The 18th International Input-Output Conference 2010

University of Sydney, Sydney, Australia, 20-25 June 2010

Green Growth Accounting with Combined Use of Hybrid Input-Output Tables and Supply - Use Matrix

Hak K. Pyo*, Dong Koo Kim† and Keun Hee Rhee‡

Abstract

Korea recently adopted an eco-friendly policy on economic growth called the Green Growth Policy. To find a theoretical base for the policy, this study conducts a structural decomposition analysis of carbon dioxide emission changes in Korea based on green growth accounting which combines hybrid input-output tables with supply and use matrix. The advantage of incorporating Supply-Use matrix in a structural decomposition analysis lies in improvement for consistent forecasting of GDP based on different scenarios of CO2 emission targets because the Supply-Use matrix links Input-Output Tables to National Income Account. This study estimates the growth rate of future gross domestic product based on the recently adopted CO2 emission reduction targets and the effect of CO2 reduction on employment through combined use of hybrid input-output tables with Supply-Use Matrix.

Keywords: Green Growth Accounting, Hybrid Input-Output Analysis, CO2 Emission Coefficient, Structural Decomposition Analysis.

JEL Classification: D24, D57, O47, Q56

* Director, Center for National Competitiveness and Faculty of Economics, Seoul National University, Seoul 151-746, Korea. Tel: +82-2-880-6395. Fax: +82-2-886-4231. E-mail: pyohk@plaza.snu.ac.kr. Corresponding author.

† Ph.D. Candidate, Department of Economics, Seoul National University, Seoul 151-746, Korea. Tel: +82-10-8866-3455. E-mail: eastnine09@gmail.com.

‡ Senior Researcher, Korea Productivity Center, Seoul 110-751, Korea. Tel: +82-2-724-1054. E-mail: ghlee@kpc.or.kr

I. Introduction

In 2008, Korea adopted the “Green Growth Policy", an eco-friendly policy on economic growth. The policy aims to achieve sustainable development by harmonizing economic development, social equality, and environment protection.

Economic growth through modern industrialization has been accompanied by large consumption of fossil fuels and environmental pollution. Among air pollutants, greenhouse gases (GHG) induce global warming. The main greenhouse gases are carbon dioxide (CO2), nitrous oxide, methane, ozone, and chlorofluorocarbons (CFCs). As the Intergovernmental Panel on Climate Change (IPCC) (2007a) analyzed, “global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004. CO2 is the most important anthropogenic GHG. Its annual emissions grew by approximately 80% between 1970 and 2004.” [§]

The sharp rise in GHG emissions have resulted in global warming. The IPCC (2007a) reported that the average temperature of the world has risen by 0.74˚ C in the last century. This rise is outside the natural range of variance over the last several thousand years. Furthermore, the IPCC (2007a) projected that the global average temperature may jump by 6.4˚ C by the end of the 21st century. Global warming is believed to be the primary cause of abnormal climate changes, which result in droughts, flooding, and scorching heat. Stern (2006) estimated that the economic loss caused by climate change is approximately 5~20% of global annual gross domestic product (GDP).

Developed countries have realized the severity of environmental pollution and global warming; hence, they have been making efforts to achieve economic development in harmony with the environment. Conventions on climate change are part of such efforts. The Kyoto Protocol, which took effect on February 16, 2005, is the most representative convention for this issue. Under the Protocol, 37 industrialized countries, called "Annex I countries", have committed to the reduction of GHG such as carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydrofluorocarbons, and perfluorocarbons. These Annex I countries have agreed to reduce their 1990 collective greenhouse gas emission levels by 5.2% from 2008 to 2012.

In August 2009, the Korean government suggested three options for its CO2 reduction target in 2020. The three suggested options involved CO2 emission reduction goals of 21%, 27%, and 30% below the business-as-usual (BAU) [**] forecast by 2020 (see Table I-1). The government decided on a CO2 reduction goal of 30% by 2020. It also announced that an energy target management system in the business sector would be introduced by 2010. While Korea is not an Annex I country, it has decided to impose voluntary limitations on GHG emissions as a part of its Green Growth Policy. According to the Presidential Committee on Green Growth (2009), Korea emitted 594 million tons (MT) of CO2 in 2005 and the projected amount of CO2 emissions will be 813 MT by 2020.

[Table I-1]

Korea's targets are in line with European Union (EU)-recommended mandates for developing countries: 15%-30% reduction in total emissions. However, the 30% reduction plan seems to be a considerably ambitious target for Korea because its CO2 emissions doubled in 1990-2005. This jump is the sharpest rise among Organisation for Economic Co-operation and Development (OECD)

[§] IPCC (2007a), Climate Change 2007: Synthesis Report, p.5.

[**] The BAU estimate is the projected amount of emissions that Korea will produce if the economy continues to grow at its current pace and no special measures to curb emissions are implemented.

countries. In addition, Korea ranks 10th worldwide in the total amount of emissions, and 16th for cumulative emissions.

In addition to the CO2 reduction plan, the Korean government aims to achieve green growth through various policies such as the commercialization of 2 and above megawatt (MW) wind-power generation, 100 MW marine wind-power project, 100 MW (33 thousand housing units) solar energy system, and a renewable power supply (RPS) system by 2012. Taken this way, the green growth policy of Korea is enterprising. The United Nations Environment Programme (UNEP) (2009)[††] has noticed the fact that Korea was the first to set green growth as a national core paradigm, and has recognized that Korea is in the forefront of the world economy's green growth.

However, the comprehensive and systematic study of the actual effects of these policies on the economy remains insufficient. Although various policies and action plans regarding green growth have been suggested, there have been few studies on the tangible effects of these policies.

This study examines the green growth accounting theory, which can serve as the theoretical base of the Green Growth Policy. This theory estimates the impact of the environment on GDP. Moreover, it forecasts GDP changes according to the CO2 reduction target of Korea. This study likewise estimates CO2 emission coefficient and CO2 emissions of industries based on hybrid input-output (I-O) tables that combine environmental statistics with I-O tables. It analyzes the factors affecting changes in CO2 emissions by structural decomposition analysis (SDA).

This paper consists of five major sections. Section II presents the theoretical background of green growth accounting, as well as the green total factor productivity (TFP) estimates for Korea. In the Section III, the methods in constructing hybrid I-O tables are discussed, and CO2 emissions of Korea are estimated by industry and by energy type based on Korean I-O tables in 2005. In Section IV, main factors of CO2 emissions are examined through the SDA methodology. Finally, the last section offers concluding remarks.

II. Green Growth Accounting

The conventional growth accounting theory breaks output growth into the factors of production (e.g., labor, material capital, and human capital) and technological progress. Total factor productivity (TFP) measures the contribution of this progress, which is not accounted for by the factors of production. However, factor-driven growth is mired with limitations because of the lack of resources and the environmental crisis.

Extant literature points out the limitations of factor-driven growth, and provides new economic growth models by considering the environment. For instance, Bovenberg and Smulders (1995) examined the link between environmental quality and economic growth in an endogenous growth model that incorporates pollution-augmenting technological change. Bye (2002) analyzed the effect of green policy on economic growth by using the general equilibrium model.

Tzouvelekas et al. (2007) suggested a green growth model for measuring TFP growth by approximating, through CO2 emission levels, the use of the environment. They analyzed the economic growth of 23 OECD countries relative to that of USA from 1965 to 1990. According to their analysis, the CO2 emissions per GDP of 13 out of 21 countries increased; whereas, emissions per GDP decreased in the rest. They reported that the growth of CO2 per worker contributes to the growth of GDP per worker. In addition, they reported that countries with high growth of CO2 per

[††] United Nations Environment Programme (UNEP), "Interim Report on Korea's Green Growth Policy," August 20, 2009.

worker are associated with high growth of GDP per worker. Clearly, this indicates that the growth of CO2 per worker contributes to the growth of GDP per worker.

Following the methodology of Tzouvelekas et al. (2007), the GDP growth of Korea is decomposed into growth factors and environmentally adjusted TFP (Green TFP). The model is as follows:

$$\dot{TFP} = \dot{Y} - s_K \dot{K} - s_L \dot{L} - s_Z \dot{Z}$$

where $\dot{TFP}$: growth rate of Green TFP

Y : real value-added or GDP at 2000 constant prices (billion of Korean won)

K : real capital stock at 2000 constant prices (billion of Korean won)

L : number of workers (thousand persons)

Z : CO2 emissions (tons of carbon; TC)

s_K : capital income share

s_L : labor income share

s_Z : energy income share

Value-added or GDP growth, capital stock, number of workers, and income shares were taken from Korea Industrial Productivity (KIP) 2008 database, and CO2 emissions by industry were from hybrid I-O tables constructed in this paper. The analyzed periods were 1995, 2000, and 2005. All types of industries were included in the dataset and integrated into three major groups: (1) agriculture, fisheries, and mining; (2) manufacturing; and (3) services (hereafter Groups (1), (2), and (3), respectively).

[Table II-1]

Table II-1 shows that the decomposition result of value added growth at Period I (1995-2000) and Period II (2000-2005). The growth rates slowed down for Groups (1) and (2) from 1.1% and 7.6% to .2% and 6.4%, respectively. However, it increased from 3.1% to 3.8% for Group (3). The TFP growth rates for Groups (1) and (2) substantially dropped from -1.6% and 6.3% to -3.3% and 4.1%, respectively. The TFP growth rate for Group (3) considerably increased from -1.4% to .3%. This indicates that capital was the major factor contributing to the value-added growth of Group (1). However, the contributions of technological progress and environmental factor were notable in Group (2). In the case of Group (3), all factors evenly contributed to value added growth.

Meanwhile, the growth rates of environmental factor in Group (1), (2), and (3) at Period II were .3%, .8%, and .4%, respectively. The corresponding value-added growth rates were .2%, 6.4%, and 3.9%, respectively. By calculation, environmental factors contributed to value-added growth by 139%, 12%, and 10%[‡‡], respectively. In other words, the contribution of environmental factors to the economy explains these magnitudes of economic growth. Given that this study utilizes the amount of CO2 emissions from the burning of fossil fuels as the environmental factor, and that this amount is part of the total emissions caused by economic activities, then the estimated contribution of the environment to economic growth is at the minimum.

‡‡ 139%=3.0/2.16, 12%=7.63/64.3, 10%=3.93/3.9

[Figure II-1]

Figure II-1 shows the estimated amount of CO2 emissions every five years until 2020. In predicting the amount, the adjusted growth rate of CO2 emissions from 2000 to 2005 was employed. The declining growth rates in 1995-2000 and in 2000-2005 were also considered. It should be noted that CO2 emissions in Korea were estimated to jump to 778 MT by 2020. The CO2 emissions employed in this prediction includes only the amount from the burning fossil fuels; hence, the estimates are less than the total amount of CO2. Thus, in order for Korea to achieve the 30% reduction plan (i.e., 569 MT of emissions by 2020), progressive and active policies should be applied. Especially, more emphasis should be placed on not only the development and/or adoption of technologies for CO2 reduction and energy efficiency, but also industry restructuring favoring low CO2 emission industries. Figure II-2 shows the predicted amount of CO2 emissions by industry.

[Figure II-2]

[Table II-3]

Table II-3 shows the predicted growth rate of GDP under the CO2 reduction target. The expected average growth rate of GDP per year is 4.51% between 2005 and 2020 if current trends of CO2 emissions continue (without producing any costs). If Korea has to reduce its CO2 emissions prior to achieving successful green growth policy, then Korea should pay for using environmental factors in production; however, the GDP growth rate would definitely drop. Under the 30% reduction plan, GDP growth rate is predicted to drop to 3.92%, which is .59% points lower than the trend. Thus, promoting the Green Growth Policy prior to being required to reduce CO2 emissions is essential for Korea to achieve sustainable growth. Figure II-3 depicts the predicted GDP until 2020 with and without compulsory CO2 reductions.

[Figure II-3]

III. Hybrid Input-Output Tables

1. Theoretic background

[Table III-1]

Table III-1 is an example of the industrial identification of the Korean government's 17 new growth engines in I/O Tables 2005. However, conventional I-O tables constructed by the Bank of Korea do not include energy or environment factors. As such, it is impossible to identify or objectively evaluate green industries by simply using the tables. Hybrid I-O tables, which combine environmental statistics and I-O tables, are necessary. Table III-2 displays the structure of hybrid I-O tables.

[Table III-2]

Building hybrid I-O tables follows the methodology of Miller and Blair (2009). Assume that there are n different industries in an economy and m industries among them are energy industries. Likewise, assume that the transaction matrix between input-output industries, final demand, and total output in

the I-O tables are Z, Y, and X, respectively. Initially, money-based inputs from energy industries, such as petroleum, coal, and natural gas, are converted into physical units of energy (i.e., tonnage of oil equivalent (TOE)). Subsequently, the physical units are again converted into the amounts of CO2 by using carbon emission factors. This transaction matrix with CO2-based inputs from energy industries is set as Z^*. Final demand and total output are converted into CO2-based vectors, Y^* and X^*, respectively. Total output vector X^* consists of CO2 column X_j, and non-CO2 column X_k, where subscripts j and k are from 1 and m+1 to m and n, respectively. If Q is total CO2 emissions induced by the use of energy in an economy, hybrid vector Q^* of total CO2 emissions is composed of Q_k and zero vector, which becomes CO2 column and non-CO2 column, respectively. Thus, transaction matrix, final demand, total output, and total CO2 emission are converted into hybrid form.

$$Z^* = \begin{pmatrix} Z_j : CO_2 \text{ column} \\ Z_k : non-CO_2 \text{ column} \end{pmatrix} \qquad Y^* = \begin{pmatrix} Y_j : CO_2 \text{ column} \\ Y_k : non-CO_2 \text{ column} \end{pmatrix}$$

$$X^* = \begin{pmatrix} X_j : CO_2 \text{ column} \\ X_k : non-CO_2 \text{ column} \end{pmatrix} \qquad Q^* = \begin{pmatrix} Q_j : CO_2 \text{ column} \\ 0 : non-CO_2 \text{ column} \end{pmatrix}$$

where $j = 1, 2, \cdots, m$ and $k = m+1, \cdots, n$

Total output in hybrid form can likewise be expressed as the product of inverse matrix coefficient $(I - A^*)^{-1}$ and final demand.

$$X^* = (I - A^*)^{-1} Y^*$$

where X^*: total output in hybrid form (n×1)
I : identity matrix (n×n)
A^*: input coefficient in hybrid form (n×n)
Y^*: final demand in hybrid form (n×1)\

Input coefficient in hybrid form, A^* is derived by dividing each element of the transaction matrix Z^* with the corresponding element of total output X^*. A^* can also be calculated.

$$A^* = Z^* (\hat{X}^*)^{-1}$$

where $\hat{X}^*$: diagonalized matrix of X^* (n×n)

When vector Q^* of total CO2 emissions is diagonalized and its non-CO2 elements are removed, this becomes $\hat{Q}$ matrix. Put $\hat{X}^*$ as a diagonalized matrix of total output X^*. Direct CO2 emission coefficient α is defined as the product of $\hat{Q}$, the inverse matrix of $\hat{X}^*$, and input coefficient A^*. α implies the amount of CO2 directly generated by producing one unit of product at each industry.

Aggregate CO2 emission coefficient δ is defined as the product of matrix $\hat{Q}$, the inverse matrix of $\hat{X}^*$, and the inverse matrix coefficient $(I - A^*)^{-1}$. δ implies the total amount of CO2 generated by all industries in producing one unit of product at each industry.

Indirect CO2 emission coefficient β can be derived by subtracting direct CO2 emission coefficient α from aggregated CO2 emission coefficient δ. β implies the amount of CO2 indirectly generated by all industries in producing one unit of product at each industry.

$$\alpha = \hat{Q}(\hat{X}^*)^{-1}A^*$$
$$\delta = \hat{Q}(\hat{X}^*)^{-1}(I - A^*)^{-1}$$
$$\beta = \delta - \alpha$$

where $\hat{Q}$: a matrix where Q^* is diagonalized and its non-CO2 column is removed (k×n)
α : direct CO2 emission coefficient (k×n)
β : indirect CO2 emission coefficient (k×n)
δ : aggregate CO2 emission coefficient (k×n)

The generated amount of CO2 emissions, P, by industry can be derived by multiplying the aggregate CO2 emission coefficient δ and the diagonalized matrix $\hat{F}$ of final demand.

$$P = \delta\hat{F}$$

where P : CO2 emissions by industry (k×n)
$\hat{F}$: diagonalized matrix of final demand (n×n)

2. Analysis result

Hybrid I-O tables (28 sector aggregates) in 1995, 2000, and 2005 were derived using linked I-O tables (95-00-05) in 2005 I-O tables§§ constructed by the Bank of Korea. Following the methodology of Choi and Lee (2006), the derivation of hybrid I-O tables was based on five primary energies (i.e., anthracite, bituminous coal, crude oil, natural gas, and hydraulic and nuclear power). Thus, industries of general I-O tables were re-categorized into 33 industries: 5 primary energy industries and 28 non-energy industries. Final energy sources, such as gasoline, city gas, and electricity, were excluded to avoid double calculation because these energy forms can be obtained by processing primary energy forms.

In the conversion of units from money-based energy inputs of general I-O tables to physical units, it was assumed that the total energy inputs of I-O tables is equivalent to primary energy consumption from the yearbook of energy statistics.*** The physical unit of energy was again converted to TOE for an objective comparison of energy consumption. Energy conversion factors in net heating value from the yearbook of energy statistics were used. Oil conversion factors, which were officially

§§ Bank of Korea (2008), 「2005 Input-Output Tables」, 2008.12.
*** Ministry of Knowledge Economy, and Korea Energy Economics Institute (2008), 「Yearbook of Energy Statistics」.

released in September 2006 by the Ministry of Industry and Resource,††† were different between domestic and imported anthracite; hence, two different factors were applied to convert anthracite into TOE according to the source of anthracite. The amount of energies used for non-CO2-emitting raw materials was deducted from energy consumption because this amount of energy does not emit CO2. For instance, crude oil can be transformed into petroleum products such as naphtha, lubricants, and asphalt, which do not emit CO2; hence, this amount of oil consumption was subtracted from the total amount of oil consumption. Likewise, the same amount of oil consumption was taken out from intermediate demand, intermediate input, and total output of I-O tables.

The carbon content of fossil fuels varies according to energy; hence, carbon emissions factors are necessary in converting TOE-based amount of energy consumption into the amount of CO2 emissions. However, Korea has no carbon emissions factors of its own; hence, the carbon emission factors suggested by the IPCC in 1997‡‡‡ were used.

There are two measures of carbon emissions. Tonnage of carbon (TC) measures the weight of carbon, while tonnage of CO2 (TCO2) measures the weight of carbon dioxide. CO2 is a compound of one carbon atom and two oxygen atoms; as such, CO2 is heavier than carbon. Hence, TCO2 can be easily derived by multiplying the mass ratio of CO2 to carbon, 44/12, to TC. In this section, TC is employed because it is more generally used in the literature.

[Figure III-1]

Figure III-1 shows the direct CO2 emission coefficient of 28 sectors in 1995, 2000, and 2005. Direct CO2 emission coefficient indicates the amount of CO2 emitted by direct combustion of primary energy in satisfying one unit of final demand (2005 constant million Korean Won) in a certain sector. If the coefficient for a certain sector is one, then 1 ton of carbon is directly emitted in satisfying the final demand of 1 million Korean Won at 2005 constant prices. It is noticeable that the coefficient were zero for almost every sector, except for Petroleum and Coal Products (.934 in 2005) and Thermal Power, Gas, and Water Services sectors (1.286 in 2005), among others. This is because almost all industries consume final energy such as gasoline. They do not directly consume primary energy such as crude oil and natural gas. It should be noted that, through time, the direct coefficient for Thermal Power, Gas, and Water Services has increased.

[Figure III-2]

Figure III-2 displays the indirect CO2 emission coefficient of 28 sectors in 1995, 2000, and 2005. Indirect CO2 emission coefficient indicates the amount of CO2 emitted by indirect combustion of primary energy through the production process of intermediate inputs in satisfying one unit of final demand (2005 constant million Korean Won) in a certain sector. The indirect coefficient in 2005 were high for Thermal Power, Gas and Water Services (.318); Transportation and Custody (.204); and Chemical Products (.201) sectors. The indirect coefficient were generally decreasing.

[Figure III-3]

††† The Ministry of Knowledge and Economy was formerly the Ministry of Industry and Resource.
‡‡‡ IPCC (1997), Revised 1996 IPCC Guideline for National Greenhouse Gas Inventories.

Figure III-3 shows the aggregate CO2 emission coefficient of 28 sectors in 1995, 2000, and 2005. Aggregate CO2 emission coefficient are the sum of direct and indirect CO2 emission coefficient. Aggregate coefficient indicate the amount of CO2 emitted by direct and indirect combustion of primary energy in satisfying one unit of final demand (2005 constant million Korean Won) in a certain sector. The aggregate coefficient in 2005 were high for Thermal Power, Gas, and Water Services (1.604); Chemical Products (.977); and Mineral Products (.285) sectors. The aggregate coefficient substantially decreased from 1995 to 2005, except for several sectors (e.g., Thermal Power, Gas, and Water Services). This result implies that the efficiency of energy use has considerably improved as identical carbon emissions factors were applied in the calculation of CO2 emissions.

[Figure III-4]

Figure III-4 displays CO2 emissions of 28 sectors in 1995, 2000, and 2005. CO2 emissions can be obtained as the product of aggregate CO2 emission coefficient and final demand. CO2 emissions do not imply that a certain sector actually emitted that amount of CO2. Instead, the emissions indicate the amount of CO2 emitted by all sectors in satisfying the final demand in a certain sector. A negative amount of CO2 emissions can be obtained if the final demand in a certain sector is negative because of inventory. It should be noted that CO2 emissions were high for Petroleum and Coal Products; Thermal Power, Gas, and Water Services; and Transportation and Custody.

[Figure III-5]

Figure III-5 shows changes in CO2 emissions in three periods (i.e., 1995-2000, 2000-2005, and 1995-2005). CO2 emitted by Korean industries increased at an annual average of 3.4%, from 98,839,008 TC in 1995 to 138,072,943 TC in 2005. The emissions were high for Petroleum and Coal Products (26,091,162 TC); Construction (11,203,087 TC); and Transportation and Custody (10,484,975 TC) sectors in 1995. In 2005, the emissions were high for Petroleum and Coal Products (31,312,991 TC); Thermal Power, Gas and Water Services (15,928,707 TC); and Construction (12,906,359 TC).

The total amount of CO2 emissions increased by 39,233,935 TC in ten years. The increase in CO2 emissions was high for Thermal Power, Gas and Water Services (9,568,542 TC); Petroleum and Coal Products (5,221,829 TC); Electronic and Electrical Machines (4,762,347 TC); and Education and Health (4,447,252 TC) sectors. Decreases in CO2 emissions were notable for Transportation and Custody (-1,446,645 TC); Fiber and Leather Products (-648,264 TC); and Agriculture and Fisheries (-355,821 TC) sectors. Considering that CO2 emissions coefficient have considerably dropped, increases in CO2 emissions were mainly caused by increases in final demand.

[Figure III-6, 7, and 8]

Figures III-6, III-7, and III-8 display CO2 emissions by industries and respective energy sources in 1995, 2000, and 2005. In 1995, the amount of CO2 emitted from the use of crude oil was 66,967,819 TC, which accounted for 67% of the total CO2 emissions. The amount emitted from the use of bituminous coal was 23,646,839 TC, which accounted for 24% of the total CO2 emissions. CO2 emissions from the use of crude oil were high for Petroleum and Coal Products (21,616,710 TC); Transportation and Custody (8,490,135 TC); and Construction (6,365,629 TC). CO2 emissions from

burning bituminous coal were high for Petroleum and Coal Products (4,140,561 TC); Construction (3,799,477 TC); and Thermal Power, Gas, and Water Services (2,891,637 TC).

In 2005, the amount of CO2 emissions from the use of crude oil was 67,113,359 TC, which accounted for 49% of the total CO2 emissions. The amount from the use of bituminous coal was 47,414,466 TC, which accounted for 34% of the total CO2 emissions. CO2 emissions from the use of crude oil were high for Petroleum and Coal Products (24,358,990 TC); Transportation and Custody (6,605,604 TC); and Construction (5,746,489 TC). CO2 emissions from burning bituminous coal was high for Thermal Power, Gas, and Water Services (9,162,357 TC); Petroleum and Coal Products (6,345,506 TC); and Construction (4,998,370 TC). The amount of CO2 emissions from the use of crude oil decreased; however, the importance of other primary energy sources increased.

[Table III-5 to 11]

Table III-5 to III-7 show the direct, indirect, and aggregate CO2 emission coefficient by industry, and Table III-8 to III-11 display CO2 emissions by industry and energy sources.

IV. Analysis of CO2 Emission Changes by Structural Decomposition Analysis

1. Methodology of Structural Decomposition Analysis

To date, CO2 emissions of Korea by industry and energy sources in 1995-2005 are derived from hybrid I-O table analyses. The amount of CO2 emissions increased by approximately 18.59 million TC from 1995 to 2000, while the amount increased by approximately 20.64 million TC from 2000 to 2005. In other words, CO2 emissions increased by 39.23 million TC in ten years (1995-2005). In order to decompose CO2 emission changes, the following methodology was applied in this paper. The emission changes ($\Delta\Pi$) between t and t+1 can be calculated as follows:

$$\Delta\Pi = \Pi_{t+1} - \Pi_t = \delta_{t+1}\hat{\hat{Y}}_{t+1} - \delta_t Y_t$$

where δ : aggregate CO2 emission coefficient

$\hat{Y}$: diagonalized matrix of final demand

Emission changes ($\Delta\Pi$) can be decomposed into two components: the effect of change in emission coefficient (δ) and the effect of change in final demand ($\hat{Y}$). There are two methods in analyzing changes in these components.

$$\begin{aligned}\Delta\Pi &= (\delta_{t+1} - \delta_t)\hat{\hat{\hat{Y}}}_{t+1} + \delta_t(Y_{t+1} - Y_t) \\ &= \Delta\delta\hat{\hat{Y}}_{t+1} + \delta_t\Delta Y\end{aligned}$$

or

$$\begin{aligned}\Delta\Pi &= (\delta_{t+1} - \delta_t)\hat{\hat{\hat{Y}}}_t + \delta_{t+1}(Y_{t+1} - Y_t) \\ &= \Delta\delta\hat{\hat{Y}}_t + \delta_{t+1}\Delta Y\end{aligned}$$

The first method was employed by Choi (1993), Song (2001), Park and Heo (2002), where they used arbitrary weights for the base years. However, this method has been heavily criticized for its arbitrariness. In contrast, Sun (1998), Cho (2001), Choi and Lee (2002), Lim (2004), Kim (2004), and Kim (2005) employed the second method, where they used the average of the values of two periods as weights.

$$\Delta\Pi = (\delta_{t+1} - \delta_t)\frac{1}{2}(\hat{\hat{\hat{\hat{Y}}}}_{t+1} + Y_t) + \frac{1}{2}(\delta_{t+1} + \delta_t)(Y_{t+1} - Y_t)$$
$$= \Delta\delta\hat{\hat{\hat{Y}}}_* + \delta_*\Delta Y$$

where $\hat{\hat{\hat{Y}}}_* = \frac{1}{2}(Y_{t+1} + Y_t)$ and $\delta_* = \frac{1}{2}(\delta_{t+1} + \delta_t)$

The advantage of the second method is that it alleviates the criticism regarding arbitrary selection of base year and equally distributes the weight to two periods. Due to this merit, the second method has been widely adopted. This method is employed in this study. Changes in CO2 emission coefficient (δ) can be decomposed into direct CO2 emission coefficient and indirect CO2 emission coefficient.

$$\Delta\delta\hat{\hat{\hat{Y}}}_* = \Delta\alpha Y_* + \Delta\beta Y_*$$

where α : direct CO2 emission coefficient

β : indirect CO2 emission coefficient

In other words, changes in CO2 emissions levels caused by changes in aggregate CO2 emission coefficient ($\Delta\delta\hat{Y}_*$) are decomposed into the effect of changes in direct CO2 emission coefficient and the effect of changes in indirect CO2 emission coefficient. Likewise, changes in final demand ΔY can be decomposed as follows:

$$\Delta\hat{\hat{\hat{\hat{\hat{\hat{Y}}}}}} = \hat{\hat{\hat{\hat{\hat{\hat{Y}}}}}}_{t+1} - Y_t = (Y_{t+1} - y_{t(t+1)}Y_{t+1}) + (y_{t(t+1)}Y_{t+1} - Y_t)$$

where $y_{t(t+1)} = \frac{\sum Y_t}{\sum Y_{t+1}}$

Here, $y_{t(t+1)}$ shows comparative changes in final demand in a certain sector. The first term $(\hat{\hat{Y}}_{t+1} - y_{t(t+1)}Y_{t+1})$ implies level effect and the second term $(y_{t(t+1)}\hat{\hat{Y}}_{t+1} - Y_t)$ indicates mixed effect. If all industries grow at the same rate, then the mixed effect would be zero. The equation can be expressed as follows:

$$\delta_*\Delta\hat{\hat{\hat{\hat{\hat{Y}}}}} = \delta_*(Y_{t+1} - y_{t(t+1)}Y_{t+1}) + \delta_*(y_{t(t+1)}Y_{t+1} - Y_t)$$

The effect of changes in final demand can be additionally decomposed into the components of final demand in I-O tables: private consumption, government consumption, private fixed capital, government fixed capital, inventory, and export.

$$Y = C + G + K_C + K_G + I + E$$

where Y : final demand

C : private consumption

G : government consumption

K_C : private fixed capital

K_G : government fixed capital

I : inventory

E : export

Likewise, level effect and mixed effect can be additionally decomposed into private consumption, government consumption, private fixed capital, government fixed capital, inventory, and export.

$$\begin{aligned}\delta_*(\hat{\hat{Y}}_{t+1} - y_{t(t+1)}Y_{t+1}) &= \delta_*(\hat{\hat{C}}_{t+1} - c_{t(t+1)}C_{t+1}) \qquad \text{(Decomposition of Level Effect)}\\ &+\delta_*(\hat{\hat{G}}_{t+1} - g_{t(t+1)}G_{t+1}) + \delta_*(\hat{\hat{\hat{K}}}_{C_{t+1}} - k_{C_{t(t+1)}}K_{C_{t+1}}) + \delta_*(K_{G_{t+1}} - k_{G_{t(t+1)}}K_{G_{t+1}})\\ &+\delta_*(\hat{\hat{\hat{I}}}_{t+1} - i_{t(t+1)}I_{t+1}) + \delta_*(E_{t+1} - e_{t(t+1)}E_{t+1})\end{aligned}$$

$$\begin{aligned}\delta_*(y_{t(t+1)}\hat{\hat{Y}}_{t+1} - Y_t) &= \delta_*(c_{t(t+1)}\hat{\hat{C}}_{t+1} - C_t) \qquad \text{(Decomposition of Mix Effect)}\\ &+\delta_*(g_{t(t+1)}\hat{\hat{G}}_{t+1} - G_t) + \delta_*(k_{C_{t(t+1)}}\hat{\hat{\hat{K}}}_{C_{t+1}} - K_{C_t}) + \delta_*(k_{G_{t(t+1)}}K_{G_{t+1}} - K_{G_t})\\ &+\delta_*(i_{t(t+1)}\hat{\hat{\hat{I}}}_{t+1} - I_t) + \delta_*(e_{t(t+1)}E_{t+1} - E_t)\end{aligned}$$

where $c_{t(t+1)} = \dfrac{\sum C_t}{\sum C_{t+1}}$, $g_{t(t+1)} = \dfrac{\sum G_t}{\sum G_{t+1}}$, $k_{C_{t\,(t+1)}} = \dfrac{\sum K_{C_t}}{\sum K_{C_{t+1}}}$,

$k_{G_{l\,(l+1)}} = \dfrac{\sum K_{G_t}}{\sum K_{G_{t+1}}}$, $i_{t(t+1)} = \dfrac{\sum I_t}{\sum I_{t+1}}$, $e_{t(t+1)} = \dfrac{\sum E_t}{\sum E_{t+1}}$

When these various components are put together, changes in CO2 emissions can be decomposed into 14 factors as follows:

$$\begin{aligned}\Delta\Pi &= \Delta\delta\hat{\hat{Y}}_* + \delta_*\Delta Y\\ &= \Delta\alpha\hat{\hat{Y}}_* + \Delta\beta Y_*\\ &+\delta_*(\hat{\hat{\hat{C}}}_{t+1} - c_{t(t+1)}C_{t+1}) + \delta_*(G_{t+1} - g_{t(t+1)}G_{t+1})\\ &+\delta_*(\hat{\hat{\hat{K}}}_{C_{t+1}} - k_{C_{t(t+1)}}K_{C_{t+1}}) + \delta_*(K_{G_{t+1}} - k_{G_{t(t+1)}}K_{G_{t+1}})\\ &+\delta_*(\hat{\hat{\hat{I}}}_{t+1} - i_{t(t+1)}I_{t+1}) + \delta_*(E_{t+1} - e_{t(t+1)}E_{t+1})\\ &+\delta_*(c_{t(t+1)}\hat{\hat{\hat{C}}}_{t+1} - C_t) + \delta_*(g_{t(t+1)}G_{t+1} - G_t)\end{aligned}$$

$$+\delta_*(k_{C_{t(t+1)}}\hat{\hat{K}}_{C_{t+1}} - K_{C_t}) + \delta_*(k_{G_{t(t+1)}}K_{G_{t+1}} - K_{G_t})$$
$$+\delta_*(i_{t(t+1)}\hat{\hat{I}}_{t+1} - I_t) + \delta_*(e_{t(t+1)}E_{t+1} - E_t)$$

A. Effects changes of CO2 emissions coefficient
   (1) Direct CO2 emission coefficient
   (2) Indirect CO2 emission coefficient
B. Level effect of final demand
   (3) Level effect of private consumption
   (4) Level effect of government consumption
   (5) Level effect of private fixed capital
   (6) Level effect of government fixed capital
   (7) Level effect of inventory
   (8) Level effect of export
C. Mixed effect of final demand
   (9) Mixed effect of private consumption
   (10) Mixed effect of government consumption
   (11) Mixed effect of private fixed capital
   (12) Mixed effect of government fixed capital
   (13) Mixed effect of inventory
   (14) Mixed effect of export

Based on this method, structural decomposition results on changes in CO2 emissions for the three given periods are shown in Figures IV-1 to 9.

The next section provides an overall analysis of the structure of changes in CO2 emissions, and offers a detailed analysis focused on industries with large CO2 emissions.

2. Analysis of Changes in CO2 Emissions Patterns

[Figure IV-1]

Figure IV-1 shows the percentage contribution of each factor to the change in CO2 emissions from 1995 to 2000. The percentage contributions of CO2 emission coefficient and final demand were -111% (-20.56 million TC) and 211% (39.15 million TC), respectively.

The percentage contribution of the CO2 emission coefficient (-110%) consisted of the effect of direct CO2 emission coefficient (-21%, 3.95 million TC) and indirect CO2 emission coefficient (-89%, 16.62 million TC). Negative percentages imply that changes in emission coefficient reduce CO2 emissions. In addition, the effects of indirect emission coefficient exceed those of direct emission coefficient.

Final demand was decomposed into level effect and mixed effect. The percentage contribution of final demand (211%) consisted of level effect (-31%, 5.74 million TC) and mixed effect (241%, 44.89 million TC). From 1995 to 2000, the financial crisis in East Asia struck Korea, causing stagnation in economic growth. The level effect of final demand is believed to have acted in the way in reducing CO2 emissions. However, the positive value of mixed effect implies that the comparatively rapid growth of industries with high CO2 emissions, such as manufacturing, exceeds the growth of industries with low CO2 emissions, such as the finance and service industries.

[Figure IV-2]

Figure IV-2 shows percentage contribution of each factor to the change in CO2 emissions from 2000 to 2005. The percentage contributions of CO2 emission coefficient and final demand were 37% (7.64 million TC) and 63% (13.01 million TC), respectively.

The percentage contribution of the CO2 emission coefficient (37%) consisted of the effect of direct CO2 emission coefficient (25%, 5.09 million TC) and indirect CO2 emission coefficient (12%, 2.54 million TC). Similar to the previous period, emission coefficient reduced CO2 emissions; however, the effect of direct emission coefficient exceeded that of indirect emission coefficient in this period. This ensued from the sharp drop of the percentage contribution of changes in indirect coefficient.

Similarly, final demand was decomposed into level effect and mixed effect. The percentage contribution of final demand (63%) consisted of level effect (153%, 31.55 million TC) and mixed effect (-90%, -18.54 million TC). While the primary source of increase in CO2 emissions was mixed effect of final demand from 1995 to 2000, an opposite pattern emerged from 2000 to 2005. The final demand steadily increased because of the relatively robust recovery of economy; consequently, the level effect of final demand substantially increased the amount of CO2 emissions. However, the negative value of mixed effect implies that the comparatively rapid growth of industries with low CO2 emissions exceeds the growth of industries with high CO2 emissions.

[Figure IV-3]

Figure IV-3 displays the percentage contribution of each factor to the change in CO2 emissions from 1995 to 2005. Accordingly, the percentage contributions of CO2 emission coefficient and final demand were -41% (-16.09 million TC) and 141% (53.33 million TC), respectively.

The percentage contribution of the CO2 emission coefficient (-41%) consisted of the effect of direct CO2 emission coefficient (2%, .89 million TC) and indirect CO2 emission coefficient (-43%, -16.09 million TC). Direct coefficient resulted in minimal changes in CO2 emissions because the negative effect from 1995 to 2000 offset the positive effect from 2000 to 2005. Indirect coefficient aided in reducing the amount of CO2 emissions. However, the effect of indirect coefficient in the most recent period (2000-2005) acted to increase CO2 emissions.

The percentage contribution of final demand (141%) consisted of level effect (171%, 67.12 million TC) and mixed effect (-30%, -11.79 million TC). Korean government's Green Growth Policy is not designed to hinder economic growth; as such, the large positive level effect of final demand itself should not be treated as an unfavorable phenomenon. It is not the goal of the Green Growth Policy to reduce final demand in order to reduce CO2 emissions. Instead, a policy should be designed to restructure the economy by developing industries with low CO2 emissions, such as high-technology, finance, and service industries.

3. Analysis of CO2 Emissions Patterns by industries

[Figure IV-4]

Figure IV-4 shows that CO2 emissions were largely led by a few sectors, such as Thermal Power, Gas, and Water Service; Petroleum and Coal Products; Electronic and Electrical Machines; and Education and Health sector.

[Figure IV-5]

Figure IV-5 shows the structural decomposition result of CO2 emissions in the Thermal Power, Gas, and Water Service sector from 1995 to 2005. The effect of CO2 emission coefficient increased CO2 emissions. However, unlike direct CO2 emission coefficient, indirect CO2 emission coefficient reduced CO2 emissions. The primary factor influencing the increase in CO2 emissions was final demand effect. In particular, the level effect of final demand was the most important factor. The positive mixed effect implies that this industry has rapidly grown as compared with other industries. Due to the nature of this industry, the final demand effect solely depends on private consumption.

[Figure IV-6]

Figure IV-6 shows the structural decomposition result of CO2 emissions in the Petroleum and Coal Products sector from 1995 to 2005. The effect of CO2 emission coefficient substantially contributed to a decrease in CO2 emissions. However, indirect CO2 emission coefficient caused CO2 emissions to increase. If a country's CO2-reducing effect of emission coefficient is big, relatively large amounts of CO2 emissions could be reduced through a small decline in final demand. Thus, the Petroleum and Coal Products sector can play a key role in reducing CO2 emissions. The main factor influencing the increase in CO2 emissions was final demand effect, particularly the level effect of final demand. The large negative mixed effect implies that this industry has slowly grown as compared with other industries because it is an industry with high CO2 emissions. Meanwhile, in this sector, the final demand effect is mostly based on private consumption and exports.

[Figure IV-7]

Figure IV-7 displays the structural decomposition result of CO2 emissions in the Electronic and Electrical Machines sector from 1995 to 2005. The effect of CO2 emission coefficient substantially decreased CO2 emissions. All the contributions resulting in changes in CO2 emission coefficient were influenced by indirect emission coefficient, and the effect of direct emission coefficient was null. The large negative effect of indirect CO2 emission coefficient in this sector implies that CO2-reducing efforts made in this sector caused a substantial decline in CO2 emissions in other related sectors. Thus, the Electronic and Electrical Machines sector can be a crucial sector in reducing CO2 emissions. The primary factor influencing the increase in CO2 emissions was the final demand effect, particularly the level effect of final demand. The positive mixed effect implies that this industry has rapidly grown as compared with other industries. Meanwhile, final demand effect is mostly based on private consumption and export effects, although the export effect is relatively larger in this sector than in others

[Figure IV-8]

Figure IV-8 shows the structural decomposition result of CO2 emissions in the Education and Health sector from 1995 to 2005. The effect of CO2 emission coefficient, to a certain degree,

contributed to an increase in CO2 emissions. Similar with the Electronic and Electrical Machines sector, all the contributions resulting in changes in CO2 emission coefficient were influenced by indirect emission coefficient, and the effect of direct emission coefficient was null. The positive effect of indirect CO2 emission coefficient in this sector implies that final demand at this sector caused increases in CO2 emissions in other related sectors.

In all these sectors, the primary factor influencing increases in CO2 emissions was final demand effect, particularly the level effect of final demand. The magnitude of mixed effect was small in these sectors. CO2 emissions result not only from private consumption but also from government consumption expenditures because of the characteristic of these industries.

V. Concluding Remarks

This study has demonstrated the contribution of the environmental to economic growth, predicted the amount of CO2 emissions, and predicted GDP in Korea according to the CO2 emissions reduction target through green growth accounting. The analysis showed that Korean CO2 emissions will increase to approximately 778 million tons by 2020. If Korea should reduce CO2 emissions by 30% from 2020 BAU levels without a successful Green Growth Policy, the average annual GDP growth rate from 2005 to 2020 will decrease to 3.92%. This rate is 0.58% points lower than the growth rate of 4.51% without compulsory CO2 reduction. Thus, promoting the Green Growth Policy prior to being required to reduce CO2 emissions is essential in achieving sustainable growth.

This study has also estimated CO2 emission coefficient and CO2 emissions by industry based on hybrid I-O tables. It analyzed the factors affecting changes in CO2 emissions by structural decomposition analysis. Results of 1995-2000-2005 hybrid I-O tables, using 2005 I-O tables, reveal that CO2 emissions are mainly generated by several industries such as Petroleum and Coal; Chemical Products; and Thermal Power, Gas and Water Services. CO2 emission coefficient dropped substantially from 1995 to 2005, except for a few industries, such as Thermal Power, Gas, and Water Services. This result implies that energy efficiency has considerably increased because identical carbon emission factors have been applied to estimate CO2 emissions. The analysis confirms that the increase in CO2 emissions has been mainly due to the growth effect of domestic final demand, while both the effects of emission coefficient and the mixed effect of final demand worked to offset CO2 emissions. Thus, harmonizing economic growth with CO2 emissions reduction by developing CO2 reduction technology and promoting low CO2 industries, such as high-technology, finance, and service industries should be the focal point of Green Growth Policy.

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Figure II-1: Prediction of CO2 Emissions (unit: million CO2 tons)

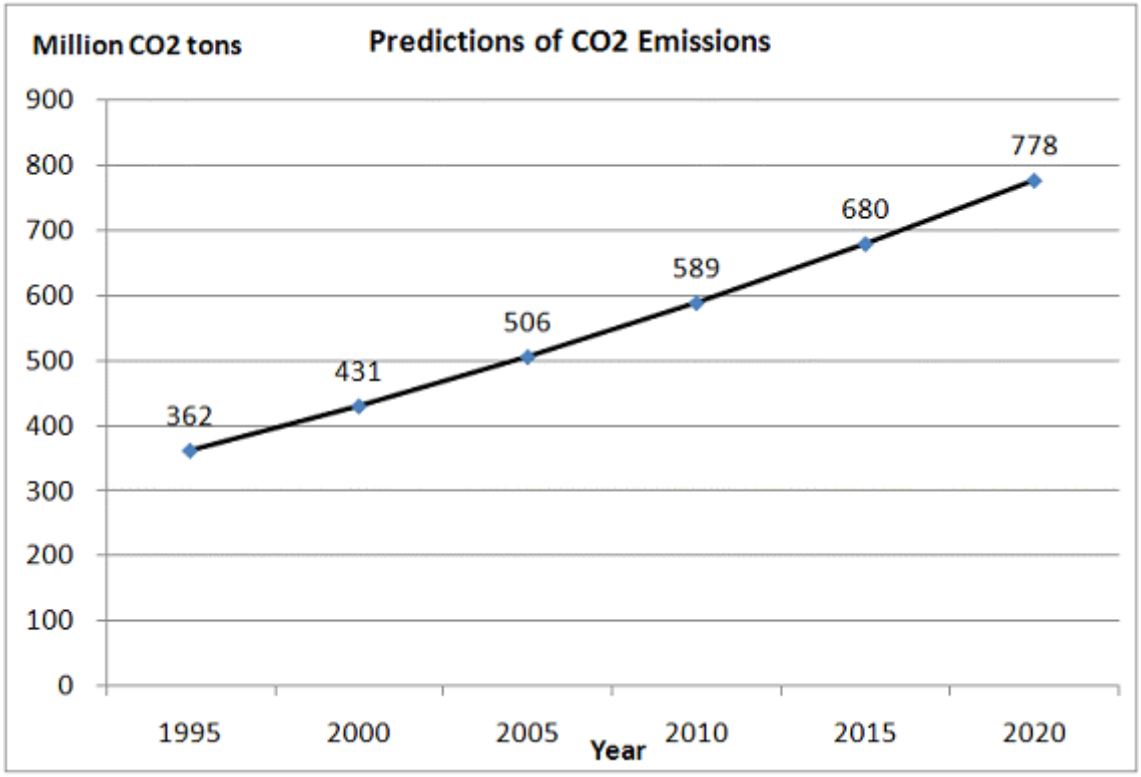

Figure II-2: Prediction of CO2 Emissions by Industry

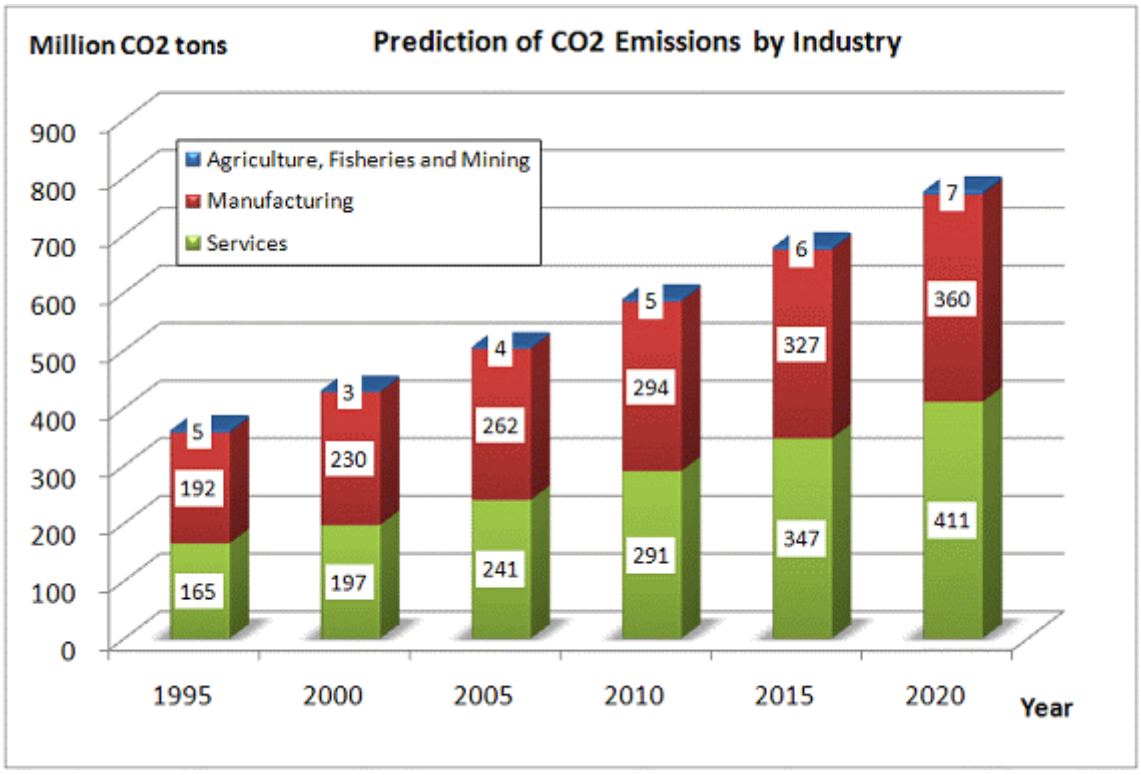

Figure II-3: GDP Prediction for CO2 Deduction Plan (unit: Billions of Korean Won)

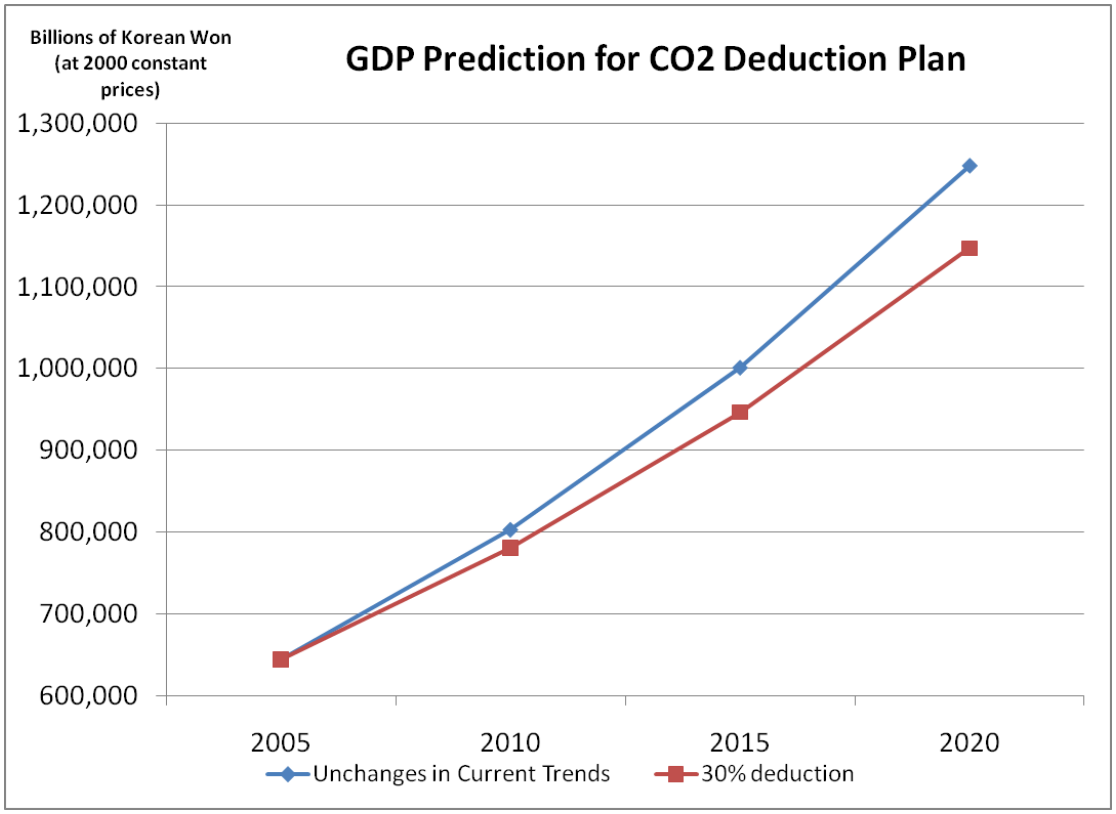

Figure III-1: Direct CO2 Emission Coefficient

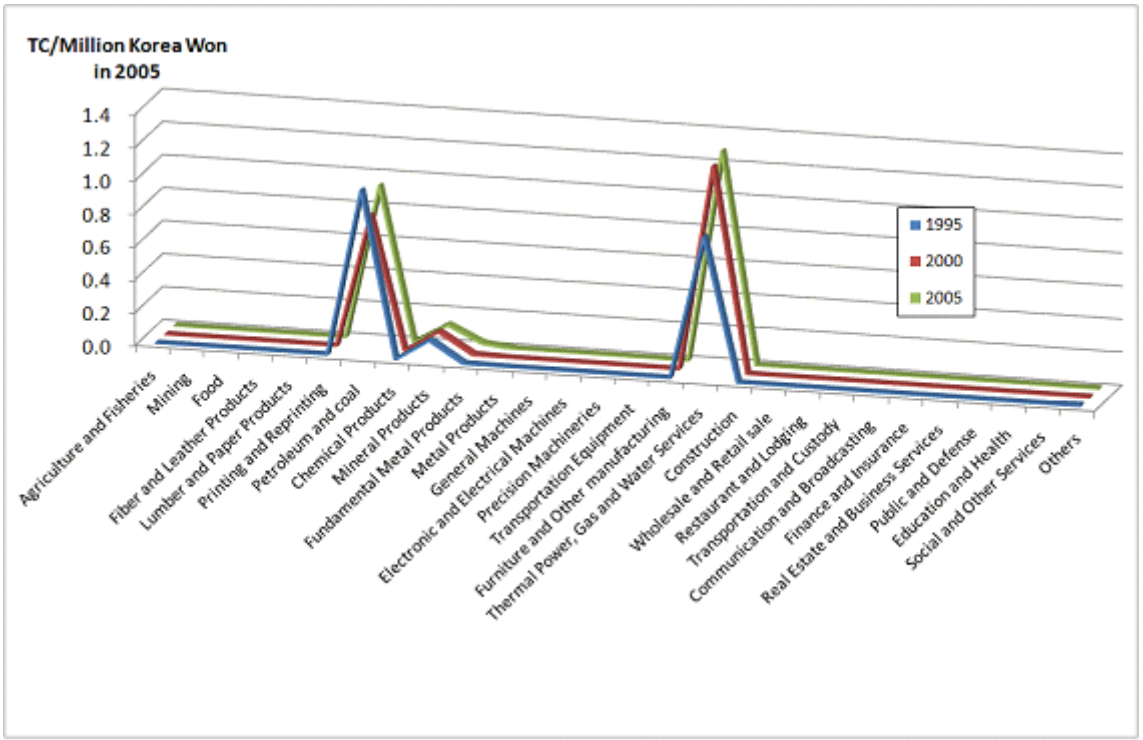

Figure III-1: Direct CO2 Emission Coefficient

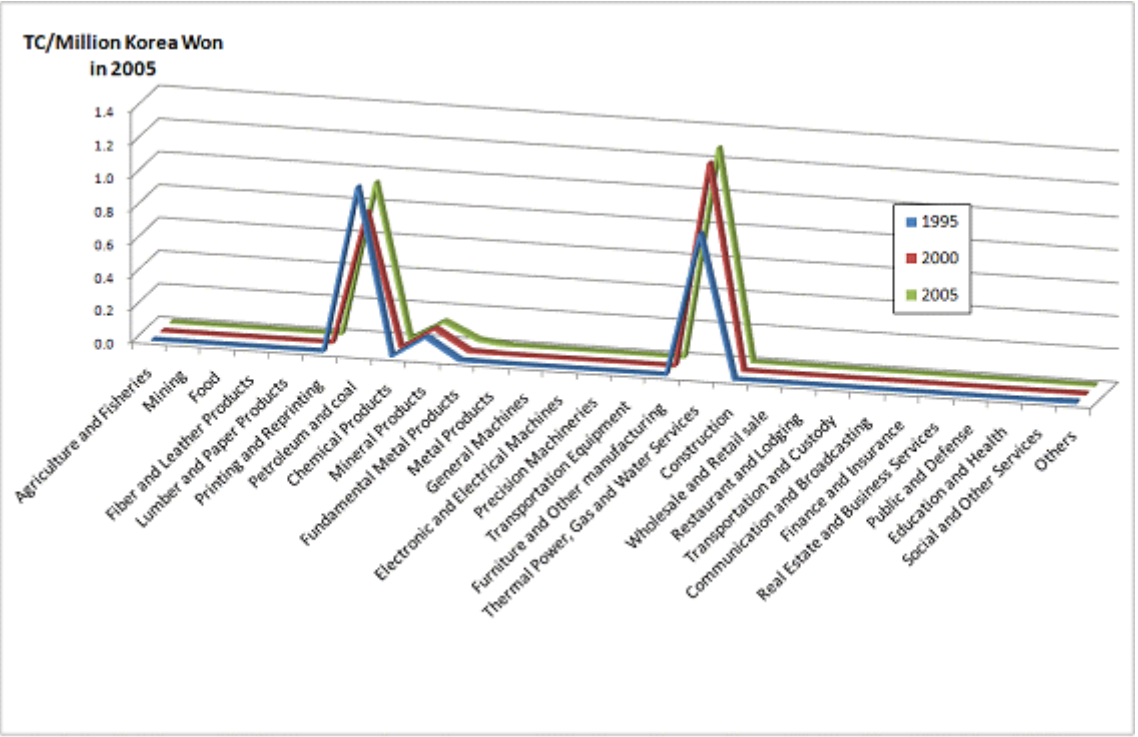

Figure III-2: Indirect CO2 Emission Coefficient

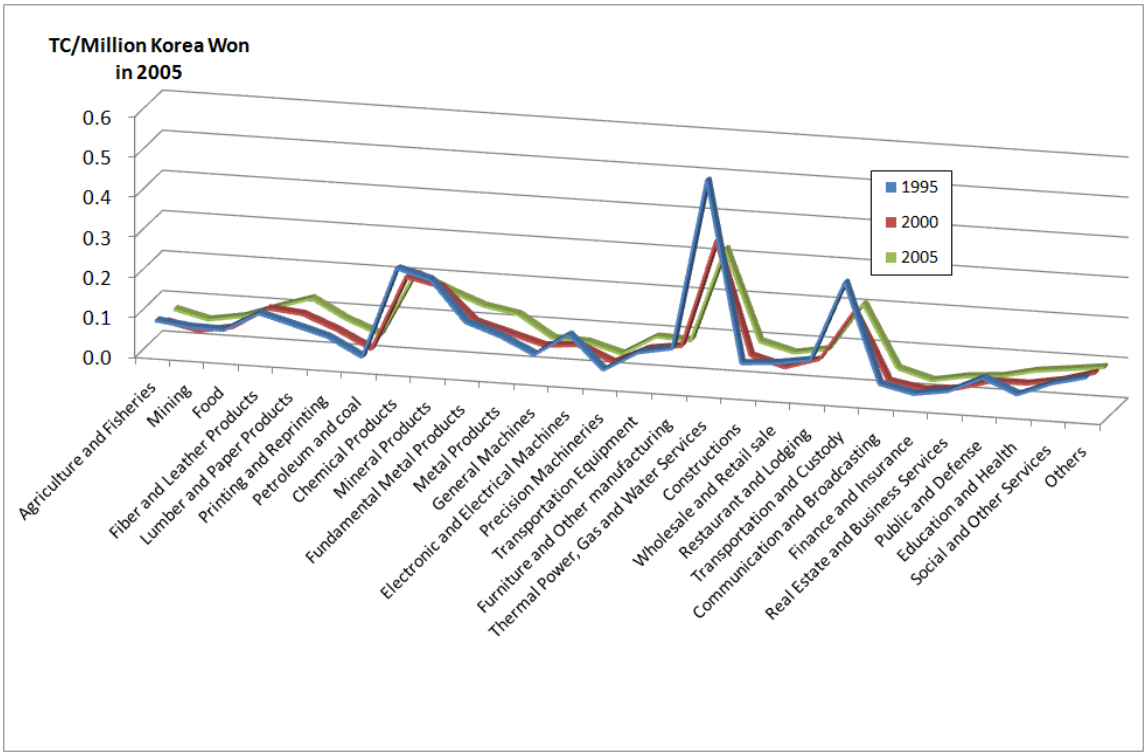

Figure III-3: Aggregate CO2 Emission Coefficient

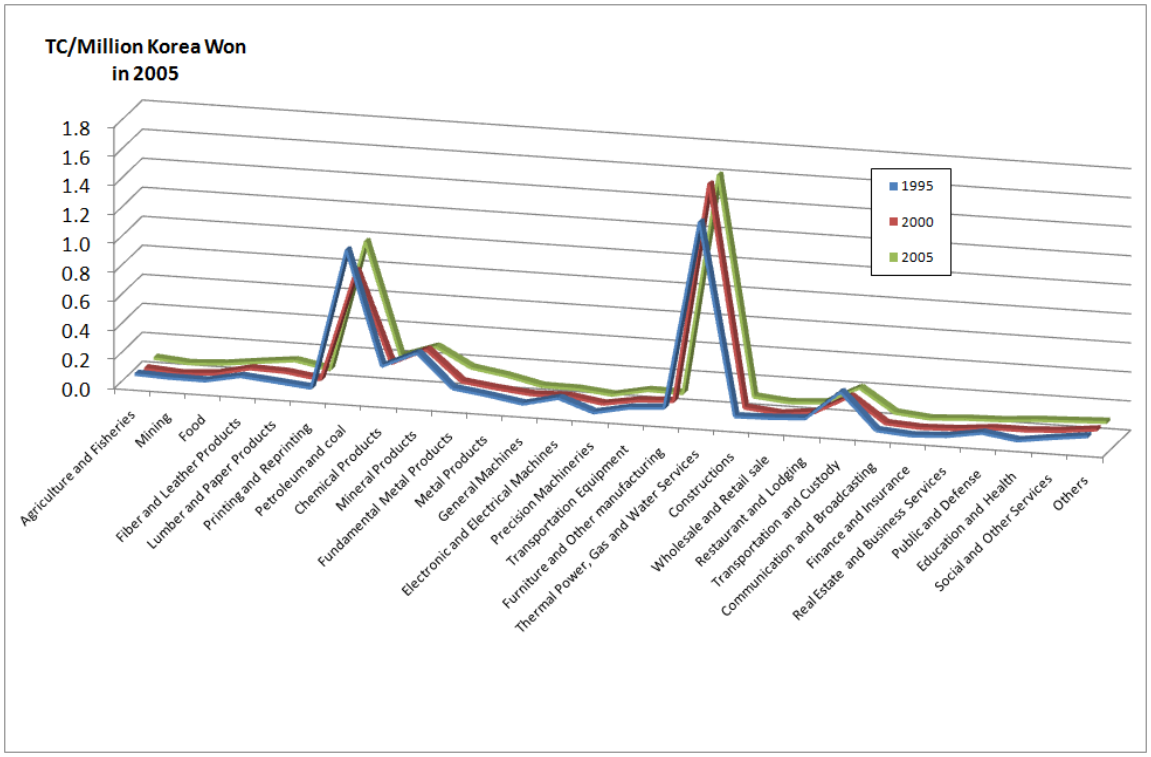

Figure III-4: CO2 Emissions by Industries

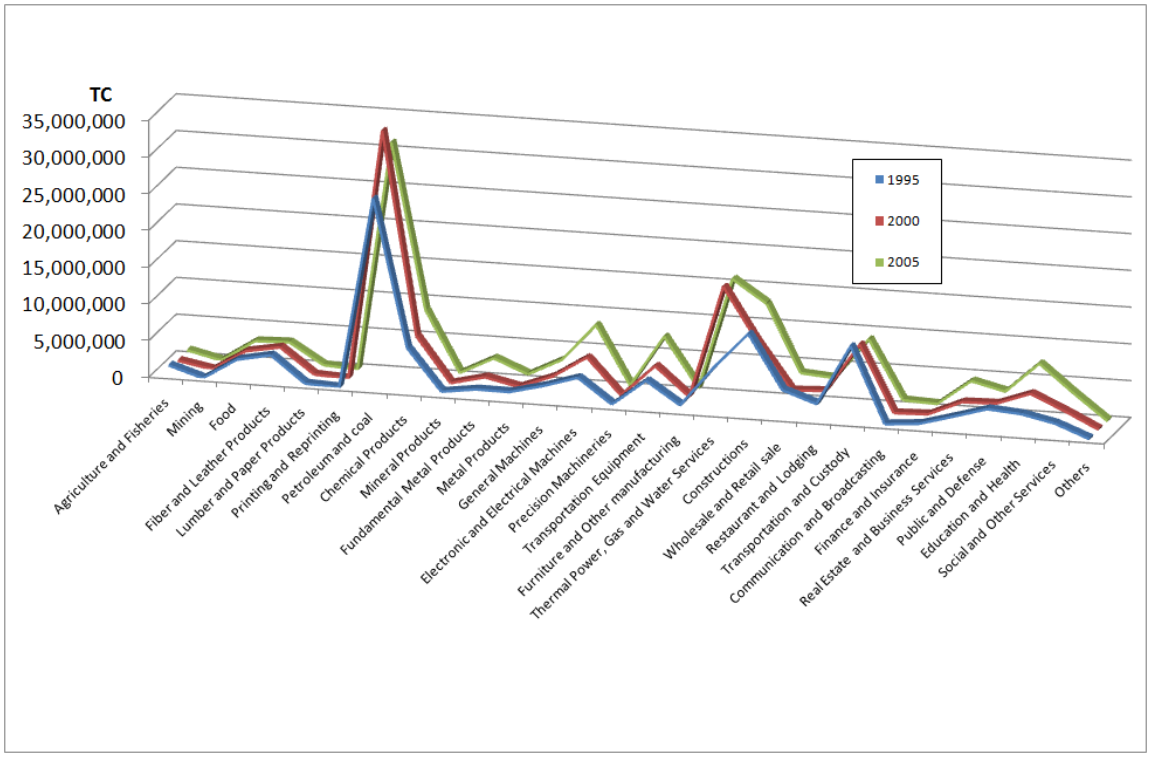

Figure III-5: Changes in CO2 Emissions

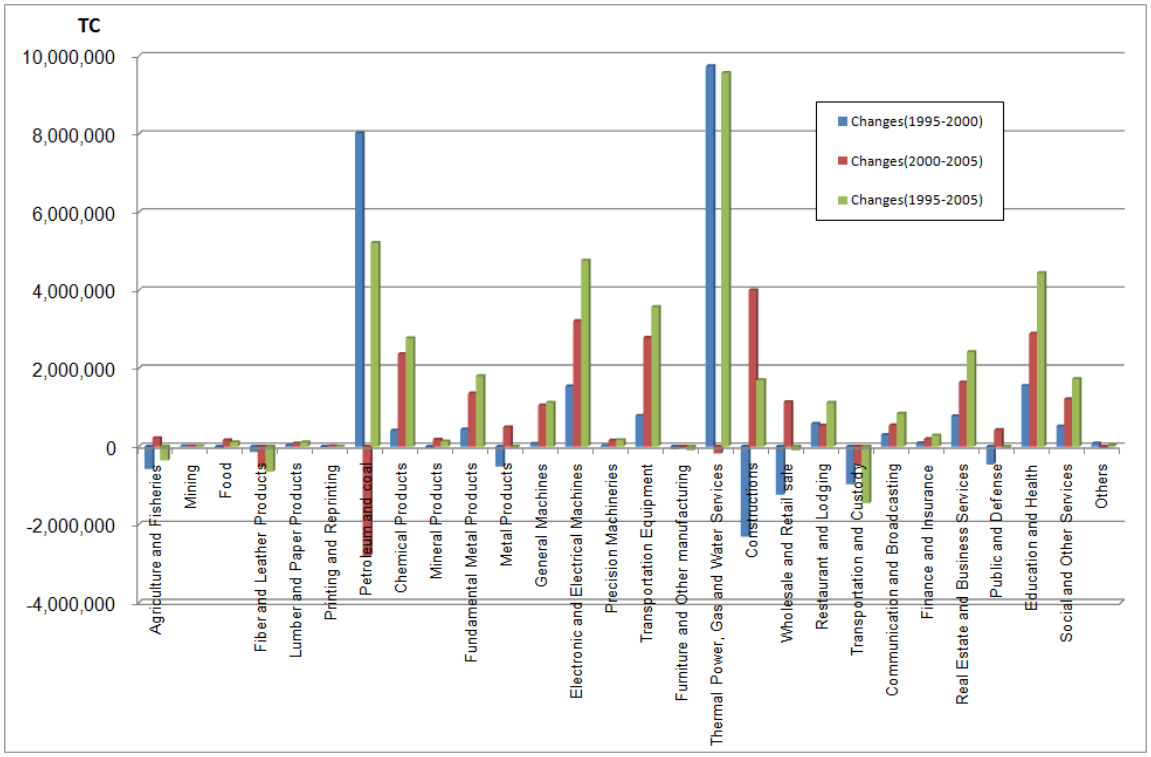

Figure III-6: CO2 Emissions by Industries and Energy Sources (1995)

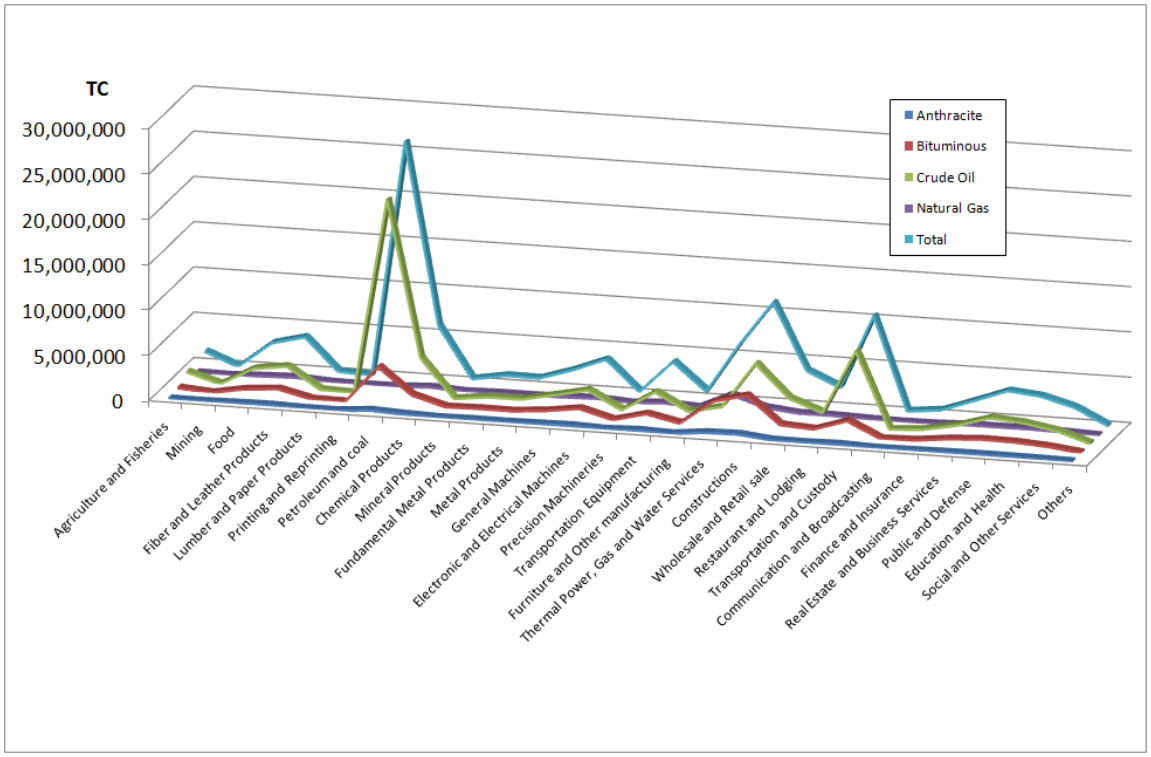

Figure III-7: CO2 Emissions by Industries and Energy Sources (2000)

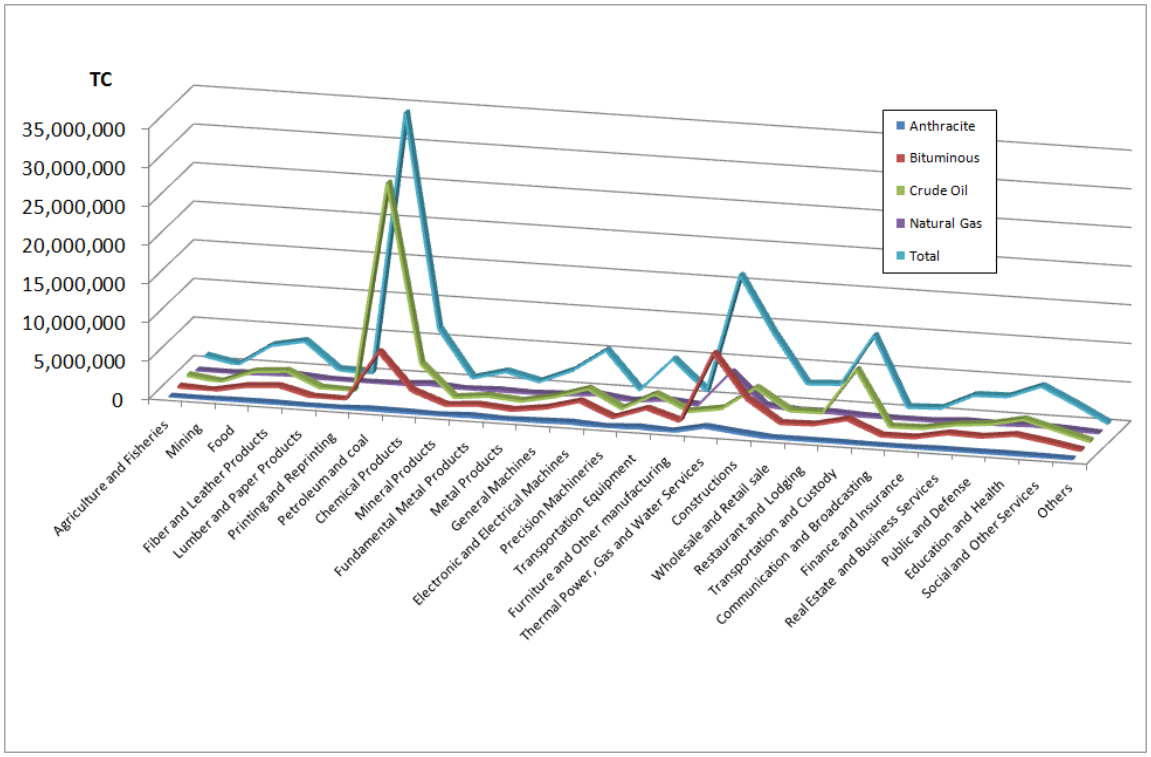

Figure III-8: CO2 Emissions by Industries and Energy Sources (2005)

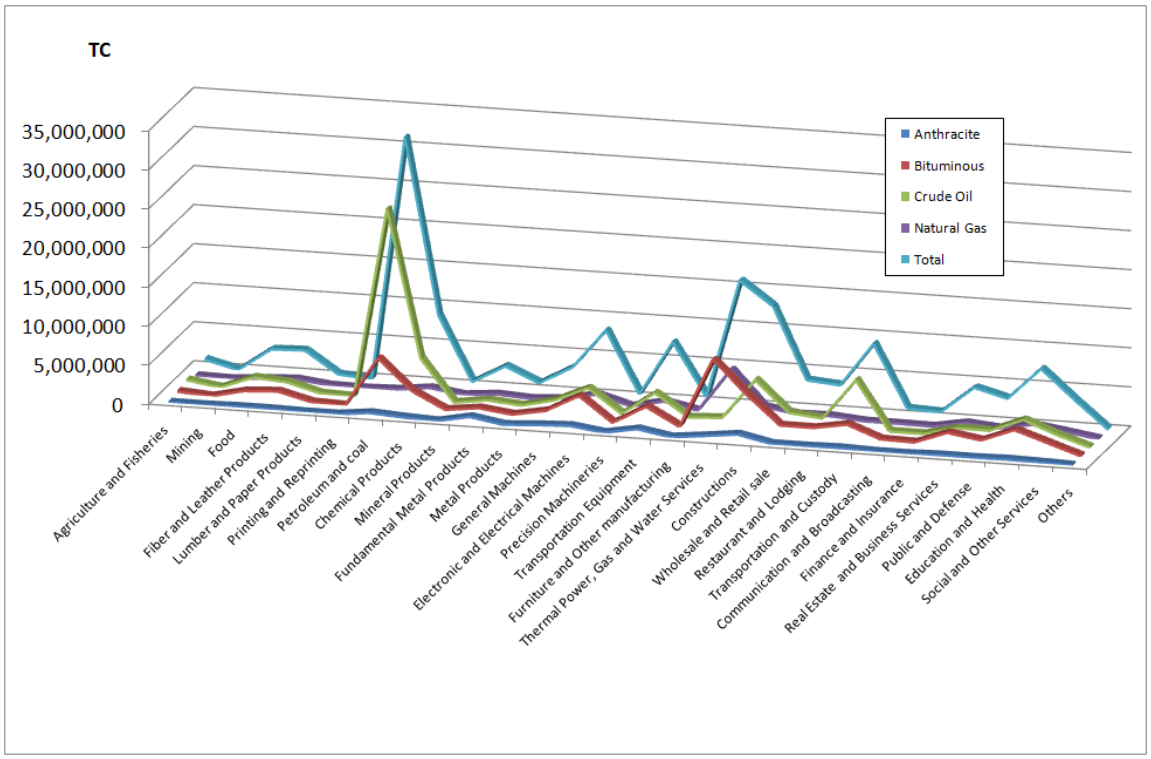

Figure IV-1: CO2 Emissions Decomposition (1995-2000) **(unit : %)**

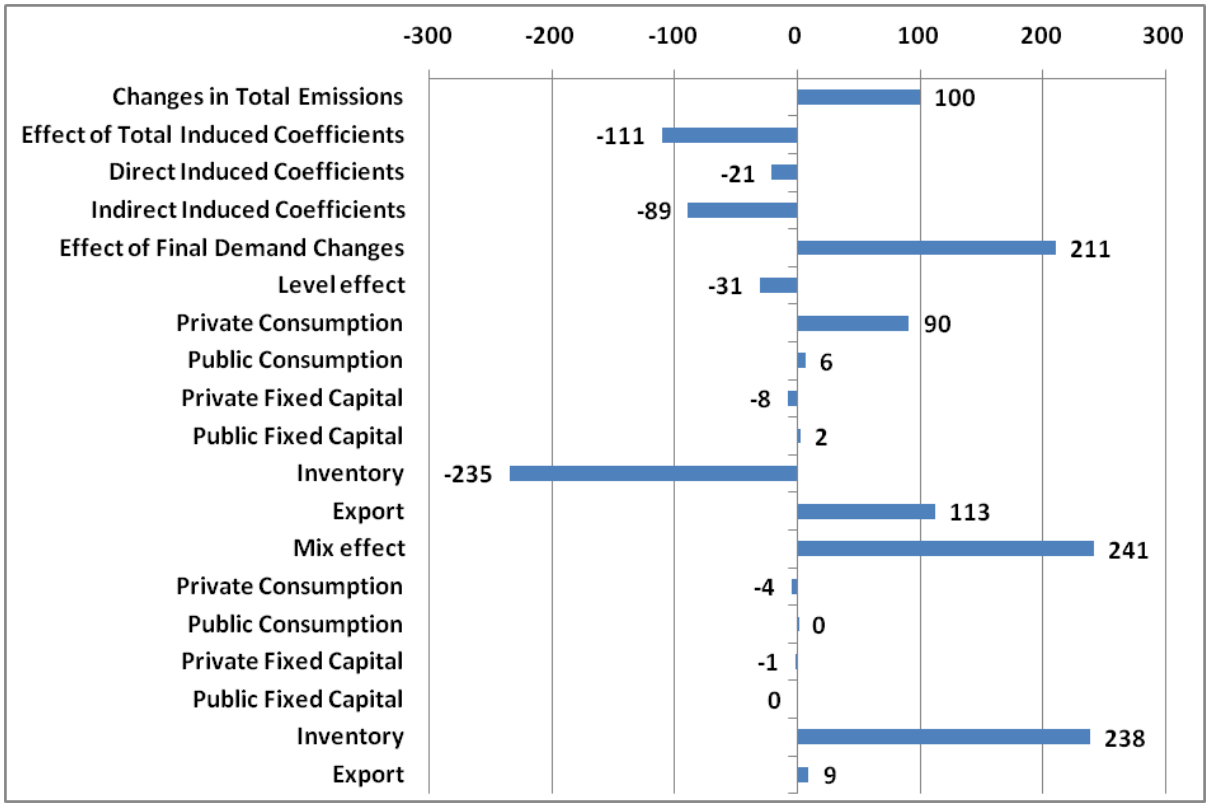

Figure IV-2: CO2 Emissions Decomposition (2000~2005) **(unit: %)**

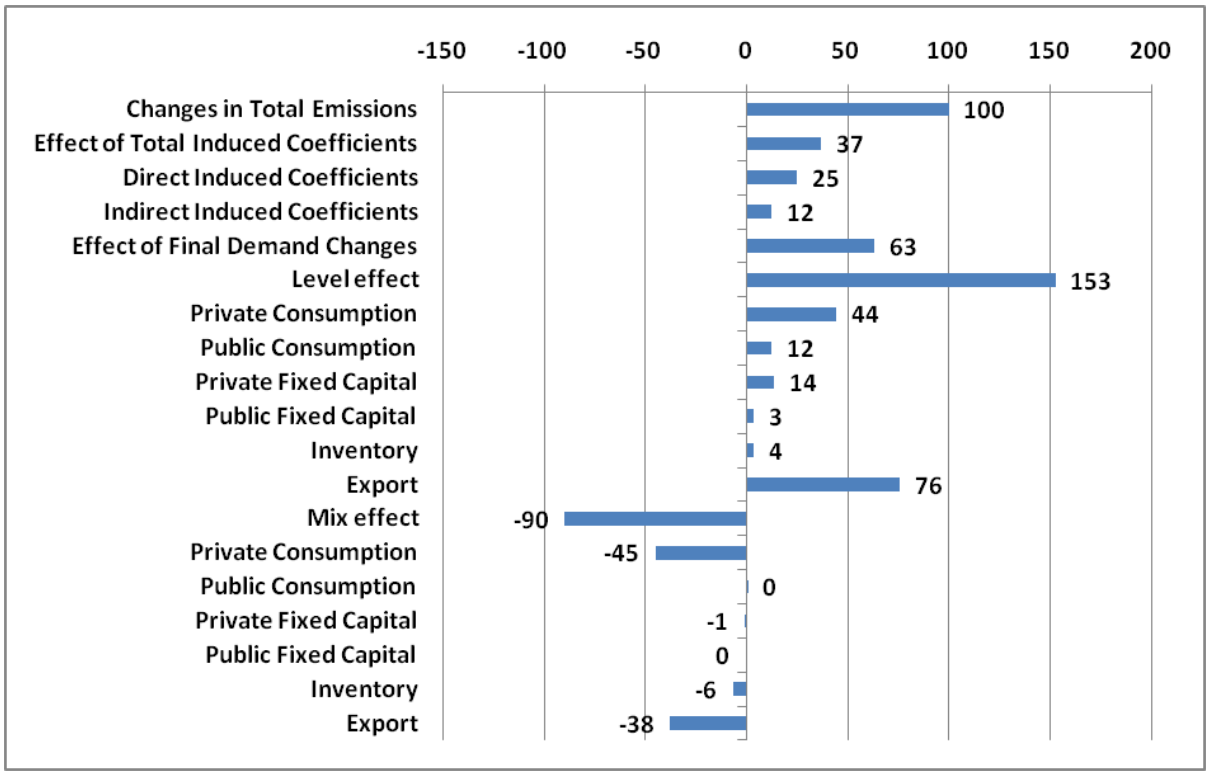

Figure IV-3: CO2 Emissions Decomposition (1995~2005) **(unit: %)**

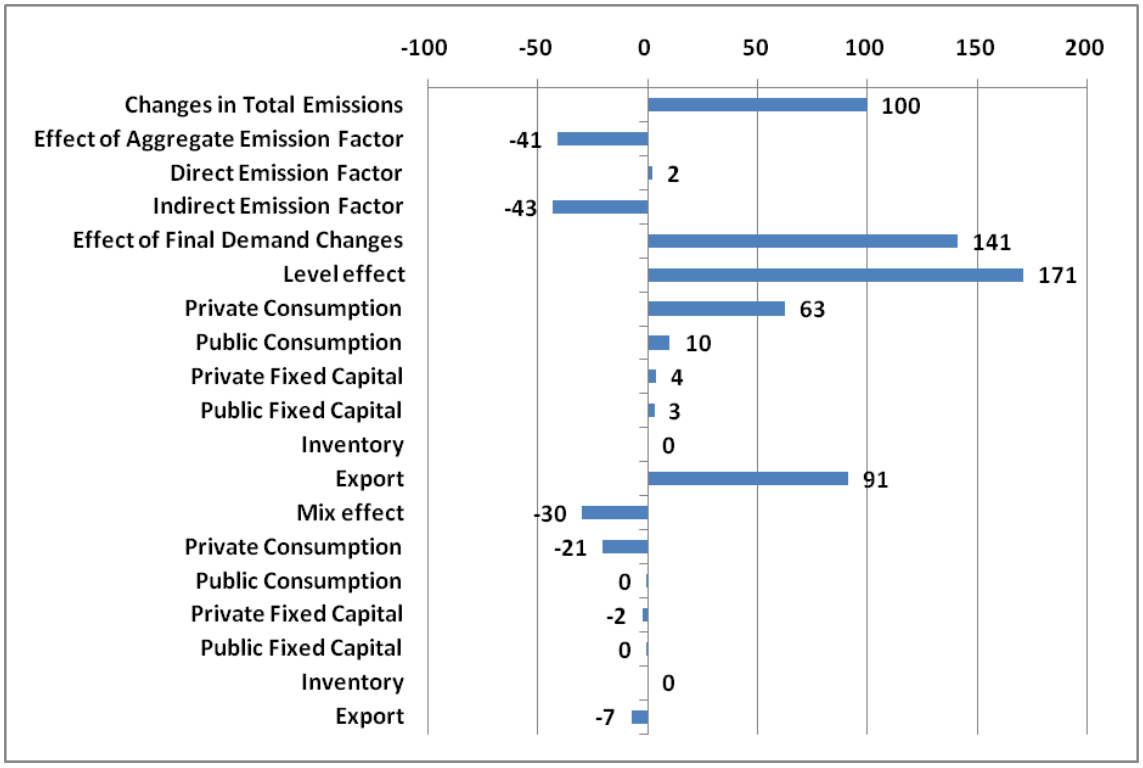

Figure IV-4: Changes in CO2 Emissions by Industries (1995-2005) **(unit: tons of carbon)**

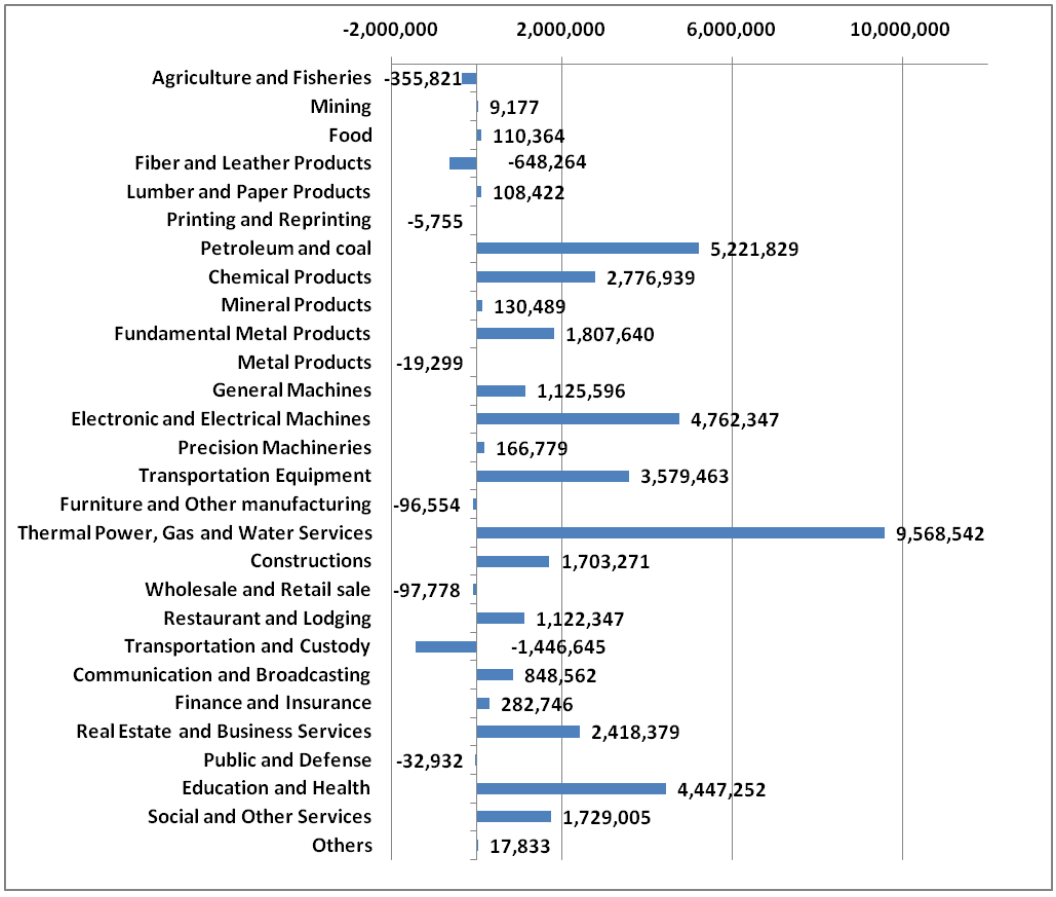

Figure IV-5: CO2 Emissions Decomposition of Thermal Power, Gas and Water Service Industry (1995-2005) **(unit: TC)**

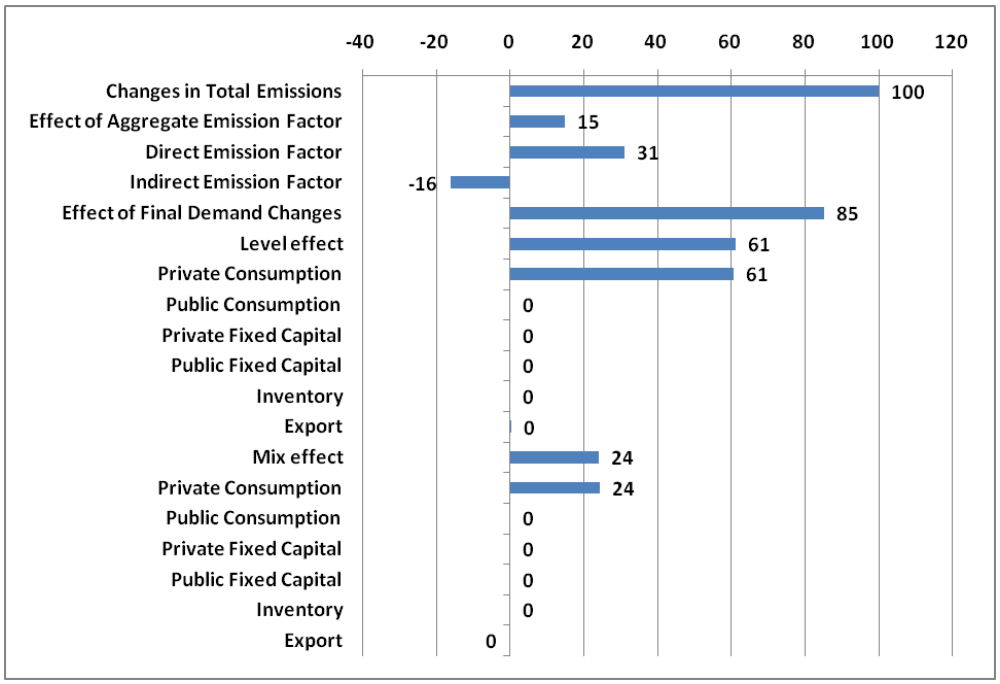

Figure IV-6: CO2 Emissions Decomposition of Petroleum and Coal Industry (1995~2005)

(unit: %)

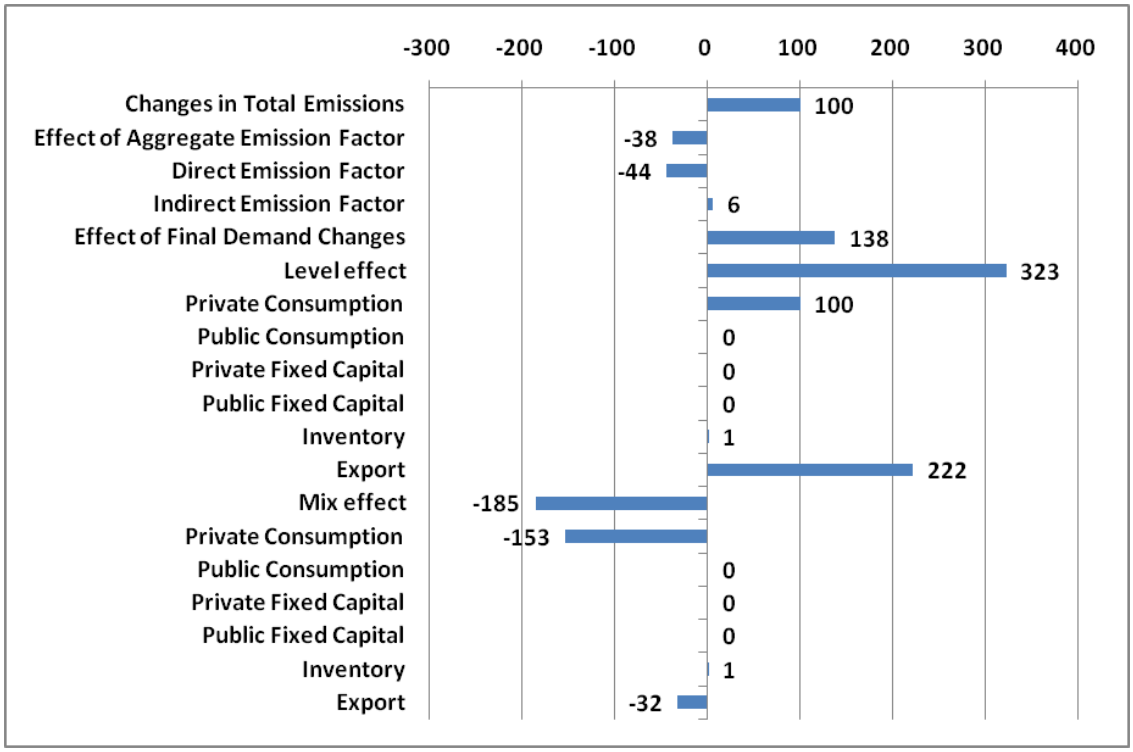

Figure IV-7: CO2 Emissions Decomposition of Electronic and Electrical Machines (1995~2005)

(unit: %)

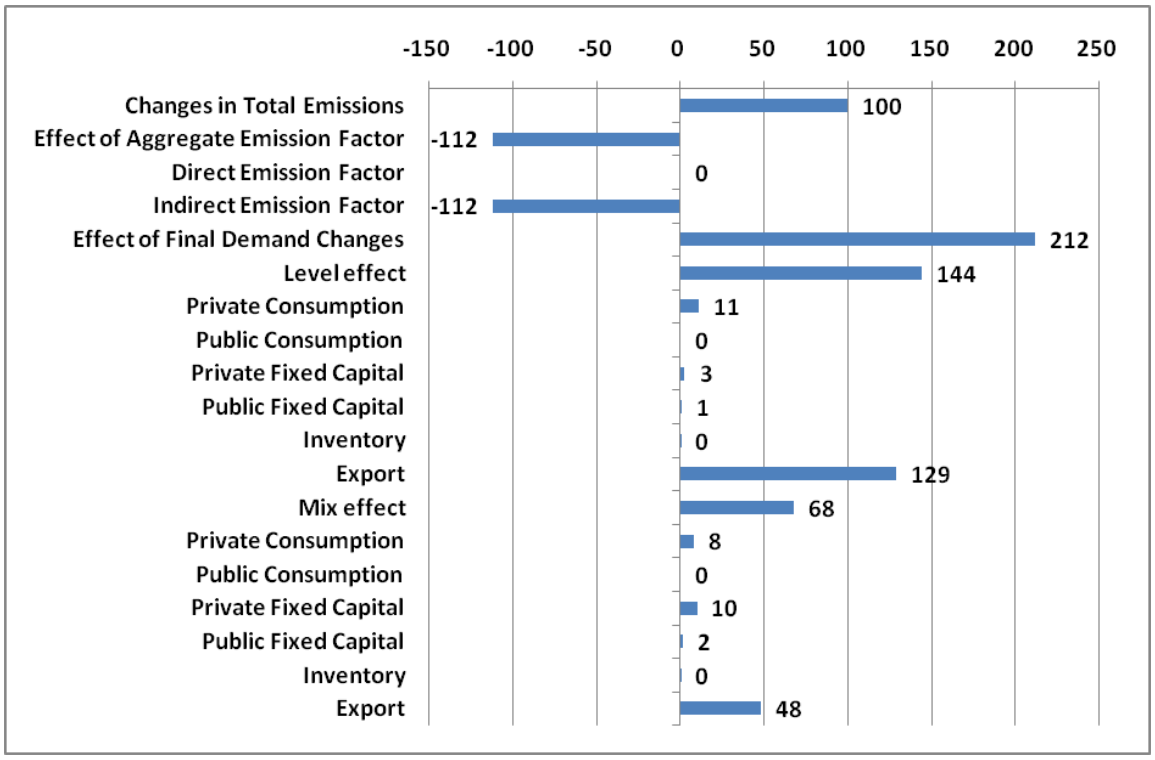

Figure IV-8: CO2 Emissions Decomposition of Education and Health Industry (1995~2005)

(unit: %)

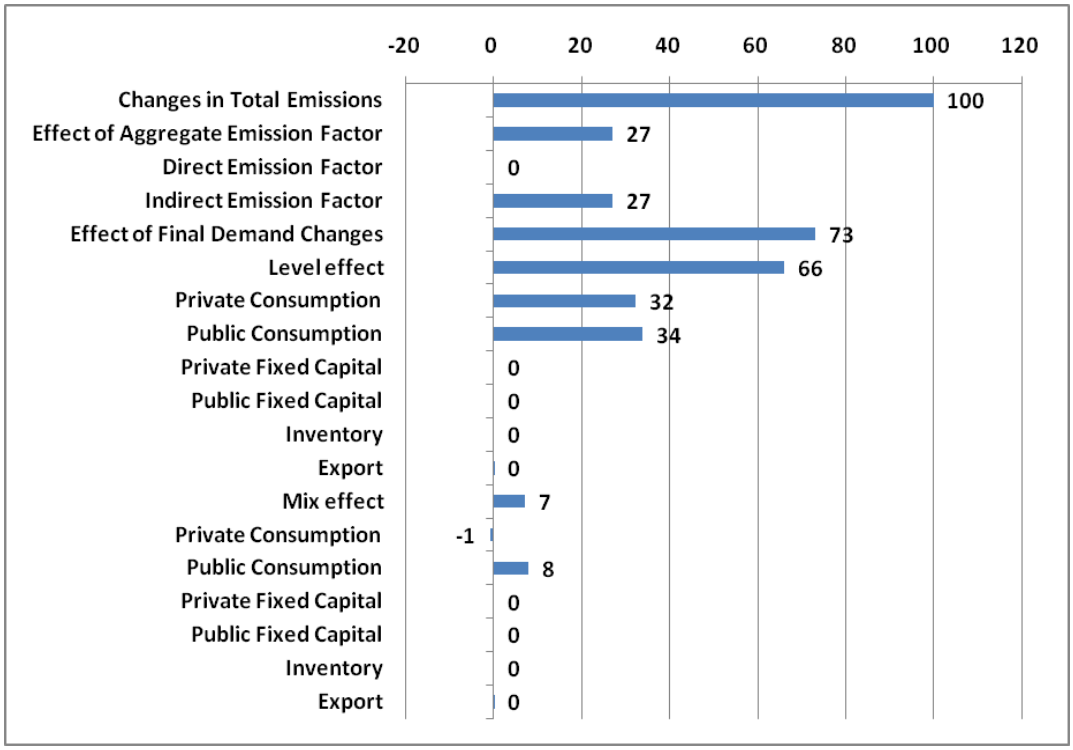

Table I-1: Scenarios for CO2 Emissions Restriction

Year	2005	2020
Carbon dioxide	594 MT	813MT(Prediction)
Targets (each year)	8%	642MT (-21%)
	0%	590MT (-27%)
	-4%	569MT (-30%)

Source : Presidential Committee on Green Growth (2009)

Table II-1: Green TFP in Korea

Industry	Period I: 1995-2000					Period II: 2000-2005				
	Average annual growth rate of value added	Growth Factors				Average annual growth rate of value added	Growth Factors			
		Capital	Labor	Environmental Factors	TFP		Capital	Labor	Environmental Factors	TFP
Agriculture, Fisheries and Mining	1.1%	3.1%	0.0%	-0.4%	-1.6%	0.2%	3.3%	-0.1%	0.3%	-3.3%
Manufacturing	7.6%	1.2%	-0.9%	1.0%	6.3%	6.4%	1.2%	0.3%	0.8%	4.1%
Services	3.1%	3.1%	1.1%	0.3%	-1.4%	3.9%	1.6%	1.5%	0.4%	0.3%

Table II-2: Growth Rate of GDP by CO2 Reduction Target

CO2 Reduction Target	**Maintaining Current Trend**	**If Korea has to reduce its CO2 emissions without successful Green Growth Policy (by 30% from 2020 BAU levels)**
Average annual growth rate of GDP (periods: 2005-2020)	4.51%	3.92% (-0.58%p)

Table III-1: Industrial Identification of 17 New Growth Engines in I/O Tables 2005

	New Growth Engine	Detail Industry	Identification Code
1	Renewable energy	Solar battery, Fuel cell	245 Battery, 301 Other power generation
		Ocean bio energy, Ocean energy	301 Other power generation, 317 Power facility
		Clean coal energy	30 Anthracite coal;, 31 Bituminous coal , 131 Coal
		Waste biomass	301 Other power generation
2	Low carbon emission energy	Carbon capture and storage	228 Air and liquidity filter cleaner
		Nuclear power generation plant, Small and medium Size research reactor	300 Nuclear power
3	Advanced water treatment industry	Membrane filtration water treatment , Management of pipeline distribution network	304 Waterworks, 314 Water supply and sewerage facilities
		Spring water	82 Spring water and ice
		Reusing treated waste water and sewerage	314 Water supply and sewerage facilities
		Ocean desalination plant	304 Waterworks
		Using deep ocean water resource	82 Spring water and ice
4	LED application	Diffusion of LED, Development of core technology	246 Light bulb & lighting equipment
5	Green transport systems	Green car	274 Motorcar for riding
		Ship ocean system	281 Steel ship, 283 Repairing ship and parts
		High-tech railroad	327 Passenger railway , 328 Freight railway, 309 Railway facilities
6	High-tech green city	U-City, ITS(Intelligent Transport Systems), GIS(Geographic Information Systems)	365 Software development and supply 367 Computer relevant service
		Low energy eco-house	305 House construction , 354 Housing service
7	Broadcasting and communication fusion system	Broadcasting and communication services, Broadcasting and communication contents	345 Information service, 346 Terrestrial television broadcasting, 347 Wire and satellite broadcasting
		Next generation network	343 Very high-speed network services

8	IT fusion system	IT fusion , RFID/USN	261 Wireless telecommunication system and broadcasting equipment
		High-tech semiconductor	251 Integrated circuit (IC)
		High-tech display	256 TV
9	Robot application	Expansion of robot market	297 Other manufacturing products
10	New materials· Nano fusion	Metals, Chemicals, Ceramic materials	219 Other metal products, 165 Other chemicals, 175 Industrial pottery
11	Bio-pharmaceuticals (resource) ·Medical equipment	Bio-pharmaceuticals	155 Pharmaceuticals, 196 Cosmetics and toothpaste
		Medical equipment	268 Medical equipment
		Bio resource	16 Seed and seedling
12	High value-added food industry	Globalization of Korean food	323 General restaurants
13	Global health care	Global health services, u-Health	377 Medical and health(public), 379 Medical and health(industry)
14	Global education service	Attraction of Superior International Education Institutes and students	374 Education(public), 376 Education(industry)
		U-Learning	260 Radio communication terminal, 346 Terrestrial television broadcasting, 347 Wire and satellite broadcasting
15	Green finance	Carbon Finance (Emission Reduction market)	350 Other financial intermediaries
		Financial assistance for Green Industry	348 Central bank and bank depositary institution
16	Contents·SW	Contents, Improving Competitiveness of SW Industry	366 Software development and supply
17	MICE·Tourism	MICE(Meeting, Incentives Convention, Exhibition), integrated tourism	326 Lodging 386 Culture services(public), 387 Culture services(others)

Table III-2: Structure of Hybrid Input-Output Table

		Industries (Intermediate Demand)		Final Demand	Total Demand	Import (Deduction)	Total Output
		Energy Industries	Industries excluding Energy				
Industries (Intermediate Input)	Energy Industries	Quantities	Quantities	Quantities	Quantities	Quantities	Quantities
	Industries except for Energy	Price	Price	Price	Price	Price	Price
Value added		Price	Price				
Total Input		Price	Price				

Sources: 1) Miller, R. E. and Blair, P. D. 1985. Input-Output Analysis : Foundations and Extensions. New Jersey : Prentice-Hall.

2) S.R Sim. 2005. 『A manual for Energy Input-Output table』

Table III-5: Direct CO2 Emission Coefficient by Industries

(unit: tons of carbon/million won)

Industries	1995	2000	2005
Agriculture and Fisheries	0.000	0.000	0.000
Mining	0.000	0.000	0.000
Food	0.000	0.000	0.000
Fiber and Leather Products	0.000	0.000	0.000
Lumber and Paper Products	0.000	0.000	0.000
Printing and Reprinting	0.000	0.000	0.000
Petroleum and Coal	1.014	0.810	0.934
Chemical Products	0.001	0.001	0.001
Mineral Products	0.132	0.130	0.120
Fundamental Metal Products	0.004	0.007	0.023
Metal Products	0.000	0.000	0.000
General Machines	0.000	0.000	0.000
Electronic and Electrical Machines	0.000	0.000	0.000
Precision Machineries	0.000	0.000	0.000
Transportation Equipment	0.000	0.000	0.000
Furniture and Other manufacturing	0.000	0.000	0.000
Thermal Power, Gas and Water Services	0.874	1.248	1.286
Construction	0.000	0.000	0.000
Wholesale and Retail sale	0.000	0.000	0.000
Restaurant and Lodging	0.000	0.000	0.000
Transportation and Custody	0.000	0.000	0.000
Communication and Broadcasting	0.000	0.000	0.000
Finance and Insurance	0.000	0.000	0.000
Real Estate and Business Services	0.000	0.000	0.000
Public and Defense	0.000	0.000	0.000
Education and Health	0.000	0.000	0.000
Social and Other Services	0.000	0.000	0.000
Others	0.008	0.002	0.000

Table III-6: Indirect CO2 Emission Coefficient by Industries

(unit: tons of carbon/million won)

Industries	1995	2000	2005
Agriculture and Fisheries	0.087	0.062	0.071
Mining	0.077	0.044	0.050
Food	0.075	0.060	0.065
Fiber and Leather Products	0.123	0.113	0.095
Lumber and Paper Products	0.100	0.104	0.121
Printing and Reprinting	0.076	0.071	0.076
Petroleum and coal	0.032	0.029	0.043
Chemical Products	0.259	0.215	0.201
Mineral Products	0.236	0.197	0.165
Fundamental Metal Products	0.136	0.116	0.133
Metal Products	0.107	0.092	0.117
General Machines	0.068	0.068	0.064
Electronic and Electrical Machines	0.124	0.074	0.061
Precision Machineries	0.041	0.038	0.037
Transportation Equipment	0.091	0.078	0.086
Furniture and Other manufacturing	0.107	0.091	0.082
Thermal Power, Gas and Water Services	0.533	0.359	0.318
Construction	0.082	0.079	0.092
Wholesale and Retail sale	0.088	0.055	0.070
Restaurant and Lodging	0.102	0.082	0.085
Transportation and Custody	0.303	0.207	0.204
Communication and Broadcasting	0.054	0.039	0.048
Finance and Insurance	0.035	0.024	0.025
Real Estate and Business Services	0.048	0.032	0.040
Public and Defense	0.087	0.056	0.047
Education and Health	0.052	0.056	0.066
Social and Other Services	0.085	0.071	0.076
Others	0.106	0.096	0.087

Table III-7: Aggregate CO2 Emission Coefficient by Industries

(unit: tons of carbon/million won)

Industries	1995	2000	2005
Agriculture and Fisheries	0.087	0.062	0.071
Mining	0.077	0.044	0.050
Food	0.075	0.060	0.065
Fiber and Leather Products	0.123	0.113	0.095
Lumber and Paper Products	0.100	0.104	0.121
Printing and Reprinting	0.076	0.071	0.076
Petroleum and coal	1.045	0.839	0.977
Chemical Products	0.260	0.216	0.202
Mineral Products	0.368	0.327	0.285
Fundamental Metal Products	0.140	0.123	0.155
Metal Products	0.107	0.092	0.117
General Machines	0.068	0.068	0.064
Electronic and Electrical Machines	0.124	0.074	0.061
Precision Machineries	0.041	0.038	0.037
Transportation Equipment	0.091	0.078	0.086
Furniture and Other manufacturing	0.107	0.091	0.082
Thermal Power, Gas and Water Services	1.407	1.606	1.604
Construction	0.082	0.079	0.092
Wholesale and Retail sale	0.088	0.055	0.070
Restaurant and Lodging	0.102	0.082	0.085
Transportation and Custody	0.303	0.207	0.204
Communication and Broadcasting	0.054	0.039	0.048
Finance and Insurance	0.035	0.024	0.025
Real Estate and Business Services	0.048	0.032	0.040
Public and Defense	0.087	0.056	0.047
Education and Health	0.052	0.056	0.066
Social and Other Services	0.085	0.071	0.076
Others	0.115	0.098	0.088

Table III-8: CO2 Emissions by Industries

(unit: tons of carbon(TC))

Industries	1995	2000	2005	Changes (1995-2000)	Changes (2000-2005)	Changes (1995-2005)
Agriculture and Fisheries	1,422,131	848,020	1,066,310	-574,111	218,291	-355,821
Mining	-4,393	460	4,785	4,853	4,324	9,177
Food	2,849,140	2,793,690	2,959,504	-55,450	165,814	110,364
Fiber and Leather Products	3,770,863	3,635,272	3,122,599	-135,590	-512,674	-648,264
Lumber and Paper Products	238,054	261,371	346,476	23,316	85,106	108,422
Printing and Reprinting	38,001	27,213	32,246	-10,788	5,033	-5,755
Petroleum and coal	26,091,162	34,116,329	31,312,991	8,025,167	-2,803,338	5,221,829
Chemical Products	6,018,167	6,428,502	8,795,106	410,336	2,366,604	2,776,939
Mineral Products	433,190	383,207	563,678	-49,982	180,471	130,489
Fundamental Metal Products	1,068,221	1,512,169	2,875,860	443,949	1,363,691	1,807,640
Metal Products	1,032,797	518,905	1,013,498	-513,891	494,592	-19,299
General Machines	2,195,286	2,265,467	3,320,882	70,181	1,055,415	1,125,596
Electronic and Electrical Machines	3,625,636	5,170,156	8,387,983	1,544,520	3,217,827	4,762,347
Precision Machineries	304,963	316,195	471,742	11,232	155,547	166,779
Transportation Equipment	3,861,637	4,649,123	7,441,100	787,487	2,791,977	3,579,463
Furniture and Other manufacturing	843,549	771,595	746,995	-71,954	-24,600	-96,554
Thermal Power, Gas and Water Services	6,360,165	16,102,398	15,928,707	9,742,233	-173,691	9,568,542
Construction	11,203,087	8,899,501	12,906,359	-2,303,586	4,006,857	1,703,271
Wholesale and Retail sale	3,873,014	2,638,959	3,775,236	-1,234,055	1,136,278	-97,778
Restaurant and Lodging	2,301,873	2,885,505	3,424,220	583,632	538,715	1,122,347
Transportation and Custody	10,484,975	9,518,679	9,038,330	-966,296	-480,349	-1,446,645
Communication and Broadcasting	211,239	512,734	1,059,800	301,495	547,067	848,562
Finance and Insurance	592,621	681,013	875,367	88,392	194,354	282,746
Real Estate and Business Services	1,887,844	2,663,449	4,306,223	775,605	1,642,774	2,418,379
Public and Defense	3,237,020	2,780,464	3,204,087	-456,556	423,623	-32,932
Education and Health	2,882,308	4,437,719	7,329,560	1,555,411	2,891,841	4,447,252
Social and Other Services	1,898,346	2,412,173	3,627,350	513,827	1,215,178	1,729,005
Others	118,115	198,291	135,948	80,176	-62,344	17,833
Total	98,839,008	117,428,560	138,072,943	18,589,552	20,644,383	39,233,935

Table III-9: CO2 Emissions by Industries and Energy Sources (1995)

(unit: tons of carbon(TC))

Industries	Anthracite	Bituminous Coal	Crude Oil	Natural Gas	Total
Agriculture and Fisheries	28,605	274,183	1,078,828	40,514	1,422,131
Mining	-108	-948	-3,110	-226	-4,393
Food	78,688	656,110	1,950,999	163,342	2,849,140
Fiber and Leather Products	115,662	919,797	2,456,553	278,850	3,770,863
Lumber and Paper Products	7,802	62,482	146,626	21,144	238,054
Printing and Reprinting	1,156	9,110	25,095	2,640	38,001
Petroleum and coal	303,085	4,140,561	21,616,710	30,807	26,091,162
Chemical Products	135,286	1,269,019	4,375,430	238,432	6,018,167
Mineral Products	22,881	226,824	169,786	13,698	433,190
Fundamental Metal Products	70,474	296,087	607,929	93,731	1,068,221
Metal Products	51,408	275,040	620,517	85,831	1,032,797
General Machines	99,264	577,032	1,352,262	166,727	2,195,286
Electronic and Electrical Machines	152,929	1,072,775	2,125,518	274,414	3,625,636
Precision Machineries	12,632	88,088	177,472	26,770	304,963
Transportation Equipment	153,949	996,538	2,433,487	277,663	3,861,637
Furniture and Other manufacturing	29,142	213,465	542,752	58,189	843,549
Thermal Power, Gas and Water Services	417,410	2,891,637	1,329,986	1,721,132	6,360,165
Construction	483,569	3,799,477	6,365,629	554,412	11,203,087
Wholesale and Retail sale	102,059	817,814	2,773,683	179,458	3,873,014
Restaurant and Lodging	73,611	593,996	1,435,417	198,850	2,301,873
Transportation and Custody	147,191	1,757,180	8,490,135	90,470	10,484,975
Communication and Broadcasting	8,879	57,188	124,724	20,448	211,239
Finance and Insurance	23,758	145,729	377,185	45,949	592,621
Real Estate and Business Services	80,975	545,391	1,070,987	190,491	1,887,844
Public and Defense	110,289	768,057	2,154,204	204,470	3,237,020
Education and Health	95,670	705,821	1,865,402	215,415	2,882,308
Social and Other Services	67,834	462,325	1,229,837	138,350	1,898,346
Others	11,497	26,062	73,774	6,781	118,115
Total	2,885,598	23,646,839	66,967,819	5,338,752	98,839,008

Table III-10: CO2 Emissions by Industries and Energy Sources (2000)

(unit: tons of carbon(TC))

Industries	Anthracite	Bituminous Coal	Crude Oil	Natural Gas	Total
Agriculture and Fisheries	14,011	217,312	577,104	39,593	848,020
Mining	10	135	281	35	460
Food	67,674	856,761	1,648,798	220,457	2,793,690
Fiber and Leather Products	96,428	1,183,065	2,001,966	353,813	3,635,272
Lumber and Paper Products	8,313	96,871	122,736	33,451	261,371
Printing and Reprinting	765	9,130	14,489	2,830	27,213
Petroleum and coal	174,631	6,566,564	27,302,259	72,875	34,116,329
Chemical Products	127,603	1,772,747	4,147,601	380,551	6,428,502
Mineral Products	19,762	229,578	117,014	16,854	383,207
Fundamental Metal Products	211,322	535,268	573,062	192,517	1,512,169
Metal Products	43,059	180,321	235,133	60,392	518,905
General Machines	154,597	773,811	1,093,581	243,478	2,265,467
Electronic and Electrical Machines	263,958	1,918,039	2,426,160	561,999	5,170,156
Precision Machineries	14,240	118,277	150,104	33,573	316,195
Transportation Equipment	257,245	1,572,339	2,349,605	469,934	4,649,123
Furniture and Other manufacturing	31,744	260,344	405,353	74,153	771,595
Thermal Power, Gas and Water Services	941,226	9,378,576	1,086,223	4,696,373	16,102,398
Construction	476,137	3,698,275	4,070,873	654,215	8,899,501
Wholesale and Retail sale	72,250	882,366	1,406,984	277,359	2,638,959
Restaurant and Lodging	82,946	1,020,142	1,443,527	338,891	2,885,505
Transportation and Custody	78,215	1,983,754	7,328,434	128,277	9,518,679
Communication and Broadcasting	18,216	193,450	232,221	68,846	512,734
Finance and Insurance	22,821	242,047	334,521	81,624	681,013
Real Estate and Business Services	107,816	1,076,581	1,088,755	390,297	2,663,449
Public and Defense	89,187	933,372	1,466,670	291,235	2,780,464
Education and Health	124,554	1,479,477	2,375,627	458,062	4,437,719
Social and Other Services	75,868	832,703	1,235,724	267,877	2,412,173
Others	9,897	62,286	108,779	17,329	198,291
Total	3,584,495	38,073,593	65,343,584	10,426,889	117,428,560

Table III-11: CO2 Emissions by Industries and Energy Sources (2005)

(unit: tons of carbon(TC))

Industries	Anthracite	Bituminous Coal	Crude Oil	Natural Gas	Total
Agriculture and Fisheries	24,590	302,708	656,130	82,882	1,066,310
Mining	110	1,386	2,879	410	4,785
Food	82,038	965,231	1,588,332	323,902	2,959,504
Fiber and Leather Products	87,219	1,212,868	1,271,184	551,328	3,122,599
Lumber and Paper Products	9,615	135,560	140,003	61,298	346,476
Printing and Reprinting	863	11,228	15,720	4,434	32,246
Petroleum and coal	473,915	6,345,506	24,358,990	134,580	31,312,991
Chemical Products	209,935	2,454,596	5,509,821	620,753	8,795,106
Mineral Products	23,289	355,702	153,180	31,508	563,678
Fundamental Metal Products	864,603	860,656	751,678	398,924	2,875,860
Metal Products	151,421	335,634	382,797	143,645	1,013,498
General Machines	427,918	1,103,931	1,343,733	445,300	3,320,882
Electronic and Electrical Machines	606,947	3,305,192	3,211,967	1,263,877	8,387,983
Precision Machineries	28,330	171,032	210,574	61,807	471,742
Transportation Equipment	793,143	2,518,914	3,153,319	975,723	7,441,100
Furniture and Other manufacturing	49,109	257,309	346,485	94,093	746,995
Thermal Power, Gas and Water Services	508,933	9,162,357	588,496	5,668,921	15,928,707
Construction	997,806	4,998,370	5,746,489	1,163,693	12,906,359
Wholesale and Retail sale	93,325	1,326,506	1,818,580	536,826	3,775,236
Restaurant and Lodging	91,895	1,323,404	1,417,539	591,381	3,424,220
Transportation and Custody	166,021	2,037,523	6,605,604	229,182	9,038,330
Communication and Broadcasting	34,112	456,626	342,125	226,938	1,059,800
Finance and Insurance	25,377	355,260	326,456	168,274	875,367
Real Estate and Business Services	148,833	1,876,354	1,357,972	923,065	4,306,223
Public and Defense	125,741	1,212,507	1,340,418	525,422	3,204,087
Education and Health	203,700	2,834,839	3,015,684	1,275,337	7,329,560
Social and Other Services	120,541	1,442,858	1,396,822	667,129	3,627,350
Others	4,907	50,405	60,382	20,254	135,948
Total	6,354,233	47,414,466	67,113,359	17,190,885	138,072,943

Table IV-1: CO2 Emissions Decomposition by Industries (1995-2000) 1/3

(unit: 1,000 TC)

	Changes in Total Emissions	Effect of Aggregate Emission Coefficient	Direct Emission Coefficient	Indirect Emission Coefficient	Effect of Final Demand Changes	Level effect	Mix effect
Agriculture and Fisheries	-574	-371	0	-371	-203	1,626	-1,830
Mining	5	1	0	1	4	122	-118
Food	-55	-649	0	-649	593	-123	716
Fiber and Leather Products	-136	-325	0	-325	190	235	-46
Lumber and Paper Products	23	12	0	12	11	394	-382
Printing and Reprinting	-11	-2	0	-2	-9	55	-64
Petroleum and coal	8,025	-6,757	-6,668	-89	14,783	-35,138	49,921
Chemical Products	410	-1,171	-13	-1,158	1,581	4,536	-2,954
Mineral Products	-50	-48	-2	-46	-2	922	-924
Fundamental Metal Products	444	-174	31	-204	618	1,541	-923
Metal Products	-514	-116	0	-116	-398	-107	-291
General Machines	70	10	0	10	60	-322	382
Electronic and Electrical Machines	1,545	-2,464	0	-2,464	4,008	957	3,051
Precision Machineries	11	-25	0	-25	36	-123	159
Transportation Equipment	787	-645	0	-645	1,432	7,533	-6,101
Furniture and Other manufacturing	-72	-134	0	-134	62	-96	158
Thermal Power, Gas and Water Services	9,742	1,448	2,717	-1,269	8,294	4,177	4,117
Construction	-2,304	-373	0	-373	-1,931	-304	-1,627
Wholesale and Retail sale	-1,234	-1,537	0	-1,537	303	558	-255
Restaurant and Lodging	584	-591	0	-591	1,175	969	206
Transportation and Custody	-966	-3,836	0	-3,836	2,870	3,067	-197
Communication and Broadcasting	301	-132	0	-132	433	174	260
Finance and Insurance	88	-260	0	-260	349	243	106
Real Estate and Business Services	776	-964	-1	-963	1,739	635	1,104
Public and Defense	-457	-1,353	-1	-1,353	897	846	50
Education and Health	1,555	311	0	311	1,244	1,131	113
Social and Other Services	514	-392	0	-392	906	651	254
Others	80	-25	-9	-16	105	98	7
Total	18,590	-20,561	-3,946	-16,616	39,151	-5,741	44,892

Table IV-2: CO2 Emissions Decomposition by Industries (1995-2000) 2/3

(unit: 1000TC)

	Level Effect	Private Consumption	Public Consumption	Private Fixed Capital	Public Fixed Capital	Inventory	Export
Agriculture and Fisheries	1,626	273	0	-2	0	1,330	25
Mining	122	0	0	0	0	120	2
Food	-123	797	0	0	0	-1,023	103
Fiber and Leather Products	235	348	0	-2	0	-1,215	1,103
Lumber and Paper Products	394	18	0	0	0	287	88
Printing and Reprinting	55	3	0	0	0	44	9
Petroleum and coal	-35,138	4,998	0	0	0	-48,421	8,284
Chemical Products	4,536	327	0	0	0	1,563	2,645
Mineral Products	922	29	0	0	0	748	144
Fundamental Metal Products	1,541	-1	0	18	-5	713	816
Metal Products	-107	31	0	-6	0	-303	170
General Machines	-322	26	0	-173	4	-459	281
Electronic and Electrical Machines	957	274	0	-186	7	-1,017	1,879
Precision Machineries	-123	9	0	-24	2	-143	33
Transportation Equipment	7,533	172	0	-166	3	6,127	1,398
Furniture and Other manufacturing	-96	98	0	-19	1	-312	136
Thermal Power, Gas and Water Services	4,177	4,159	0	0	0	0	18
Construction	-304	0	0	-708	416	-22	10
Wholesale and Retail sale	558	584	0	-79	1	-229	281
Restaurant and Lodging	969	777	0	0	0	0	193
Transportation and Custody	3,067	1,301	0	-18	1	-1,234	3,017
Communication and Broadcasting	174	163	0	0	0	0	10
Finance and Insurance	243	218	0	0	0	0	25
Real Estate and Business Services	635	652	23	-75	4	-50	81
Public and Defense	846	0	846	0	0	0	0
Education and Health	1,131	847	281	0	0	0	3
Social and Other Services	651	667	21	0	0	-100	63
Others	98	-4	0	0	0	0	102
Total	-5,741	16,768	1,171	-1,440	433	-43,593	20,921

Table IV-3: CO2 Emissions Decomposition by Industries (1995-2000) 3/3

(unit: 1000TC)

	Mix Effect	Private Consumption	Public Consumption	Private Fixed Capital	Public Fixed Capital	Inventory	Export
Agriculture and Fisheries	-1,830	-277	0	8	0	-1,531	-29
Mining	-118	0	0	0	0	-116	-2
Food	716	-245	-16	0	0	1,058	-81
Fiber and Leather Products	-46	-488	0	8	2	1,244	-811
Lumber and Paper Products	-382	-55	0	0	0	-300	-27
Printing and Reprinting	-64	-14	0	0	0	-49	-1
Petroleum and coal	49,921	-1,988	0	0	0	49,836	2,073
Chemical Products	-2,954	-1,105	0	0	0	-1,793	-56
Mineral Products	-924	-110	0	0	0	-795	-19
Fundamental Metal Products	-923	6	0	-40	6	-775	-121
Metal Products	-291	-77	0	-321	1	294	-186
General Machines	382	-18	0	-50	14	450	-15
Electronic and Electrical Machines	3,051	210	0	1,066	32	1,024	720
Precision Machineries	159	-8	0	27	7	144	-11
Transportation Equipment	-6,101	-116	0	0	10	-6,337	342
Furniture and Other manufacturing	158	-80	0	0	2	320	-83
Thermal Power, Gas and Water Services	4,117	4,128	0	0	0	0	-11
Construction	-1,627	0	0	-1,560	-93	22	4
Wholesale and Retail sale	-255	-556	0	161	-2	218	-76
Restaurant and Lodging	206	217	0	0	0	0	-11
Transportation and Custody	-197	-1,517	0	91	1	1,251	-22
Communication and Broadcasting	260	263	0	0	0	0	-3
Finance and Insurance	106	96	0	0	0	0	10
Real Estate and Business Services	1,104	649	-13	384	11	51	22
Public and Defense	50	0	50	0	0	0	0
Education and Health	113	135	-25	0	0	0	2
Social and Other Services	254	133	24	0	0	101	-5
Others	7	-9	0	0	0	0	17
Total	44,892	-828	21	-227	-10	44,316	1,619

Table IV-4: CO2 Emissions Decomposition by Industries (2000-2005) 1/3

(unit: 1000TC)

	Changes in Total Emissions	Effect of Aggregate Emission Coefficient	Direct Emission Coefficient	Indirect Emission Coefficient	Effect of Final Demand Changes	Level effect	Mix effect
Agriculture and Fisheries	218	126	0	126	92	210	-118
Mining	4	0	0	0	4	2	2
Food	166	232	0	232	-66	497	-563
Fiber and Leather Products	-513	-587	0	-587	74	773	-699
Lumber and Paper Products	85	45	0	45	40	93	-53
Printing and Reprinting	5	2	0	2	3	10	-7
Petroleum and coal	-2,803	4,988	4,492	496	-7,792	7,320	-15,112
Chemical Products	2,367	-514	-6	-508	2,881	2,661	220
Mineral Products	180	-67	-16	-51	247	208	39
Fundamental Metal Products	1,364	502	246	255	862	888	-26
Metal Products	495	180	0	180	315	270	45
General Machines	1,055	-179	0	-179	1,234	804	430
Electronic and Electrical Machines	3,218	-1,427	0	-1,427	4,644	2,641	2,004
Precision Machineries	156	-12	0	-12	168	111	57
Transportation Equipment	2,792	558	0	558	2,234	1,907	327
Furniture and Other manufacturing	-25	-75	0	-75	50	191	-141
Thermal Power, Gas and Water Services	-174	-27	380	-407	-147	2,515	-2,662
Construction	4,007	1,638	0	1,638	2,369	2,304	65
Wholesale and Retail sale	1,136	750	0	750	386	654	-268
Restaurant and Lodging	539	106	0	106	433	564	-132
Transportation and Custody	-480	-144	0	-144	-337	2,248	-2,585
Communication and Broadcasting	547	170	0	170	377	156	221
Finance and Insurance	194	28	0	28	166	144	21
Real Estate and Business Services	1,643	756	-2	758	887	711	176
Public and Defense	424	-522	0	-522	945	1,310	-365
Education and Health	2,892	923	0	923	1,969	1,717	252
Social and Other Services	1,215	202	0	202	1,013	594	420
Others	-62	-19	-4	-15	-44	45	-89
Total	20,644	7,635	5,091	2,544	13,009	31,549	-18,540

Table IV-5: CO2 Emissions Decomposition by Industries (2000-2005) 2/3

(unit: 1000TC)

	Level Effect	Private Consumption	Public Consumption	Private Fixed Capital	Public Fixed Capital	Inventory	Export
Agriculture and Fisheries	210	139	0	3	1	55	11
Mining	2	0	0	0	0	2	1
Food	497	411	0	0	0	21	65
Fiber and Leather Products	773	305	0	2	0	15	450
Lumber and Paper Products	93	11	0	0	0	6	76
Printing and Reprinting	10	1	0	0	0	1	7
Petroleum and coal	7,320	1,893	0	0	0	182	5,245
Chemical Products	2,661	257	0	0	0	126	2,278
Mineral Products	208	19	0	0	0	56	133
Fundamental Metal Products	888	-5	0	-25	-5	95	828
Metal Products	270	17	0	31	1	39	182
General Machines	804	14	0	411	6	16	356
Electronic and Electrical Machines	2,641	159	0	181	15	26	2,259
Precision Machineries	111	11	0	46	3	5	46
Transportation Equipment	1,907	151	0	241	12	4	1,499
Furniture and Other manufacturing	191	56	0	31	4	36	64
Thermal Power, Gas and Water Services	2,515	2,496	0	0	0	0	20
Construction	2,304	0	0	1,597	659	44	4
Wholesale and Retail sale	654	371	0	64	2	11	206
Restaurant and Lodging	564	494	0	0	0	0	71
Transportation and Custody	2,248	595	0	11	1	9	1,633
Communication and Broadcasting	156	144	0	0	0	0	12
Finance and Insurance	144	126	0	0	0	0	19
Real Estate and Business Services	711	381	39	202	6	0	82
Public and Defense	1,310	5	1,305	0	0	0	0
Education and Health	1,717	599	1,116	0	0	0	2
Social and Other Services	594	519	35	0	0	6	34
Others	45	0	0	0	0	0	45
Total	31,549	9,169	2,496	2,796	706	754	15,628

Table IV-6: CO2 Emissions Decomposition by Industries (2000-2005) 3/3

(unit: 1000TC)

	Mix Effect	Private Consumption	Public Consumption	Private Fixed Capital	Public Fixed Capital	Inventory	Export
Agriculture and Fisheries	-118	-136	0	2	2	40	-25
Mining	2	1	0	0	0	3	-2
Food	-563	-464	0	0	0	-30	-69
Fiber and Leather Products	-699	526	0	-4	-1	-34	-1,185
Lumber and Paper Products	-53	-12	0	0	0	10	-52
Printing and Reprinting	-7	-4	0	0	0	1	-4
Petroleum and coal	-15,112	-7,294	0	0	0	-1,494	-6,324
Chemical Products	220	340	0	0	0	48	-168
Mineral Products	39	6	0	0	0	23	11
Fundamental Metal Products	-26	-21	0	61	12	27	-105
Metal Products	45	-27	0	77	2	-9	2
General Machines	430	-15	0	279	4	-14	176
Electronic and Electrical Machines	2,004	180	0	-331	37	-21	2,139
Precision Machineries	57	29	0	-2	4	-4	30
Transportation Equipment	327	205	0	-381	38	191	274
Furniture and Other manufacturing	-141	-9	0	-11	13	-8	-126
Thermal Power, Gas and Water Services	-2,662	-2,663	0	0	0	0	0
Construction	65	0	0	220	-140	0	-15
Wholesale and Retail sale	-268	152	0	-326	4	-6	-92
Restaurant and Lodging	-132	103	0	0	0	0	-235
Transportation and Custody	-2,585	-615	0	-83	0	-32	-1,855
Communication and Broadcasting	221	217	0	0	0	0	4
Finance and Insurance	21	26	0	0	0	0	-4
Real Estate and Business Services	176	-89	-22	267	4	-1	16
Public and Defense	-365	25	-390	0	0	0	0
Education and Health	252	-265	520	0	0	0	-4
Social and Other Services	420	504	-24	0	0	-3	-57
Others	-89	11	0	0	0	0	-100
Total	-18,540	-9,290	85	-231	-20	-1,313	-7,770

Table IV-7: CO2 Emissions Decomposition by Industries (1995-2005) 1/3

(unit: 1000TC)

	Changes in Total Emissions	Effect of Aggregate Emission Coefficient	Direct Emission Coefficient	Indirect Emission Coefficient	Effect of Final Demand Changes	Level effect	Mix effect
Agriculture and Fisheries	-356	-250	0	-250	-105	449	-555
Mining	9	0	0	0	10	3	7
Food	110	-430	0	-430	541	1,293	-752
Fiber and Leather Products	-648	-901	0	-901	253	1,737	-1,484
Lumber and Paper Products	108	57	0	57	51	175	-124
Printing and Reprinting	-6	0	0	0	-6	18	-23
Petroleum and coal	5,222	-1,961	-2,273	312	7,183	16,857	-9,673
Chemical Products	2,777	-1,944	-22	-1,922	4,721	5,731	-1,010
Mineral Products	130	-131	-19	-112	262	341	-79
Fundamental Metal Products	1,808	197	249	-52	1,610	1,727	-117
Metal Products	-19	91	0	91	-110	459	-569
General Machines	1,126	-164	0	-164	1,290	964	326
Electronic and Electrical Machines	4,762	-5,331	0	-5,331	10,094	6,854	3,239
Precision Machineries	167	-44	0	-44	210	154	56
Transportation Equipment	3,579	-324	0	-324	3,903	3,766	138
Furniture and Other manufacturing	-97	-211	0	-211	114	322	-208
Thermal Power, Gas and Water Services	9,569	1,419	2,976	-1,556	8,149	5,843	2,306
Construction	1,703	1,379	0	1,379	324	1,948	-1,624
Wholesale and Retail sale	-98	-921	0	-921	823	1,734	-911
Restaurant and Lodging	1,122	-556	0	-556	1,678	1,532	146
Transportation and Custody	-1,447	-3,884	0	-3,884	2,437	5,821	-3,383
Communication and Broadcasting	849	-73	0	-73	922	447	474
Finance and Insurance	283	-276	0	-276	559	432	128
Real Estate and Business Services	2,418	-574	-2	-572	2,992	1,555	1,437
Public and Defense	-33	-2,105	-1	-2,104	2,072	2,388	-316
Education and Health	4,447	1,197	0	1,197	3,251	2,933	318
Social and Other Services	1,729	-315	0	-315	2,044	1,537	506
Others	18	-35	-10	-25	53	97	-44
Total	39,234	-16,092	897	-16,989	55,326	67,118	-11,793

Table IV-8: CO2 Emissions Decomposition by Industries (1995-2005) 2/3

(unit: 1000TC)

	Level Effect	Private Consumption	Public Consumption	Private Fixed Capital	Public Fixed Capital	Inventory	Export
Agriculture and Fisheries	449	409	0	2	2	10	27
Mining	3	0	0	0	0	0	2
Food	1,293	1,144	0	0	0	4	145
Fiber and Leather Products	1,737	795	0	1	0	2	939
Lumber and Paper Products	175	28	0	0	0	1	147
Printing and Reprinting	18	3	0	0	0	0	14
Petroleum and coal	16,857	5,227	0	0	0	30	11,599
Chemical Products	5,731	706	0	0	0	21	5,004
Mineral Products	341	49	0	0	0	9	283
Fundamental Metal Products	1,727	-13	0	-13	-9	15	1,747
Metal Products	459	46	0	17	2	6	387
General Machines	964	35	0	211	11	2	705
Electronic and Electrical Machines	6,854	541	0	127	34	5	6,146
Precision Machineries	154	29	0	25	5	1	94
Transportation Equipment	3,766	403	0	133	22	1	3,207
Furniture and Other manufacturing	322	152	0	18	8	6	139
Thermal Power, Gas and Water Services	5,843	5,807	0	0	0	0	36
Construction	1,948	0	0	833	1,100	7	8
Wholesale and Retail sale	1,734	1,167	0	42	4	2	520
Restaurant and Lodging	1,532	1,375	0	0	0	0	158
Transportation and Custody	5,821	1,817	0	7	1	2	3,995
Communication and Broadcasting	447	420	0	0	0	0	27
Finance and Insurance	432	385	0	0	0	0	47
Real Estate and Business Services	1,555	1,151	67	126	13	0	198
Public and Defense	2,388	15	2,373	0	0	0	0
Education and Health	2,933	1,430	1,500	0	0	0	4
Social and Other Services	1,537	1,409	53	0	0	1	75
Others	97	0	0	0	0	0	97
Total	67,118	24,530	3,992	1,528	1,192	125	35,750

Table IV-9: CO2 Emissions Decomposition by Industries (1995-2005) 3/3

(unit: 1000TC)

	Mix Effect	Private Consumption	Public Consumption	Private Fixed Capital	Public Fixed Capital	Inventory	Export
Agriculture and Fisheries	-555	-411	0	11	2	-110	-48
Mining	7	0	0	0	0	10	-4
Food	-752	-632	-16	0	0	23	-127
Fiber and Leather Products	-1,484	-51	0	2	1	4	-1,441
Lumber and Paper Products	-124	-68	0	0	0	1	-57
Printing and Reprinting	-23	-17	0	0	0	-3	-3
Petroleum and coal	-9,673	-8,012	0	0	0	27	-1,688
Chemical Products	-1,010	-800	0	0	0	-52	-157
Mineral Products	-79	-99	0	0	0	31	-12
Fundamental Metal Products	-117	-10	0	27	18	45	-198
Metal Products	-569	-108	0	-270	3	15	-209
General Machines	326	-28	0	263	17	-9	83
Electronic and Electrical Machines	3,239	373	0	487	74	7	2,298
Precision Machineries	56	14	0	24	10	1	6
Transportation Equipment	138	38	0	-458	45	-10	522
Furniture and Other manufacturing	-208	-84	0	-13	14	32	-156
Thermal Power, Gas and Water Services	2,306	2,316	0	0	0	0	-10
Construction	-1,624	0	0	-1,436	-222	40	-5
Wholesale and Retail sale	-911	-474	0	-283	2	-8	-149
Restaurant and Lodging	146	304	0	0	0	0	-158
Transportation and Custody	-3,383	-2,055	0	-23	0	-13	-1,292
Communication and Broadcasting	474	475	0	0	0	0	-1
Finance and Insurance	128	120	0	0	0	0	7
Real Estate and Business Services	1,437	635	-34	785	17	0	35
Public and Defense	-316	24	-340	0	0	0	0
Education and Health	318	-37	355	0	0	0	0
Social and Other Services	506	537	5	0	0	4	-40
Others	-44	0	0	0	0	0	-44
Total	-11,793	-8,048	-31	-885	-19	36	-2,846