# The Impact of Introducing Recycling Taxes on China's Environmental Policy: Case Study on E-waste Recycling

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**Abstract**

E-waste could be an important source of valuable metals if we can design an effective recovery mechanism. This article aims to: enhance the rate of E-waste recycling, treatment and the rate of recycled metal (secondary metal); and reduce the extraction of primary metals (virgin metals) by introducing an E-waste recycling tax, by minimizing $CO_2$ emissions as a requirement of China's climate change policy. On this basis, we designed a dynamic environmental-social economic model for the period 2008-2020. Upon comprehensive consideration of economic benefits and environmental impacts, the results show that by imposing a 4% levy on production volume for electronics manufacturing and imposing specific taxes on consumers for recycling E-wastes, the total GDP is maximized and is higher than without introducing any tax. Among the metals, the highest substitution ratios were tin at 30.90% and copper at 29.25%.

**Keywords:** E-waste, E-waste recycling tax, Recycled metal, Environmental-social, Economic model, Simulation

## 1. Introduction

Metals are key natural resources for economic development. As shown in Table 1, China's rapid economic growth in the last decades has made it both the largest producer and consumer of metals (China Nonferrous Metals industry Association, 2009; China Metallurgical Industry Press, 2009). Many studies have stressed the importance of E-waste recycling (Qu, 2007; Greenpeace East Asia[a;b]); therefore, to assure continuous economic growth and balanced supply-demand for key metal resources, we need to introduce a large-scale recycling system for these metals.

The E-waste generation is growing at a dramatic rate of 5%-10% annually (Wang et al., 2010), the fastest for solid waste. Typical E-waste such as televisions, refrigerators, computers, air conditioners, mobile phones and washing machines contain common metals including iron, copper, aluminum, and rare metals such as gold, silver and nickel. Recycling these metals can be another supply source to meet market demand and reduce use of virgin resources. Reducing use of virgin resources saves the energy investment during the stages of ore mining, ore dressing and smelting. As a result, greenhouse gas emissions, especially $CO_2$, could be reduced. It is notable that in addition to rich metal resources, E-waste contains a large number of toxic substances such as mercury, chromium and cadmium, which can leach into the surrounding environment and endanger human health if not disposed of properly. Therefore, regularly recycling E-waste can contribute to renewing and reusing metal resources, and to controlling the flow of toxic substances and protecting human health.

Most developed countries already have E-waste legislation. These countries have relatively comprehensive and detailed laws governing E-waste recycling, including but not limited to the European Union's (EU) Directives on E-waste Recycling (Waste Electrical and Electronic Equipment (WEEE) Directive, Restriction of Hazardous Substances (RoHS), etc.), and the Law for the Recycling of Household Appliances of Japan. In China, the recycling, treatment and management of E-waste are still in an initial and exploratory stage. There are no relevant laws or regulations. In January 2011, China formally began to implement the Regulations on the Administration of Recycling and Disposal of Waste Electrical Appliances and Electronic Products ("the Regulation"), which clearly stipulates the subject of liability, supervision authorities, methods of penalty, etc., and it proposes to establish a national fund for treatment of E-waste. Nevertheless, detailed rules for implementing the Regulations have not been issued, and it is still not clear how economic liabilities will be dealt with. The investment in initial stages of E-waste treatment and ensuing costs on recycling, cannibalization and management are huge, and operations tend to be difficult without support from a special subsidy from the government (Wang et al., 2010). Therefore, both the producers and consumers of electronic products are responsible for corresponding costs or fees incurred by E-waste recycling and treatment to support effective management by the state. In developed countries such as Europe and the United States, where the Extended Producer Responsibility (EPR) system is used, the electronic product manufacturers are responsible for treating and recycling E-waste while consumers share a relatively lower financial responsibility. In contrast, the costs incurred in the process of E-waste treatment in Japan are mainly assumed by consumers. In China, it would be unreasonable to allocate the financial cost only on either producers or consumers based on its special conditions. Producers benefit from the sale of electronic products, and consumers benefit from the utility of entertainment. Thus, the cost of discarded electronic products ought to be shared by both producers and consumers.

This study aims to calculate the optimal cost allocation ratio between producers and consumers of electronic products by minimizing carbon dioxide emissions, where the cost allocation has not been specified in the Regulations, and provided that gross domestic product (GDP) growth will remain the same. The study also analyzes the changes in the volume of generation and recycling of E-waste, and the substitute relationship between the metal recycled from E-waste and primary metal.

There have been some studies that use economic instruments on waste management policies. Dinan (1993), Fullerton et al. (1995), Tong et al. (2011), Li et al. (2004) and Niu et al. (2008) analyzed the impact of waste tax on waste management policies. Higano (1995; 2000) and Miyata (2006) presented research about constructing environmental-social economic models, which covered both the circulation of economic value and of materials, and made a dynamic simulation analysis of the optimal environmental value-added tax. Li et al. (2005) and Matsumoto et al. (2007) analyzed the optimal tax-subsidy policy for air pollutant emissions reduction in Japan. Uchida and Higano (2006; 2010) evaluated energy systems policy through waste recovery and introduction of new technologies. Also with respect to E-waste recycling, Terazono (2010) analyzed the advantages and disadvantages of import and export trade between China and Japan on E-waste recycling and obtaining recycled metal resources. Yoshida et al. (2008) discussed the development of China's metal recycling industry, the contribution of metal recycling, and reuse in E-waste to the development of China's circular economy. However, Yoshida et al. (2008) did not predict the future potential of recycled metal utilization in China from the perspective of simulation experiments. In short, to the best of our knowledge, no study has examined the effects of increasing E-waste recycling and treatment while reducing $CO_2$ emissions, or how a recycling tax may affect E-waste treatment, use of recycled metal, and primary metal mining.

## 2. Model of Social and Economic Environment

### *2.1 Model Summary*

Achieving a circular economy is one of the key goals of China's Policy towards sustainability. However, there is always a conflict between promoting "economic development" and "reducing environmental pollution". Secondary metal, for instance, differs from primary metal in many ways, such as production process, energy consumption, environmental impacts and economic value, which relate directly or indirectly to all industry sectors. Furthermore, economic change in the industrial sectors will directly or indirectly affect the environment. Therefore, an optimal proportion coordinating all the factors can only be obtained by building an environmental-social economic model concerning both the economy and the environment.

In this research, we designed an environmental-social economic model by considering material balance and value balance. For this, we used an Input-Output table as a base. The economic agent in the model is shown in

Table 2. Figure 1 shows material flow and value flow between subjects. The model includes seven general industry sectors, one electronic product manufacturing sector, eight metal production sectors, the newly established E-waste processing sector, household consumption and the government sector.

The E-waste recycling tax set in the model was intended to be jointly shared by electronics manufacturers and consumers. Ad valorem duties were imposed on electronic product manufacturing enterprises according to unit production volume and on consumers by set according to the type of E-waste discharged (see the section 3.2 for details). The model also set up carbon emission tax. The total revenue of two kinds of taxes above is transferred for E-waste processing industry operations.

Based on the above conditions and on the carbon dioxide emission constraint, to maximize the yearly GDP for the study period (2008-2020), we adjust the allocation of E-waste recycling tax, and circulate E-waste recycling rates and the substitution relationship between recycled metal and virgin metal. Linear programming software LINGO of America LINDO Systems Company was used for simulation equipment.

*2.2 Preconditions*

First, due to data limitations, the E-wastes considered in this study only include the six most frequently used electronic waste products: televisions, refrigerators, computers, air conditioners, mobile phones and washing machines.

Second, electronic product innovations take place rapidly. Material use differs greatly among the same electronics of different years and models. By collecting references, this study adopts the average value (Table 3; see Li et al., 2006).

Third, this study does not include E-waste from import and export sources. The Basel Convention expressly prohibits E-waste import and export. However, there is trade in E-wastes for economic interests, termed “scrap metal”. Such E-waste is not included in present study because of the availability of statistics.

*2.3 Construction of the Model*

Table 4 shows the use and meaning of the subscripts in this simulation. Letters with cross-bars usually represent endogenous variables, but in this model they represent exogenous variables. The letter with the waved line means a vector diagonal matrix.

2.3.1 Balance of the Material Flow in Sectors of Usual Goods and Services

In the formula below, the left side represents the supply and the right side represents the demand. Usually, the supply of industrial sectors is greater than or equal to the demand. The input coefficient of production is the ratio of the input of each industry (based on the 2007 Input-Output Table of China) to the domestic volume of production (China National Bureau of Statistic, 2009).

$$\begin{aligned} X_1(t) \geq\ & A_{11}X_1(t) + A_{12}X_2(t) + A_{13}X_3(t) + A_{14}X_4(t) + C_1(t) + \overline{G}_1 + Q_{11}\Delta K_1(t) + \\ & Q_{12}\Delta K_2(t) + Q_{13}\Delta K_3(t) + Q_{14}\Delta K_4(t) + Q_{1g}\Delta K_g(t) + E_1(t) - M_1(t) + \overline{TZ}_1 \end{aligned} \tag{1}$$

Where

$X(t)$: Endogenous column vectors of products of each industry in the sector

$A$: Exogenous matrices of input coefficients of goods to each industry in the sector

$C(t)$: Endogenous column vectors of private consumption of goods

$\overline{G}$: Exogenous column vectors of governmental consumption of goods

$Q$: Exogenous matrices of input coefficients of goods for the fixed capital formation by each industry of the sector

$\Delta k(t)$: Endogenous column vectors of fixed capital formation by each industry of the sector

$E(t)$: Endogenous column vectors of the export of goods

$M(t)$: Endogenous column vectors of the import of goods

$\overline{TZ}$: Exogenous column vectors of the modulation of goods

2.3.2 Balance of the Material Flow in the Manufacture of Electronic Products

$$\begin{aligned} X_2(t) \geq\ & A_{21}X_1(t) + A_{22}X_2(t) + A_{23}X_3(t) + A_{24}X_4(t) + C_2(t) + \overline{G}_2 + Q_{21}\Delta K_1(t) + \\ & Q_{22}\Delta K_2(t) + Q_{23}\Delta K_3(t) + Q_{24}\Delta K_4(t) + Q_{2g}\Delta K_g(t) + E_2(t) - M_2(t) + \overline{TZ}_2 \end{aligned} \tag{2}$$

2.3.3 Balance of the Material Flow in Metal Producing Sectors

In this study, we assume a complete substitution relationship between the same kinds of metals; that is, the secondary metals processed from E-waste are all used for replacement of primary metals. Replacement rate is the ratio of secondary metal volume and primary metal volume; that is, the percentage of primary metal that can be saved if all secondary metals are used for industrial production. Generally, metal is the total of primary metal and secondary metal. Formulae 3 and 4 express the material balance. Metals are divided into 8 kinds. The first seven kinds of metals are commonly used in the industry, while the eighth kind (termed "other metal") mainly refers to precious metals such as gold and silver. However, given that the Input-Output Table does not make reclassification of such metals, in this study, such metals are collectively referred to as "other metal".

$$X_m(t) = X_3(t) + \widetilde{X}_4^j(t)^t TTP^j(t) \qquad (j = 1...8) \tag{3}$$

$$X_m(t) \geq A_{m1}X_1(t) + A_{m2}X_2(t) + A_{m3}X_3(t) + A_{m4}X_4(t) + E_m(t) - M_m(t) + \overline{TZ}_m \tag{4}$$

Where

$TTP(t)$: Endogenous row vectors of the unit income of recycled metal from E-waste

2.3.4 Balance of the Material Flow in the Sector of E-Waste Treatment

Consumer's E-waste discharge is divided into "recycled" and "not recycled". The recycled portion is all assumed to be treated, so there is no deposition, and "recovery quantity" means "handling capacity". The total material that was not recycled and processing residues are defined as final waste and assumed to be taken to the landfill. The weight of final waste is assumed to be equal to or smaller than that of the first year. Processing residues include nonmetals such as plastic, glass and rubber, which can be reused during the actual recycling process. Due to the focus on metal of this study, processing residues are included in the scope of final waste. E-waste genetic coefficient is fixed as an exogenous variable, which represents the production ratio of actual discharge of six kinds of E-waste and the corresponding electronic product in 2007. However, there are many factors influencing E-waste emergence size, such as service life of electronic products, consumption and demographic change, etc. Due to lack of relevant data, this study does not consider the above factors.

$$EWT_c^i(t) = Aet^i \cdot C_2(t) \tag{5}$$

$$W_{c-ewaste}(t) = Ae \cdot^t EWT_c^i(t) \tag{6}$$

$$EHT_c^i(t) = Ahc^i(t) \cdot E\widetilde{W}T_c^i(t) \tag{7}$$

$$R_{c-ewaste}(t) = Ae \cdot^t EHT_c^i(t) \tag{8}$$

$$X_4(t) = R_{c-ewaste}(t) \tag{9}$$

$$W(t) = W_{c-ewaste}(t) - X_4(t) + \widetilde{X}_4(t) \cdot SS \tag{10}$$

Where

$EWT_c^i(t)$: Endogenous row vectors of the amount of 6 kinds of E-waste discarded by consumers

$EHT_c^i(t)$: Endogenous row vectors of the amount of 6 kinds of E-waste amounts recycled by consumers

$Aet^i$: Exogenous row vectors of the amount of 6 kinds of E-waste discarded coefficient

$Ae$: Exogenous matrices of the component of 6 kinds of E-waste

$Ahc^i(t)$: Endogenous row vectors of the amount of 6 kinds of E-waste recycled and treated coefficient

$SS$: Exogenous column vectors of the non-recycled and residues discarded coefficient

$W_{c-ewaste}(t)$: Endogenous column vectors of 6 kinds of E-waste discarded heft

$R_{c-ewaste}(t)$: Endogenous column vectors of 6 kinds of E-waste recycled heft

$W(t)$: Endogenous column vectors of the non-recycled and residue of E-waste

2.3.5 Total $CO_2$ Emissions

Carbon dioxide emissions are obtained by multiplying the volume of production of all industries and consuming sectors by the emission factor.

$$W_{GHG}(t) = A_{1GHG}X_1(t) + A_{2GHG}X_2(t) + A_{3GHG}X_3(t) + A_{4GHG}X_4(t) + A_{cGHG} \cdot C_1(t) \tag{11}$$

Where

$W_{GHG}(t)$: Endogenous variable of total emission of $CO_2$, single value

$A_{GHG}$: Exogenous row vectors of $CO_2$ emission coefficients

2.3.6 Value Balances in General Sectors of Usual Goods and Services

The left side of the formula refers to the income and the right side to the expenses. The income of each industry shall not exceed the expenses of that industry. The price ratio of each industry in year 1 is set to 1 as the reference value for the price ratio of the later years.

$$P_1(t)\widetilde{X}_1(t) \le P_1(t)A_{11}\widetilde{X}_1(t) + P_2(t)A_{21}\widetilde{X}_1(t) + P_m(t)A_{m1}\widetilde{X}_1(t) + Y_{h1}(t) + \delta_1\widetilde{X}_1(t) + \tau_1\widetilde{X}_1(t) + Tkk \cdot A_{1GHG}\widetilde{X}_1(t) \tag{12}$$

Where

$P(t)$ : Endogenous row vectors of price ratio of goods

$Y_h(t)$ : Endogenous row vectors of the national income of each industry in the sector

$\delta$ : Exogenous row vectors of the depreciation rate of each industry in the sector

$\tau$ : Exogenous row vectors of the indirect tax rate of each industry in the sector

$Tkk$ : Exogenous value of $CO_2$ emission tax rate, the operating variable

2.3.7 Value Balances in Electronic Products Manufacturer

$$\left(1-\tau_2^{ri}\right)P_2(t)\widetilde{X}_2(t) \le P_1(t)A_{12}\widetilde{X}_2(t) + P_2(t)A_{22}\widetilde{X}_2(t) + P_m(t)A_{m2}\widetilde{X}_2(t) + Y_{h2}(t) + \delta_2\widetilde{X}_2(t) + \tau_2\widetilde{X}_2(t) + Tkk \cdot A_{2GHG}\widetilde{X}_2(t) \tag{13}$$

Where

$\tau_2^{ri}$ : Exogenous value of the tax rate for resources recycling assumed by the manufacturers of electronic products, the operating variable

$\tau_c^{ri}$ : Exogenous value of the tax rate for resources recycling assumed by the consumers, the operating variable

2.3.8 Value Balances in the Sector of Primary Metal Producing

$$P_3(t)\widetilde{X}_3(t) \le P_1(t)A_{13}\widetilde{X}_3(t) + P_2(t)A_{23}\widetilde{X}_3(t) + P_m(t)A_{m3}\widetilde{X}_3(t) + Y_{h3}(t) + \delta_3\widetilde{X}_3(t) + \tau_3\widetilde{X}_3(t) + Tkk \cdot A_{3GHG}\widetilde{X}_3(t) \tag{14}$$

2.3.9 Value Balances in the Industry of E-Waste Treatment

The value of the metal obtained from E-waste treatment is decided by the E-waste recycling tax. The operational income of an E-waste treatment industry should not exceed the cost of such treatment and the carbon emission tax paid.

$$TTP(t)\cdot \widetilde{X}_4(t) \le P_1(t)A_{14}\widetilde{X}_4(t) + P_2(t)A_{24}\widetilde{X}_4(t) + P_m(t)A_{m4}\widetilde{X}_4(t) + TTP(t)\cdot SS \cdot \widetilde{X}_4(t) + Y_{h4}(t) + \delta_4\widetilde{X}_4(t) + \tau_4\widetilde{X}_4(t) + Tkk \cdot A_{4GHG}\widetilde{X}_4(t) \tag{15}$$

2.3.10 Tax Revenue

The total amount of E-waste recycling tax is used for the E-waste treatment industry. Government revenue consists of direct taxes and indirect taxes. Direct taxes equal the product of income and direct tax rate. The expenses of the government include government consumption and savings.

$$RI(t) = \tau_2^{ri} \cdot P_2(t)X_2(t) + \tau_c^{ri} \cdot {}^t EWT_c^i(t) + Tkk \cdot W_{GHG}(t) \tag{16}$$

$$TTP(t)\cdot X_4(t) = RI(t) \tag{17}$$

$$TZE(t) = \tau^d\left\{l^tY_{h1}(t) + l^tY_{h2}(t) + l^tY_{h3}(t) + l^tY_{h4}(t)\right\} + \tau_1X_1(t) + \tau_2X_2(t) + \tau_3X_3(t) + \tau_4X_4(t) \tag{18}$$

$$TZE(t) = \overline{G}_1 + \overline{G}_2 + S^g(t) \tag{19}$$

Where

$RI(t)$ : Endogenous value of E-waste recycling tax

$TZE(t)$ : Endogenous value of the total government tax revenue

$S^g(t)$ : Endogenous value of government savings

$\tau^d$ : Exogenous value of direct tax rate

$l$ : A row vector for summation

2.3.11 Balance of Investment and Saving

On the left side, the sum of net investment and net export is equal to the sum of household savings and government savings on the right.

$$(l-\delta_1)\Delta K_1(t) + (l-\delta_2)\Delta K_2(t) + (l-\delta_3)\Delta K_3(t) + (l-\delta_4)\Delta K_4(t) + (l-\delta_g)\Delta K_g(t) + (E_1(t)-M_1(t))l + E_2(t) - M_2(t) + (E_m(t)-M_m(t))l = S^p(t) + S^g(t) \tag{20}$$

2.3.12 Household Consumption and Saving Level

Disposable income equals the excess of national dividend to the part paid as direct taxes. Disposable income is allocated according to the consumption ratio of different industries. Except for household savings, all dispensable income is used for consumption distribution. The product of disposable income and resident savings rate is equal to the amount of household savings.

$$Y_d(t) = (1-\tau^d)\{l^t Y_{h1}(t) + l^t Y_{h2}(t) + l^t Y_{h3}(t) + l^t Y_{h4}(t)\} \quad (21)$$

$$P_1(t)\widetilde{C}_1(t) + Tkk \cdot A_{cGHG} \cdot \widetilde{C}_1(t) = Y_d(t)\alpha_1 \quad (22)$$

$$P_2(t)C_2(t) + \tau_c^{ri} \cdot l^t EWT_c^i(t) = Y_d(t)\alpha_2 \quad (23)$$

$$S^p(t) = \beta Y_d(t) \quad (24)$$

$$l^t\alpha_1 + l^t\alpha_2 + \beta = 1 \quad (25)$$

Where

$Y_d(t)$ : Endogenous value of the disposable income of the household sector

$\alpha$ : Exogenous row vectors of the consumption with goods in general sectors

$S^p(t)$ : Endogenous value of personal savings

$\beta$ : Exogenous value of saving ratio

2.3.13 Balance of Capital and Production

The product of production volume and capital coefficient of production is less than or equal to capital.

$$\gamma X(t) \le K(t) \quad (26)$$

Where

$\gamma$ : Exogenous column vector of capital and production coefficient of each industry in sector

2.3.14 Dynamic Equations of Capital Stock

By this linkage equation, the model can be expressed as a prediction model for economic and environmental status for the next 13 years.

$$K(t+1) = (l-\delta)\widetilde{K}(t) + {}^t\Delta K(t) \qquad (t \le 12) \quad (27)$$

2.3.15 Limiting $CO_2$ Emissions

In 2009, the Chinese government announced that it would reduce the intensity of carbon emissions by 40-45% per unit of GDP in 2020, using 2005 as a baseline. In 2005, China's GDP was about 18 trillion Yuan, and carbon dioxide emission was about 5.8 billion tons. That means carbon dioxide emissions per unit GDP were 3.05405t-$CO_2$/ ten thousand Yuan. To reduce the $CO_2$ intensity by 40-45%, the carbon dioxide emission per unit GDP in 2020 should be 1.67973-1.83243t-$CO_2$/ ten thousand Yuan. However, improving the intensity of $CO_2$ emissions does not necessarily mean reducing the total release of $CO_2$ emissions. Therefore, to reduce carbon dioxide emissions, this study limits the carbon dioxide emissions across the 13 year study period to the baseline level, which is less than or equal to emissions in 2005.

$$W_{GHG}(t) \le W'_{GHG}(t) \quad (28)$$

Where

$W_{GHG}(t)$ : Exogenous value of the actual level of the emission of the $CO_2$ pollution as of 2005 in China

2.3.16 Balance of Energy

Energy consumption by the primary metal occurs in the process of ore mining, ore dressing and smelting. Energy consumption by the recycled metal occurs in treating discarded metal and melting with the primary metal. However, given that the proportion of energy expended during melting is very small, this study does not involve that calculation.

$$e \cdot X_1^6(t) \ge q_1X_1(t) + q_2X_2(t) + q_3X_3(t) + q_4X_4(t) + q_c \cdot C_1(t) \quad (29)$$

$$BMe(t) = K\widetilde{m}a \cdot X_4^j(t) + q_3 \cdot {}^tTTP^j(t) \cdot X_4^j(t) \qquad (j = 1...8) \quad (30)$$

$$RMe(t) = \widetilde{q}_4^{\,j} \cdot X_4^j(t) \qquad (j = 1..8) \quad (31)$$

$$EMe(t) = BMe(t) - RMe(t) \quad (32)$$

Where

$e$ : Exogenous value of the supply coefficient of energy

$q$ : Exogenous row vectors of the consumption coefficient of energy

$BM_e(t)$ : Endogenous column vectors of the energy expended in the production of primary metal with the amount equal to that of the recycled metal

$Kma$ : Exogenous column vectors of the consumption coefficient of energy expended in the process of ore mining

$RM_e(t)$ : Endogenous column vectors of the consumption coefficient of energy of the recycled metal from the E-waste treatment

$EM_e(t)$: Endogenous column vectors of the energy saved

2.3.17 Maximization of the Objective Function (GDP)

$$Max \quad GDP(t) = V_1X_1(t) + V_2X_2(t) + V_3X_3(t) + V_4X_4(t) \tag{33}$$

Where

$V$: Exogenous row vectors of the value-added rate of each industry in sector

*2.4 Setting Cases in Simulation Experiments*

By restricting carbon dioxide emissions, the maximum GDP sum of the 13 years is obtained, followed by three kinds of E-waste recycling tax rates, six kinds of E-waste recycling treatment rates, and the replacement ratio of secondary metal and primary metal, etc. The different cases are shown in Table 5.

Case0 is the Basic Case; that is, the case forecasting and analyzing the economic trends in China during the period 2008-2010 by only restricting $CO_2$ emission without E-waste recycling taxes and the E-waste treatment industry. In Case1 to Case6, the E-waste treatment industry is introduced together with all or part of E-waste recycling taxes. Three kinds of E-waste recycling tax rates are set as exogenous variables, which can be adjusted to obtain the maximum of the total GDP of the 13 years, the rate of E-waste recycling and treatment, and the substitution ratio of recycled metal and primary metal.

## 3. Result of Simulation Experiments

*3.1 Basic Case*

Under the premise of restricting $CO_2$ emissions and following the current situation where no E-waste recycling tax is introduced and there is no industry of E-waste treatment, the economic trends of China in 2008-2020 are forecasted (Figure 2).

First, when $CO_2$ emissions of the 13 years are fixed to the level less than or equal to the 2005 benchmark, the average growth rate of GDP over 13 years is 1.02%, which is much lower than the 8% expected value set by the Chinese government. However, as with $CO_2$ emissions per unit GDP (see Figure 2: Basic Case), the value has significantly decreased compared with the actual value in 2008-2010 (calculated according to the total energy consumed in 2006 to 2011 in *the Yearbook of Energy Statistic of China*, which has been converted to $CO_2$ emission, and the GDP in 2006 to 2011 in *the Yearbook of Statistic of China*). In each year, the $CO_2$ emissions per unit GDP can reach the reduction goal.

Second, we also included a simulation forecast implemented to correspond with the carbon dioxide emissions per unit GDP by 2020 (Figure 2: Objective Case). In modular form (28) in 2.3.15, the restriction formula is set between 1.67973-1.83243t-$CO_2$/ten thousand Yuan for carbon dioxide emissions per unit GDP of year 13 (2020). The result shows that with the growth of GDP, carbon dioxide emissions per unit GDP reach their peak at year 8 (2015). Though the emissions of per unit GDP in 2020 can reach the standard, the total emissions are 2.41 times higher than those in 2005. As mentioned above, the goal of carbon emissions reduction cannot be achieved only by restricting $CO_2$ emissions per unit GDP. Therefore, the following cases limit the $CO_2$ emissions to 2005 levels.

*3.2 The Introduction of E- waste Treatment Industry and E-waste Recycling Taxes*

In Japan, consumers pay recycling fees for discarded E-waste (namely, computers, washing machines, air conditioners, televisions and refrigerators). Compared with the sale price of each set, the recycling fee of a computer equals about 2% of its sale price; for washing machines, the proportion is about 3%; for air conditioners, the proportion is about 2%; for television sets, the proportion is about 3%; and for refrigerators, the proportion is about 3% (Price of Home Appliances, 2010; Association for Electric Home Appliances, 2010). Cell phones have not yet been included in the recycling scheme. In this study, the recycling fee of a mobile phone is temporarily set as 2% of its sale price. According to the above proportions, the E-waste recycling fee imposed on Chinese consumers shall be set as 20 to 40 Yuan each mobile phone, 100 to 120 Yuan each computer, 100 to 120 Yuan each washing machine, 100 to 120 Yuan each air conditioner, 90 to 110 Yuan each TV set and 90 to 110 Yuan each refrigerator.

Case1: The tax is only imposed on manufacturers of electronic products. The tax rate is calculated one by one from 0% to 50% of the volume of production, but no results were obtained.

Case2: The tax is only imposed on consumers. In this case, each fee set above has been used for trial calculation but no results were obtained.

Case3: Only carbon the emissions tax is imposed. Results were obtained when the tax was more than 60

Yuan/t-$CO_2$. No results were obtained if the tax is smaller than 60 Yuan/t-$CO_2$.

Case4-Case6: These cases combine different E-waste recycling tax rates. In the case6 (Figure 3: Best Case), the total GDP of the 13 years can be maximized and the average growth rate of GDP is 1.07% (the construct of tax or fee imposed on different objective is as follows: Fees imposed on consumers: 30 Yuan/set for mobile phones, 110 Yuan/set for computers, 110 Yuan/set washing machines, 110 Yuan/set for air conditioners, 100 Yuan/set for televisions, and 100 Yuan/set for refrigerators; Tax imposed on electronic products manufacturers for resource renewable tax 4% of unit value of production; Tax imposed on enterprises for carbon dioxide emissions is 68.9 Yuan/t-$CO_2$.) However, the value of maximized GDP is far from the Chinese government's goal which keep GDP average growth rate at more than 8%. Therefore to lower the environmental load while maintain the 8% GDP growth rate, advanced E-waste processing technology must be imported to balance the relationship between economic development and easing the environment load, which is also the focus of the author afterwards. Additionally, compared with the Basic Case, the volume of production of primary metal manufacturing and the enterprises with large $CO_2$ emissions can be restricted to a certain extent by introducing recycling taxes. However, the simulation experiments showed that developing newly built industries of E-waste treatment more vigorously, and the total GDP of the 13 years in the Best Case is larger than that in the Basic Case. This difference can be attributed to the high added value of the newly established enterprises of E-waste treatment and to the fact that $CO_2$ emissions of such enterprises are smaller than those of primary metal manufacturing.

Sensitivity analysis is shown in Table 6. The sensitivity coefficient is the ratio of the total GDP of the 13 years under each case and the total GDP of the 13 years under the Best Case. The changes in the tax rate for electronic products manufacturing have the greatest relevance to changes in GDP. Compared with the 4% tax rate, the sensitivity coefficient reduces by 0.0366951 when the tax rate is increased by 0.01%, and the sensitive coefficient reduces by 0.0226796 when the tax rate is decreased by 0.01%; both of the above changes are larger than changes in the sensitivity coefficient of the other two tax rates.

### *3.3 The Substitution Relationship of Metal under the Best Case*

#### 3.3.1 Estimation of the Volume of E-waste Recycling Rate

In 2007, discarded E-waste in China included 40.7 million mobile phones, 30.79 million computers, 9.9 million washing machines, 77.12 million air conditioners, 24.5 million televisions and 72.75 million refrigerators. Assuming that all the E-waste can be recycled and treated, the potential for eight reusable metals to be recycled in 2007 can be estimated by multiplying the six kinds of components of E-waste, as shown in Table 3, with the volume of E-waste units. Accordingly, the potential volume of eight kinds of metals in 2007 is: 1,520,000 tons of iron, 290,000 tons of copper, 180,000 tons of aluminum, 2,559 tons of lead, 20,000 tons of zinc, 2,375 tons of nickel, 6,846 tons of tin, and 177 tons of other metals. These products would account for 0.31% (iron), 8.32% (copper), 1.46% (aluminum), 0.09% (lead), 0.43% (zinc), 2.05% (nickel), 4.60% (tin) and 0.32% (other metals) of the production volume of primary metal. However, due to the incomplete recycling system and the uncertainty in the allocation of recycling costs in practice, the recycling rate is less than 6% of the total volume of E-waste (the recycling rate of mobile phone is 1.95%, rate for computers is 2.52%, rate for washing machines is 5.36%, rate for air conditioners is 4.51%, rate for televisions is 5.2% and rate for refrigerators is 5.95%). A large amount of valuable metals cannot be recycled and reused, which causes a huge waste of resources.

Figure 4 illustrates the average recycling rate for six kinds of E-waste in 13 years in the Best Case. Mobile phones have the highest average rate of recycling and treatment for the 13 years; that is, the mobile phone rate is 72.15%, followed by that of air conditioners at 59.68%, washing machines at 57.63%, televisions at 54.34%, computers at 53.55% and refrigerators at 35.50%. Compared with the rate of recycling and treatment in 2007, mobile phones have the highest increase. Although mobile phones are light in weight, they have the largest volume. In addition, the proportions of other metals (such as gold, silver and other highly precious metals), nickel and tin in mobile phones are higher than that in other 5 kinds of E-waste. Therefore, more recycled mobile phones are involved in the simulation experiment.

#### 3.3.2 Metal Substitution Relationship

In order to maintain stable economic development, China should ensure the balance between the supply and demand of metal resources. Through the simulation forecast test, eight kinds of metals recycled in best case (year 13) are: 13.71 million tons of iron, 3.37 million tons of copper, 1.97 million tons of aluminum, 20,000 tons of lead, 160,000 tons of zinc, 20,000 tons of nickel, 70,000 tons of tin, and 1,600 tons of other metals. In year 13, the ratio of production quantity of alternative primary metal processed from E-waste is shown in Table 7. Due to low carbon dioxide emissions during the treatment process and great market demand, and so on, the alternative effect of copper and tin is the most significant. The average substitution rates of year 13 are 30.50% for tin and 29.25% for copper. The substitution rates of other six valuable metals are: 16.30% for aluminum, 12.24% for nickel, 4.50% for zinc, 2.67% for iron, 0.68% for lead, and 0.19% for other metals. Regarding energy consumption, Table 8 demonstrates that the excess $CO_2$ emissions for primary metal exploitation, whose emissions equal those of recycled metal, is the quantity of energy saved. This provided that the excess is above zero, which means that the energy for recycling is less than the energy for mining in respect to that metal (see Formula 29-32). The energy savings for aluminum are the most obvious, followed by copper and tin.

## 4. Discussion and Conclusion

On January 1, 2011, China began to officially implement the Regulations on the Administration of Recycling and Disposal of Waste Electrical Appliances and Electronic Products to strictly manage manufacturers and regulate the entire E-waste recycling industry by levying a resource renewable tax on electronic products manufacturing and consumption. In this context, this study, introduces a model which restricts $CO_2$ emissions and forecasts the economic development of China during 2008-2020. The study estimates the volume of E-waste recycling rate during that period and solves the substitution relationship between recycled metal and primary metal by introducing environment taxes. The result shows that the total GDP of the 13 years can be maximized by imposing: 1) a recycling fee on consumers (mobile phone 30 Yuan/set, computer 110 Yuan/set, washing machine 110 Yuan/set, air conditioner 110 Yuan/set, TV 100 Yuan/set and refrigerator 100 Yuan/set), 2) a 4% recycling tax per unit production on manufacturers, and 3) a 68.9 Yuan/t-$CO_2$ carbon tax. In doing so, the substitution relation between secondary metal and primary metal from E-waste is obtained, considering carbon dioxide emissions during the E-waste recycling process, treatment costs, market demand on metal, metal price, etc. Therefore, the allocation of economic liabilities, which is not specified in the regulation, can be solved as described above between enterprises and consumers. The substitution rates of iron, lead and other metals are less than 2%, with insignificant alternative effect. By contrast, tin and copper have the most significant substitution effect, with average substitution rates of 30.90% and 29.25% for year 13. Considering both economic and environmental factors, the forecast on this significant substitution effect shows that more attention should be paid to copper and tin recovery.

There are important factors that this study has not addressed. For one, the study does not take into account the service life of products, the buying power of the consumers and the changes in the population into consideration in the forecast of the volume of E-waste. Meanwhile, the study does not conduct a comparison of the effects of domestic equipment and foreign equipment in the selection of treatment equipment. In addition, with respect to policies, the study refers to the experience of Japan who adopts “post-paid” approach for consumers, but such policy is not suitable to the specific circumstance in China. This is because that the most significant barrier to managing E-waste in China is how to guarantee that E-waste is recycled. If the post-paid system is imposed on consumers, it will be even more difficult to guarantee the volume of E-waste recycling. Accordingly, in future research, the author will consider a pre-paid policy on consumers. When the product is discarded, the consumer who delivers E-waste to the designated recycling management center can be reimbursed accordingly. This could guarantee the volume of E-waste recycling, and it could use the pre-paid fees from consumers for capital turnover in the E-waste treatment industry. The above three points will be supplemented and completed in the following studies.

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Table 1. Trends in supply and demand of major metals in China and their respective worldwide shares

| Metal | Year | Production | | | Consumption | | | Domestic Supply and Demand Balance in China |
|---|---|---|---|---|---|---|---|---|
| | | China | the World | Share | China | the World | Share | |
| Fe | 2006 | 418,780 | 1,247,178 | 33.58% | 384,050 | 1,113,200 | 34.50% | 34,730 |
| | 2007 | 489,175 | 1,346,130 | 36.34% | 402,500 | 1,178,600 | 34.15% | 86,675 |
| | 2008 | 500,312 | 1,327,189 | 37.70% | 442,800 | 1,250,500 | 35.41% | 57,512 |
| Cu | 2006 | 3,003 | 17,343 | 17.32% | 3,614 | 16,974 | 21.29% | -611 |
| | 2007 | 3,499 | 17,980 | 19.46% | 4,863 | 18,099 | 26.87% | -1,364 |
| | 2008 | 3,795 | 18,480 | 20.53% | 5,134 | 18,084 | 28.39% | -1,339 |
| Al | 2006 | 9,358 | 33,971 | 27.55% | 8,648 | 34,366 | 25.16% | 710 |
| | 2007 | 12,588 | 38,141 | 33.01% | 12,347 | 37,953 | 32.53% | 241 |
| | 2008 | 13,178 | 39,883 | 33.04% | 12,413 | 38,147 | 32.54% | 766 |
| Pb | 2006 | 2,715 | 8,012 | 33.88% | 2,222 | 8,051 | 27.60% | 493 |
| | 2007 | 2,788 | 8,178 | 34.10% | 2,574 | 8,353 | 30.81% | 215 |
| | 2008 | 3,452 | 8,925 | 38.68% | 3,135 | 8,704 | 36.02% | 317 |
| Zn | 2006 | 3,163 | 10,660 | 29.67% | 3,156 | 10,896 | 28.96% | 7 |
| | 2007 | 3,743 | 11,357 | 32.95% | 3,632 | 11,295 | 32.15% | 111 |
| | 2008 | 4,042 | 11,662 | 34.66% | 4,019 | 11,361 | 35.37% | 24 |
| Ni | 2006 | 102 | 1,311 | 7.77% | 234 | 1,366 | 17.16% | -132 |
| | 2007 | 116 | 1,352 | 8.56% | 328 | 1,353 | 24.23% | -212 |
| | 2008 | 129 | 1,324 | 9.72% | 305 | 1,294 | 23.58% | -177 |
| Sn | 2006 | 132 | 351 | 37.59% | 115 | 362 | 31.68% | 17 |
| | 2007 | 149 | 349 | 42.61% | 134 | 357 | 37.50% | 15 |
| | 2008 | 140 | 343 | 40.76% | 128 | 337 | 37.94% | 12 |

Note: Data spans 2006 to 2008; Unit: kiloton

Data source: China Nonferrous Metals industry Association, 2009; China Metallurgical Industry Press, 2009

Table 2. Sectors classification and codes

| NO. | Usual Goods and Services | Manufacture of Electronic Products | |
|---|---|---|---|
| 1 | Agriculture, Forestry, Animal Husbandry & Fishery | Manufacture of Electronic Products | |
| 2 | Mining of Ferrous Metal Ores | | |
| 3 | Mining of Non-Ferrous Metal Ores | | |
| 4 | Mining and Processing of Nonmetal Ores and Other Ores | | |
| 5 | Other Manufacture | | |
| 6 | Production and Supply of Electric Power and Heat Power | | |
| 7 | Construction and Service Industry | | |
| NO. | Metal Producing | E-waste Treatment | |
| 1 | Steel | Steel | E-waste Component |
| 2 | Copper | Copper | |
| 3 | Aluminum | Aluminum | |
| 4 | Lead | Lead | |
| 5 | Zinc | Zinc | |
| 6 | Nickel | Nickel | |
| 7 | Tin | Tin | |
| 8 | Other Metals | Other Metals | |
| 9 | - | Other Discarded | |

Table 3. The components of 6 types of E-waste

| Material | Mobile Phone | Computer | Washing Machine | Air Conditioner | Television | Refrigerator |
|---|---|---|---|---|---|---|
| Fe | 0.00606 | 30.43438 | 18.28037 | 13.03215 | 1.40761 | 36.87560 |
| Cu | 0.00784 | 1.40000 | 4.32636 | 13.05389 | 1.91845 | 7.84754 |
| Al | 0.01020 | 1.85000 | 1.41991 | 8.66505 | 1.02297 | 2.83133 |
| Pb | 0.00011 | 0.06798 | 0.00703 | 0.01768 | 0.00684 | 0.01213 |
| Zn | 0.00044 | 0.16758 | 0.35974 | 0.18580 | 0.01909 | 0.73554 |
| Ni | 0.00047 | 0.07417 | 0.00111 | 0.00278 | 0.00107 | 0.00191 |
| Sn | 0.00016 | 0.10550 | 0.10657 | 0.07679 | 0.01566 | 0.21441 |
| Other Metal | 0.00027 | 0.00441 | 0.00046 | 0.00115 | 0.00044 | 0.00079 |
| Waste | 0.07445 | 15.89597 | 8.49846 | 6.96472 | 25.60785 | 11.48075 |
| Total | 0.1 | 50 | 33 | 42 | 30 | 60 |

Note: Unit: kg/set

Data source: E-waste treatment technology (Li et al., 2006)

Table 4. List of subscripts

| Index | Meaning | Index | Meaning | |
|---|---|---|---|---|
| 1 | Usual Goods and Services | i | 1= mobile telephone | 2= computer |
| 2 | Manufacture of Electronic Products | | 3= washing machine | 4= air-conditioning |
| 3 | Primary Metal Producing | | 5=TV | 6= refrigerator |
| 4 | E-waste | j | 1= Steel | 2= Copper |
| m | Total Metals | | 3= Aluminum | 4= Lead |
| g | Government | | 5= Zinc | 6= Nickel |
| | | | 7= Tin | 8= Other Metals |

Table 5. Case settings in simulation experiments

| Case | E-waste | $\tau_2^{ri}$ | $\tau_c^{ri}$ | Tkk | $CO_2$ |
|---|---|---|---|---|---|
| Case0 | × | × | × | × | ○ |
| Case1 | ○ | ○ | × | × | ○ |
| Case2 | ○ | × | ○ | × | ○ |
| Case3 | ○ | × | × | ○ | ○ |
| Case4 | ○ | ○ | ○ | × | ○ |
| Case5 | ○ | ○ | × | ○ | ○ |
| Case6 | ○ | ○ | ○ | ○ | ○ |

Note:

$\tau_2^{ri}$: Exogenous value of recycling tax rate assumed by the manufacturers of electronic products

$\tau_c^{ri}$: Exogenous value of recycling fees paid by consumers for each discarded set of the 6 kinds of E-waste

Tkk: Exogenous value of carbon tax rate, the operating variable

Table 6. Sensitivity analysis of the best case

| Case | Basic | Best | Case6 (-0.1) | Case6 (+0.1) |
|---|---|---|---|---|
| $\tau_2^{ri}$(%) | - | 4 | 4 | 4 |
| $\tau_c^{ri}$(Yuan/ set) | - | 30(mobile phone)<br>110(computer)<br>110(washing machine)<br>110(air conditioner)<br>100(TV)<br>100(refrigerator) | 29.9(mobile phone)<br>109.9(computer)<br>109.9(washing machine)<br>109.9(air conditioner)<br>99.9(TV)<br>99.9(refrigerator) | 30.1(mobile phone)<br>110.1(computer)<br>110.1(washing machine)<br>110.1(air conditioner)<br>100.1(TV)<br>100.1(refrigerator) |
| Tkk(Yuan/t-$CO_2$) | - | 68.9 | 68.9 | 68.9 |
| Sensitive coefficient | 0.8194983 | 1.0000000 | 0.9974055 | 0.9999990 |
| Case | Case6(68.8) | Case6 (69) | Case6 (3.99%) | Case6 (4.01%) |
| $\tau_2^{ri}$(%) | 4 | 4 | 3.99 | 4.01 |
| $\tau_c^{ri}$(Yuan/ set) | 30(mobile phone)<br>110(computer)<br>110(washing machine)<br>110(air conditioner)<br>100(TV)<br>100(refrigerator) | 30(mobile phone)<br>110(computer)<br>110(washing machine)<br>110(air conditioner)<br>100(TV)<br>100(refrigerator) | 30(mobile phone)<br>110(computer)<br>110(washing machine)<br>110(air conditioner)<br>100(TV)<br>100(refrigerator) | 30(mobile phone)<br>110(computer)<br>110(washing machine)<br>110(air conditioner)<br>100(TV)<br>100(refrigerator) |
| Tkk(Yuan/t-$CO_2$) | 68.8 | 69 | 68.9 | 68.9 |
| Sensitive coefficient | 0.9999345 | 0.9870968 | 0.9773204 | 0.9633049 |

Table 7. Substitution rate of recycled metal and primary metal in E-waste

| Year | Fe | Cu | Al | Pb | Zn | Ni | Sn | Other | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2007 | 0.02 | 1.54 | 0.23 | 0.01 | 0.03 | 0.07 | 0.41 | 0.002 | 0.02 |
| 1 | 0.13 | 1.15 | 0.36 | 0.05 | 0.11 | 1.04 | 1.47 | 0.01 | 0.13 |
| 2 | 4.13 | 24.39 | 3.01 | 1.07 | 7.77 | 17.16 | 21.99 | 0.05 | 4.13 |
| 3 | 4.69 | 33.34 | 27.78 | 1.19 | 7.25 | 19.55 | 30.79 | 0.19 | 4.69 |
| 4 | 5.16 | 33.34 | 30.05 | 1.21 | 8.03 | 19.70 | 53.69 | 0.46 | 5.16 |
| 5 | 4.65 | 33.34 | 29.10 | 1.11 | 7.54 | 18.19 | 51.04 | 0.42 | 4.65 |
| 6 | 1.66 | 34.15 | 33.33 | 0.37 | 3.28 | 3.01 | 28.08 | 0.12 | 1.66 |
| 7 | 3.66 | 33.34 | 26.92 | 0.96 | 5.86 | 16.58 | 43.44 | 0.37 | 3.66 |
| 8 | 3.21 | 33.34 | 26.65 | 0.57 | 7.71 | 7.72 | 46.75 | 0.23 | 3.21 |
| 9 | 2.38 | 33.34 | 10.57 | 0.29 | 2.24 | 13.81 | 37.76 | 0.09 | 2.38 |
| 10 | 1.27 | 33.34 | 7.69 | 0.51 | 1.72 | 11.52 | 19.67 | 0.17 | 1.27 |
| 11 | 1.26 | 33.34 | 5.26 | 0.45 | 2.64 | 9.18 | 23.39 | 0.08 | 1.26 |
| 12 | 1.26 | 33.34 | 5.79 | 0.44 | 2.69 | 8.98 | 23.59 | 0.15 | 1.26 |
| 13 | 1.25 | 20.60 | 5.44 | 0.59 | 1.67 | 12.68 | 19.99 | 0.16 | 1.25 |
| Average | 2.67 | 29.25 | 16.30 | 0.68 | 4.50 | 12.24 | 30.90 | 0.19 | 2.67 |

Note: Units are by percentage.

Table 8. Reductions in $CO_2$ emissions

| Year | Fe | Cu | Al | Pb | Zn | Ni | Sn | Other | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2007 | -182 | 173 | 145 | 0 | -2 | 5 | 58 | 2 | 200 |
| 1 | -1,429 | 155 | 237 | 2 | -6 | 95 | 233 | 13 | -699 |
| 2 | -5,925 | 1,699 | 1,666 | 6 | -39 | 272 | 1,187 | 46 | -1,087 |
| 3 | -6,241 | 1,763 | 1,833 | 7 | -37 | 320 | 1,204 | 52 | -1,098 |
| 4 | -6,683 | 1,897 | 1,943 | 8 | -41 | 335 | 1,303 | 56 | -1,182 |
| 5 | -6,100 | 1,855 | 1,870 | 7 | -38 | 296 | 1,208 | 51 | -851 |
| 6 | -1,900 | 2,069 | 2,090 | 2 | -17 | 32 | 472 | 14 | 2,762 |
| 7 | -4,937 | 1,675 | 1,709 | 6 | -30 | 247 | 979 | 44 | -306 |
| 8 | -4,269 | 1,963 | 1,674 | 3 | -39 | 109 | 1,011 | 27 | 479 |
| 9 | -3,582 | 978 | 993 | 4 | -23 | 172 | 692 | 30 | -736 |
| 10 | -1,974 | 414 | 482 | 3 | -9 | 127 | 357 | 20 | -580 |
| 11 | -1,988 | 375 | 361 | 2 | -13 | 95 | 386 | 18 | -765 |
| 12 | -1,987 | 375 | 363 | 2 | -14 | 93 | 389 | 17 | -761 |
| 13 | -2,013 | 231 | 341 | 3 | -8 | 133 | 332 | 19 | -964 |
| average | -49,028 | 15,449 | 15,561 | 55 | -313 | 2,326 | 9,755 | 407 | -5,788 |

Note: Units are in thousand tons.

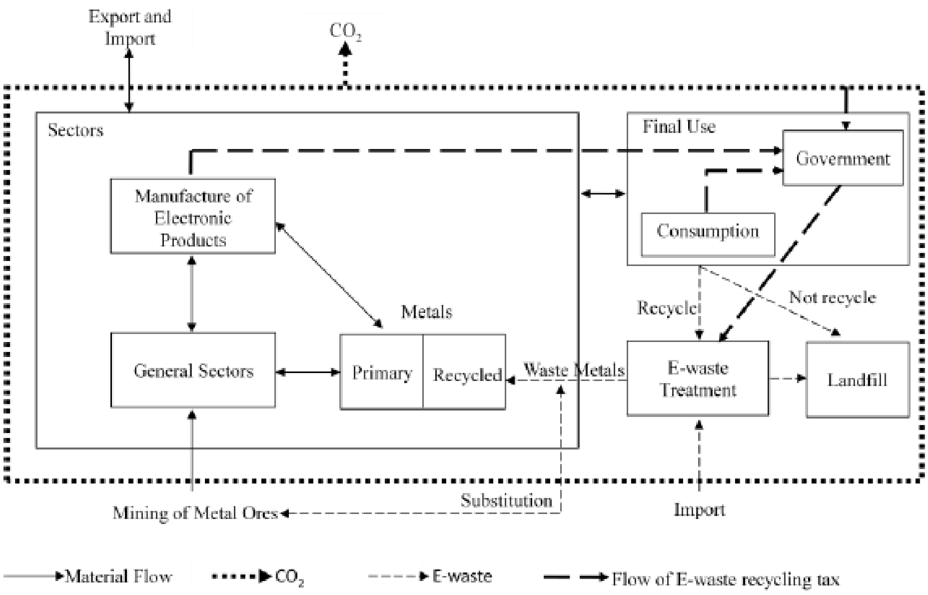
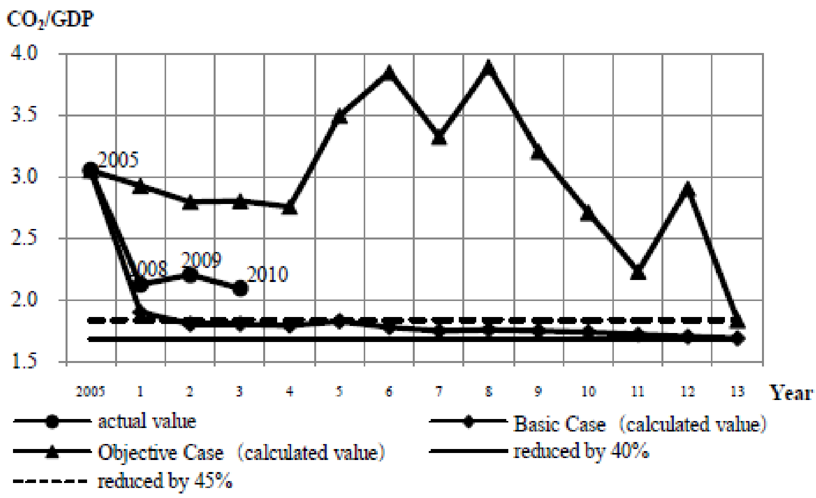



Figure 1. Framework of the relationship between economic subjects in environmental-social economic model




Data source: "actual value": calculated according to the total energy consumed in 2006 to 2011 in *the Yearbook of Energy Statistic of China*, which has been converted to $CO_2$ emission, and the GDP in 2006 to 2011 in *the Yearbook of Statistic of China*

Figure 2. Changes in $CO_2$ Emissions per unit GDP

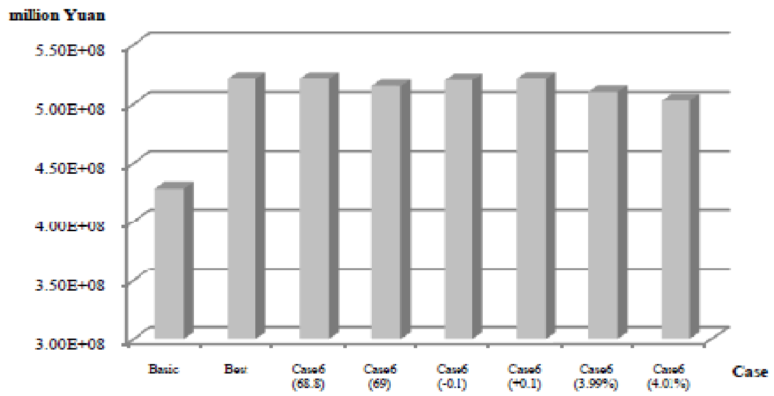



Figure 3. GDP Combined Forecast in the 13 year (Calculated value) following the introduction of E-waste Recycling Taxes

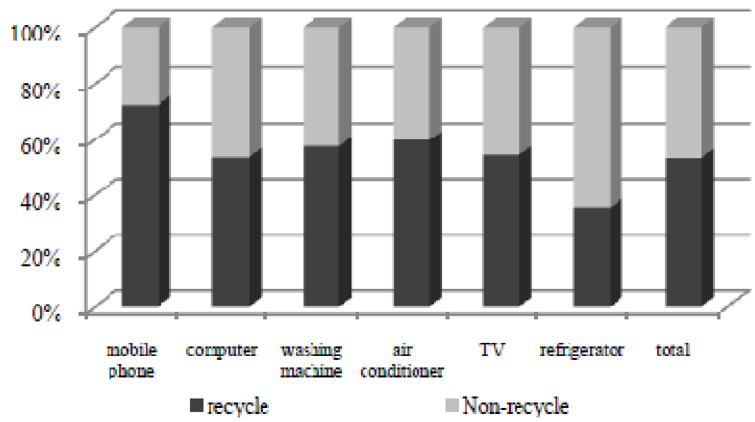



Figure 4. Average Rate of Recycling and Treatment of E-waste in the 13 year study period

(Calculated value)