper over the cracks'. It is better to accept and be aware of the limitations, and when applying the model and analyzing the results, it is important to keep these issues in mind.

It is our sincere hope and wish that this research and its conclusions contribute to the understanding of waste management policy in Japan.

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Appendix Model Formulation of ODIN-WR Model

Index (See Table 1 for abbreviations)

i,j : Goods or Industry
={AGRP, AGRS, MINP, MINS, FODP, FODS, TEX, PAPP, PAPS, CHM, CSCP, CSCS, IASP, IASS, NFMP, NFMS, MAC, OMF, CON, WAH, SER, COL, OIL, ELC, GAS}.
e: Energy
={COL, OIL, ELC, GAS}.
m: Non-energy
={AGRP, AGRS, MINP, MINS, FODP, FODS, TEX, PAPP, PAPS, CHM, CSCP, CSCS, IASP, IASS, NFMP, NFMS, MAC, OMF, CON, WAH, SER}.
p_s: Primary-Secondary Aggregate
={AGR, MIN, FOD, PAP, CSC, IAS, NFM}.
p: Primary Goods or Industry for Primary-Secondary Aggregate
={AGRP, MINP, FODP, PAPP, CSCP, IASP, NFMP}.

s: Secondary Goods or Industry for Primary-Secondary Aggregate
={AGRS, MINS, FODS, PAPS, CSCS, IASS, NFMS}.
n_r: Primary Goods or Industry
={TEX, CHM, MAC, OMF, CON, WAH, SER}.

First Stage (Domestic Production)

$$\max_{X_{p_s j}, X_{n_r j}, X_{KELj}} (1+sb_j)P_j^x Z_j - \sum_{p_s} P_{p_s j} X_{p_s j} - \sum_{n_r} P^d_{n_r j} X_{n_r j} - P_{KELj} X_{KELj},$$

$$s.t. \qquad Z_j = \min\left\{\frac{X_{p_s j}}{ax_{p_s j}}, \frac{X_{n_r j}}{ax_{n_r j}}, \frac{X_{KELj}}{a_{KELj}}\right\}.$$

Z_j	Domestic Production;
P_j^x	Price of Z_j;
X_{psj}	Intermediate Input of Primary-Secondary Aggregate;
P_{psj}	Price of X_{psj};
X_{nrj}	Intermediate Input of Primary Goods;
P^d_{nrj}	Price of X_{nrj};
X_{KELj}	Intermediate Input of Capital-Energy-Labor Aggregate;
P_{KELj}	Price of X_{KELj};
$ax_{psj}, ax_{nrj}, a_{KELj}$	Parameter of Leontief Production Function;
sb_j	Subsidy Rate (Exogenous).

Second Stage a (Primary-Secondary Aggregate)

$$\max_{X_{pj}, X_{sj}} P_{p_s j} X_{p_s j} - P^d_{pj} X_{pj} - P^d_{sj} X_{sj},$$

$$s.t. \qquad X_{p_s j} = \beta_{psj}(\alpha_{pj} X_{pj}{}^{\rho_{psj}} + \alpha_{sj} X_{sj}{}^{\rho_{psj}})^{\frac{1}{\rho_{psj}}}.$$

X_{pj}	Intermediate Input of Primary Goods;
P^d_{pj}	Price of X_{pj};
X_{sj}	Intermediate Input of Secondary Goods;
P^d_{sj}	Price of X_{sj};
β_{psj}	Output Parameter of CES Production Function;
α_{pj}, α_{sj}	Share Parameter of CES Production Function;
ρ_{psj}	Elasticity Parameter of CES Production Function ($\sigma = 0.3$).

Second Stage b (Capital-Energy-Labor Aggregate)

$$\max_{X_{KEj}, X_{Lj}} P_{KELj} X_{KELj} - P_{KEj} X_{KEj} - P_L X_{Lj},$$

$$s.t. \qquad X_{KELj} = \beta_{KELj}(\alpha_{KEj} X_{KEj}{}^{\rho_{KELj}} + \alpha_{Lj} X_{Lj}{}^{\rho_{KELj}})^{\frac{1}{\rho_{KELj}}}.$$

X_{KEj}	Intermediate Input of Capital-Energy Aggregate;
P_{KEj}	Price of X_{KEj};

X_{Lj}	Labor Input;
P_L	Labor Price $(=1)$;
β_{KELj}	Output Parameter of CES Production Function;
$\alpha_{KEj}, \alpha_{Lj}$	Share Parameter of CES Production Function;
ρ_{KELj}	Elasticity Parameter of CES Production Function ($\rho=0.8$).

Third Stage (Capital-Energy Aggregate)

$$\max_{X_{Kj}, X_{Ej}} P_{KEj} X_{KEj} - P_K X_{Kj} - P_{Ej} X_{Ej},$$

$$s.t. \qquad X_{KEj} = \beta_{KEj} (\alpha_{Kj} X_{Kj}{}^{\rho_{KEj}} + \alpha_{Ej} X_{Ej}{}^{\rho_{KEj}})^{\frac{1}{\rho_{KEj}}}.$$

X_{Kj}	Capital Input;
P_K	Capital Price;
X_{Ej}	Intermediate Input of Energy Aggregate;
P_{Ej}	Price of X_{Ej};
β_{KEj}	Output Parameter of CES Production Function;
α_{Kj}, α_{Ej}	Share Parameter of CES Production Function;
ρ_{KEj}	Elasticity Parameter of CES Production Function ($\sigma=0.3$).

Fourth Stage (Energy Aggregate)

$$\max_{X_{ej}} P_{Ej} X_{Ej} - \sum_e P^d_{ej} X_{ej},$$

$$s.t. \qquad X_{Ej} = \beta_{Ej} (\sum_e \alpha_{ECej} X_{ej}{}^{\rho_{Ej}})^{\frac{1}{\rho_{Ej}}}.$$

X_{ej}	Intermediate Input of Energy;
P^d_{ej}	Price of X_{ej};
β_{Ej}	Output Parameter of CES Production Function;
α_{ECej}	Share Parameter of CES Production Function;
ρ_{Ej}	Elasticity Parameter of CES Production Function ($\sigma=1.1$).

Exports, Imports and Balance of Payments

$$Z_i = \beta_{Ti} (\alpha_{TEi} EX_i{}^{\rho_{Ti}} + \alpha_{TDi} D_i{}^{\rho_{Ti}})^{\frac{1}{\rho_{Ti}}}.$$

$$Q_i = \beta_{Ai} (\alpha_{AMi} IM_i{}^{\rho_{Ai}} + \alpha_{ADi} D_i{}^{\rho_{Ai}})^{\frac{1}{\rho_{Ai}}}.$$

$$P_i^{EX} = \varepsilon \ \pi_i^{EX}.$$

$$P_i^{IM} = \varepsilon \ \pi_i^{IM}.$$

$$\sum_i \pi_i^{EX} EX_i + S^F = \sum_i \pi_i^{IM} IM_i.$$

EX_i	Exports;
D_i	Domestic Goods;
β_{Ti}	Output Parameter of CET Function;
$\alpha_{TEi}, \alpha_{TDi}$	Share Parameter of CET Function;
ρ_{Ti}	Elasticity Parameter of CET Function;
Q_i	Armington Goods;
IM_i	Imported Goods;
β_{Ai}	Output Parameter of CES Function;
$\alpha_{AMi}, \alpha_{ADi}$	Share Parameter of CES Function;
ρ_{Ai}	Elasticity Parameter of CES Function;
P^{EX}_i	Export Price in Yen;
π^{EX}_i	Export Price in Dollars (Exogenous);
P^{IM}_i	Import Price in Yen;
π^{IM}_i	Import Price in Dollars (Exogenous);
ε	Exchange Rate;
S^F	Savings by Foreign Sector (Exogenous).

Household Sector

$$\max_{C_i}\left(\sum_i \alpha_{CONSi} C_i^{\rho_{CONS}}\right)^{\frac{1}{\rho_{CONS}}},$$

$$s.t. \qquad P_K K + P_L L = \sum_i P_i^d C_i + S^P + T^D.$$

C_i	Consumption of Good i;
P_i^d	Price of Good i;
K	Capital Endowment (Exogenous);
L	Labor Endowment (Exogenous);
S^P	Household Savings (Savings rate is exogenous);
T^D	Income Tax;
α_{CONSi}	Share Parameter of CES Utility Function;
ρ_{CONS}	Elasticity Parameter of CES Utility Function ($\sigma = 1$).

Government Sector

$$\max_{G_i}\left(\sum_i \alpha_{GOVi} G_i^{\rho_{GOV}}\right)^{\frac{1}{\rho_{GOV}}},$$

$$s.t. \qquad T^D + T^O + T^{IM} + T^W = \sum_i P_i^d G_i + S^G + SUB.$$

G_i	Government Expenditure for Good i;
T^D	Income Tax Revenue;
T^O	Output Tax Revenue;
T^{IM}	Import Tax Revenue;
T^W	Waste Tax Revenue;
S^G	Government Savings (Savings rate is exogenous);

SUB	Subsidy to Industry;
α_{GOVi}	Share Parameter of CES Utility Function;
ρ_{GOV}	Elasticity Parameter of CES Utility Function ($\sigma=1$).

Investment Sector

$$\max_{INV_i}(\sum_i \alpha_{INVi} INV_i^{\rho_{INV}})^{\frac{1}{\rho_{INV}}},$$

$$s.t. \qquad S^P + S^G + \varepsilon S^F = \sum_i P_i^d INV_i.$$

INV_i	Investment Demand for Good i;
α_{INVi}	Share Parameter of CES Utility Function;
ρ_{INV}	Elasticity Parameter of CES Utility Function ($\sigma=1$).

Market-Clearing Condition

$$K = \sum_j X_{Kj}.$$

$$L = \sum_j X_{Lj}.$$

$$Q_i = C_i + G_i + INV_i + \sum_j X_{ij}.$$

Waste

$$WW_j = TW_j \times \sum_i X_{ij}.$$

$$P_i^d = P_i + t_i^W.$$

$$P_{ij}^d = P_i + t_{ij}^W.$$

$$\sum_j WW_j \leq \overline{WW}.$$

WW_j	Waste Discharge or Recovery;
$\overline{WW}$	Waste Discharge Limit (Exogenous);
TW_j	Coefficient of Waste Discharge or Recovery (Ton/ 0.1 Billion Yen);
P_i^d	Price of Good i in Final Demand Sector;
t_i^W	Waste Tax on Good i in Final Demand Sector;
P_{ij}^d	Price of Good i in Industry j;
t_{ij}^W	Waste Tax on Good i in Industry j.