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Harmonization of Carbon Tax and Energy Taxes

December 2012

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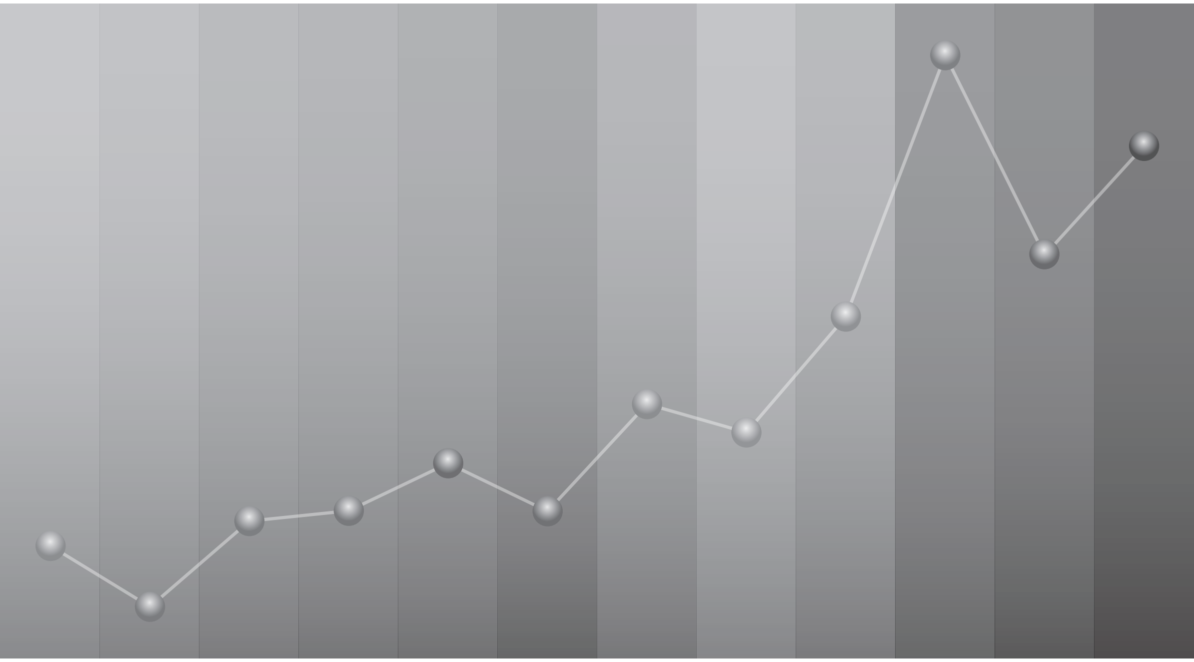

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Introduction

Notwithstanding the ongoing world economic crisis, one further aggravated by the European financial crisis, efforts to address climate change continue to be heightened across the globe. For example, the European Union launched its Emissions Trading Scheme (EU ETS) in 2005 and is currently in the process of implementing the second phase (2008-2012). Despite the economic slowdown stemming from the financial crisis, the EU has been pursuing as planned the expansion of this system to include aviation emissions. The Korean government has also announced long-term carbon emissions reduction targets as part of its efforts to secure future growth engines under the national green-growth paradigm. More specifically, it has established a legal framework for a carbon cap-and-trade system scheduled to enter into effect in 2015.

Along with carbon emissions trading systems, taxation measures including carbon taxes are commonly employed as a means to combat emissions of carbon dioxide and other greenhouse gases. Such taxation is intended to reduce carbon emissions in areas not covered by emissions trading systems, given that such systems can be only implemented centered on large business endeavors where it is possible to monitor the volume of carbon emissions. Having taken a relatively proactive stance on environmental issues, European nations began to adopt the concept of a carbon tax on fossil fuels as early as the 1990s.

The EU implementation of a carbon tax and its adoption and expansion of an emissions trading scheme for reducing greenhouse gas discharges have also influenced non-member countries involved in trade with the EU. Specifically, as the EU has extended its emissions trading system to the airline industry, non-European airlines operating within EU territory are faced with increased obligations together with European-based airlines. In line with international efforts towards greenhouse gas mitigation and in consideration of trade relations with the EU which drive such efforts, the Republic of Korea should similarly devise an aggressive greenhouse gas reduction plan. Although the country has determined to initiate carbon trading from 2015, it should also give consideration to other approaches, such as a carbon tax designed to reduce carbon emissions outside large-scale business establishments. In addition, when adopting a carbon tax, the tax rate should be determined while taking into consideration its interrelations with existing individual consumption taxes, including transportation, energy and environmental taxes, which have been imposed at substantial levels. However, the majority of previous studies have simply examined either carbon taxes or emissions trading systems, and examinations of carbon taxes have failed to consider existing energy-related taxes (Kim Seung-rae et al., 2010, etc.).

This report designs a carbon tax that is compatible with existing energy taxes. Essentially, we select and analyze key subjects concerning the harmonization of a carbon tax with other energy-related taxes. The scope of the research was set to include important subjects to which little attention has been directed in existing studies. This is necessary to avoid overlap with previous studies and present an in-depth analysis of specific subjects. The main topics include an analysis of energy consumption in the manufacturing and household sectors, European experiences of the harmonization of carbon taxes and energy taxation, designing of a carbon tax, and the economic impact of a new carbon tax. Though not intimately related to one another, these are all crucial issues that must be considered in discussions on carbon tax.

To begin, we will examine the price effect of energy consumption through an analysis of the industry sector, a main sector in terms of energy consumption, and from the household sector, which represents a unit of domestic living. With the industrial sector, a careful approach is required in the imposition of a carbon tax, keeping international competitiveness in mind. Harmonizing such a tax with the upcoming emissions trading system is another important consideration for this sector. The household sector was selected due to its signalling effect on the tax acceptance of individuals, although energy consumption by this sector might not be considerable. Specifically, the industrial sector will be analyzed in terms of various factors which can give us useful implications. We first decompose energy consumption into four factors, such as production level, industrial structure, share of value added, and energy intensity (total energy consumption divided by value added), then identify important factors based upon which the effect of energy prices is to be analyzed. The impact of prices on the household energy demand is examined using demand function analysis. The study explicitly addresses the necessity of energy goods in the analysis.

In addition, we analyze the experiences of some developed European countries which have adopted carbon taxes, especially in terms of how they harmonized them with their existing energy taxes. This is intended to know the way to design a carbon tax according to the various existing scopes of energy taxes. Specifically, we look at how the introduction of a carbon tax impacted the overall scope of taxation on energy products and whether or not it was introduced in the form of an independent tax item. Based on this analysis of energy demand and cases of other countries, we design a carbon tax suitable for the South Korean context and analyze the estimated tax revenue effect. In order to investigate the economic impact of carbon taxes which have several expenditure options, along with emissions trading systems, their influence on economic growth and other indicators is examined using a general equilibrium model.

This paper is organized as follows. Chapter II presents analyses of the energy demands of the manufacturing and household sectors, while Chapter III introduces experiences of how selected countries have harmonized existing energy taxation with a carbon tax. In Chapter IV, a carbon tax appropriate for the circumstances of South Korea is formulated, while in the following Chapter V its economic effects are analyzed by applying a general equilibrium model. Finally, Chapter VI presents the overall conclusion of the study.

II

Analysis of Energy Consumption

1 Analysis of Industrial (Manufacturing) Energy Consumption

A. Background

Efforts to reduce greenhouse gases largely target fossil fuels. This is due to the majority of greenhouse gases being emitted via the burning of such fuels. In South Korea, energy-intensive industries have developed to a great extent since the period of rapid growth in the 1970s and 1980s, leading to a sharp increase in energy consumption. Therefore, how to deal with this problem going forward is a key factor in crafting policy for lowering greenhouse gas emissions. An analysis needs to be performed as to what factors have steered energy consumption in South Korea to its current state. This is crucial in designing a comprehensive greenhouse gas mitigation policy that spans not only pricing policies including a carbon tax, but also addresses industrial restructuring policies such as high value-adding.

This study examines the sources of the increase in energy consumption since 1991. It particularly focuses on the manufacturing sector, which accounts for more than half of final energy consumption and plays a central role in promoting exports and growth, since while implementing greenhouse gas reduction programs it is essential to maintain the competitiveness of the manufacturing sector, a major growth engine for the South Korean economy. Decomposing the change of energy consumption in the manufacturing sector by several factors—for example, the level of economic activity, industrial structure, share of value added, and change in energy intensity—may assist in devising more effective policy measures. South Korea displays elevated energy intensity compared to other countries, reflecting the influence of its more energy-intensive manufacturing industries. We use the Log Mean Divisia Index (LMDI) method proposed in Ang and Liu (2001). This technique is employed in a great number of studies as it leaves no residual following factor decompositions.

For the factor analysis of changes in energy consumption in manufacturing, we divided the factors into production, industrial structure, value added and energy intensity effects. We explicitly decomposed production intensity effect into value added effect and value added intensity effect. Furthermore, to address the change of energy demand structure, we added an analysis in which final energy was converted into primary energy in order to allow power generation losses to be included. This was undertaken in an effort to more clearly analyze the effects arising from the change of final energy consumption by energy source.

The analysis revealed that the increase in energy consumption over the period 1991-2009 was driven largely by the production effect, as well as to a considerable extent by the increase in energy intensity. Growth in energy intensity means increased energy input per unit of value added, indicating that the input structure has changed to become more energy-dependent. In contrast, the industrial structure and value added ratio served as factors to reduce energy consumption. A fall in the value added ratio indicates that more production is required to generate the same value added, and thus it served to exacerbate the energy dependence of the economy. The magnitudes of effects are the production effect, intensity effect, industrial structure effect, and value added effect in a decreasing order. This order does not change even when considering losses in power generation. We performed a separate analysis for the 1998-2009 period, taking into consideration the changes in energy consumption patterns and data classification system in the wake of the Asian financial crisis, as discussed in previous studies and materials. As a result, the rise in energy consumption due to the production effect further increased while the effects of intensity, industrial structure and value added diminished.

B. Previous Studies and Methodology

The LMDI decomposition analysis method has commonly been used in studies on energy consumption and greenhouse gas emissions. Ang (2005) demonstrated that the LMDI method could be applied to a three-factor analysis of energy consumption in the industrial sector and a five-factor analysis of energy-related carbon emissions.

Examples of empirical studies using this methodology are Han and Shin (2007), Lee You-ah and Heo Eun-nyeong (2009), and Oh et al. (2010), which analyzed carbon dioxide emission sources. Studies on energy consumption structure include Na In-gang and Lee Sung-keun (2008), Park Hoon (2009) and Kim Su-yi and Kim Hyun-seok (2011).

Among similar previous studies, Na In-gang and Lee Sung-keun (2008) applied the LMDI method to the industrial sector and extended the decomposition using a quantitative model which performed a regression analysis of decomposed indices as functions of aggregate variables such as other prices and value added. However, this study was limited in that it used oil import price as an explanatory variable which may not address domestic energy production process and tax policy. There is also the limitation that it employed an analysis method based on value added and thus failed to reflect the change of the value added structure within industries. Park Hoon (2009) explained that changes in energy consumption in the manufacturing sector could be classified into the effects of production, industrial structure and value added energy intensity, but did not in fact apply the decomposition method. Kim Su-yi and Kim Hyun-seok (2011) analyzed changes in energy consumption by manufacturing during the 1991-2007 period using the LMDI method. This study decomposed energy consumption into three effects—production, industrial structure and production energy intensity—and applied both additive (based on the amount of increase) and multiplicative (analyzing the rate of increase) methods. These projects used decomposition methods to investigate the industrial (or manufacturing) sector, but they remained limited for lacking detailed classification of the factors to be analyzed and failing to consider the loss upon conversion that arises from the use of final energy consumption data. As presented in Ang (2005), the methodology of decomposition analysis was also restricted to the three factors of production, industrial structure and value added energy intensity. Therefore, the problem arises that the impact of value added ratio, which is an important factor in determining energy efficiency, cannot be separately analyzed.

This study contributes in three major ways. Firstly, it further subdivided decomposition factors from the existing three[1)] to four factors. That is, among the three factors used in previous investigations—production effect, structure effect and intensity effect—the intensity effect was further divided into value added ratio and value added energy intensity effects. Through this decomposition, we can distinguish the technical intensity of manufacturing from the effect of a change in value added ratio. This would help in formulating well-targeted policies. Secondly, this study explicitly considered loss upon conversion, which may have been overlooked by previous studies focusing on final energy. Even at the same level of final energy consumption, the more electricity is used, the higher is the energy consumption in terms of primary energy. Total energy consumption can be well defined by including the loss in electricity generation. Thirdly, we performed a regression analysis of the impact of energy prices on the contribution of energy intensity in order to evaluate the effectiveness of energy pricing policies. This analysis is able to illuminate how past energy pricing policies influenced the increase of energy consumption through changes in energy intensity, which will, in turn, offer grounds to predict the effectiveness of a carbon tax and other pricing policies.

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1) The existing three-way decomposition can be applied to both production and value added. When this method is applied to production, intensity is defined based upon production. When this decomposition method is applied to value added, however, the connection with production disappears and value added is decomposed into the effect of the increase of value added, the effect of industrial structure based on value added, and the effect of intensity based on value added.

Specifically, changes in manufacturing energy consumption are analyzed through a decomposition method. Decomposition is essentially a method of measuring the change in energy consumption triggered by a certain factor, assuming that all the other factors remain constant. The first of the four factors responsible for consumption changes is production effect. This measures the amount of increase in energy consumption upon an increase in production activity (Q). The second is industrial structure effect, which refers to the change in energy consumption resulting from a change in the share of particular industries within the overall manufacturing sector (Q_i/Q) . The structure effect analyzes the change in energy consumption triggered by variations in the proportion of energy-intensive industries. The third is value added effect, which measures the change in energy consumption that occurs as a result of a change in the ratio of value added to production on a sub-industry basis (V_i/Q_i). When energy consumption per added value is fixed, a rise in the value added ratio of manufacturing leads to an increase in energy consumption. The final factor is intensity effect, which measures the effect of a change in the energy input required per unit of value added (E_i/V_i). As this factor analyzes energy intensity while change in the ratio of value added is controlled, it is arguably similar to the concept of the energy efficiency of the production process. This includes the technical energy efficiency of production process such as machinery and heating systems.

$$E=\sum_i E_i=\sum_i Q\frac{Q_i}{Q}\frac{V_i}{Q_i}\frac{E_i}{V_i}=\sum_i QS_iP_iI_i$$

E: energy consumption of manufacturing
E_i: energy consumption of manufacturing sector i
Q: production of manufacturing
Q_i: production of manufacturing sector i
V_i: value added of manufacturing sector i
S_i: share of sector i in manufacturing production
P_i: value added ratio of manufacturing sector i
I_i: value added energy intensity of manufacturing sector i

If you decompose energy consumption as in the equation above using Ang (2005)'s LMDI method, the resulting formulas are as follows. When using a multiplicative decomposition method, which analyzes the rate of change, the change in energy use is decomposed into: the activity effect, which measures the change in energy use due to a change in manufacturing production (D_{act}); the structural effect, which shows the change in energy consumption as a result of changed industrial structure (D_{str}); the change in energy consumption stemming from a change in value added ratio by manufacturing sector (D_{vad}); and the change in energy consumption caused by a change in value added energy intensity (D_{ins}).[2)]

$$D_{tot}=\frac{E^T}{E^0}=D_{act}\,D_{str}\,D_{vad}\,D_{ins}$$

$$D_{act}=\exp\left(\sum_i \frac{\left(E_i^T-E_i^0\right)/\left(\ln E_i^T-\ln E_i^0\right)}{\left(E^T-E^0\right)/\left(\ln E^T-\ln E^0\right)}\,ln\left(\frac{Q^T}{Q^0}\right)\right)$$

$$D_{str}=\exp\left(\sum_i \frac{\left(E_i^T-E_i^0\right)/\left(\ln E_i^T-\ln E_i^0\right)}{\left(E^T-E^0\right)/\left(\ln E^T-\ln E^0\right)}\,ln\left(\frac{S_i^T}{S_i^0}\right)\right)$$

$$D_{vad}=\exp\left(\sum_i \frac{\left(E_i^T-E_i^0\right)/\left(\ln E_i^T-\ln E_i^0\right)}{\left(E^T-E^0\right)/\left(\ln E^T-\ln E^0\right)}\,ln\left(\frac{P_i^T}{P_i^0}\right)\right)$$

$$D_{ins}=\exp\left(\sum_i \frac{\left(E_i^T-E_i^0\right)/\left(\ln E_i^T-\ln E_i^0\right)}{\left(E^T-E^0\right)/\left(\ln E^T-\ln E^0\right)}\,ln\left(\frac{I_i^T}{I_i^0}\right)\right)$$

The following model is constructed to derive the impact of energy prices on the change in energy intensity in manufacturing. This is to know the effects of energy prices on energy intensity. We construct the following regression model.

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2) The validity of the relation formulas can be verified by substituting each factor in the structural formula (Ang and Liu, 2001).

$$Intensity\ Effect\left(\frac{E_{i,t}}{V_{i,t}}\right) = \beta_0 + \beta_1(CPI_{E,t}/WR_t) + \epsilon_t$$

In the above equation, CPI_E is the consumer price index of energy products[3] and WR_t refers to the average wage level. In essence it is intended to examine how the variable of relative energy price to labor cost[4] affects energy intensity and consumption. The consumer price index is used here since the government of South Korea has exerted considerable efforts in influencing energy prices as an attempt to curb inflation and consequently created price differentials despite changes in import or producer prices.

C. Data

To analyze the factors affecting energy consumption of the manufacturing sector, we used energy consumption, production and value added data by manufacturing sub-sector. Disaggregated energy consumption data were retrieved from the Yearbook of Energy Statistics published by the Korea Energy Economics Institute. This yearbook details annual energy consumption by manufacturing sub-sector (thermal basis). The manufacturing sector can be divided into eleven sub-sectors—food and tobacco, textile and clothing, lumber and wood products, pulp and printing, petrochemicals, non-metals, primary metals, nonferrous metals, fabricated metals, other manufacturing and energy industries.

With respect to production and value added by manufacturing sub-sector, because it provides consistent data on the production and value added we referred to the Report on Mining and Manufacturing Survey by Statistics Korea.[5] As production and value added are provided at current prices, they were converted to 2005 constant prices using the producer price index by industry.

3) Weighted average of the price indices of electricity and gas
4) The use of relative price means assuming a substitutable relationship between energy and labor in corporate production functions.
5) The Bank of Korea's Quarterly National Accounts also provides the value added of manufacturing, but we could not use it in our analysis because this publication does not offer value added and production by manufacturing sub-sector.

<Table II-1> Data for Decomposition Analysis

Data List	Data Source	Remarks
Energy Consumption	Yearbook of Energy Statistics (2011), Korea Energy Economics Institute	1000 TOE
Production	Korean Statistical Information Service, Statistics Korea	Current price
Value Added	Korean Statistical Information Service, Statistics Korea	Current price
Producer Price	Korean Statistical Information Service, Statistics Korea	As of 2005

D. Results

We decomposed energy consumption of the manufacturing sector, including power generation losses. Energy conversion losses were explicitly addressed, which can be a source of bias as the electricity demand grows. As a result of the analysis, it was revealed that the increased share of electricity consumption led total energy consumption to increase by 2.371 times during the 1991-2009 period, up slightly from the figure of 2.356 times obtained when generation losses were not included.[6] The direction of effects of each factor remained unchanged from when generation losses were excluded, but the size of effects changed. As power generation losses were included, the production, structural, and value added effects slightly changed to the direction of increasing total energy consumption. The production effect rose from the previous figure of 3.354 to 3.365 times, while the structure and value added effects increased from 0.678 and 0.722 to 0.707 and 0.737, respectively. On the other hand, the intensity effect declined from 1.433 times to 1.354 times. The relative drop in the intensity effect is due to the fact that as generation losses were included, the share of energy-intensive industries in overall energy consumption fell.

6) This is because power generation losses are not large compared with the increase in energy consumption.

<Table II-2> Decomposition of the Rate of Increase in Energy Consumption (Including Generation Losses) (1991 Benchmark)

(Unit: times)

	Production Effect	Structural Effect	Value Added Effect	Intensity Effect	Overall Effect
1992	1.089	1.005	1.008	1.050	1.158
1993	1.192	1.007	1.001	1.050	1.261
1994	1.343	0.997	1.032	0.982	1.357
1995	1.522	0.976	1.032	0.943	1.445
1996	1.655	0.971	0.989	0.991	1.573
1997	1.732	0.971	0.975	1.097	1.797
1998	1.472	0.987	1.000	1.202	1.745
1999	1.563	0.947	0.962	1.303	1.856
2000	1.776	0.927	0.861	1.388	1.967
2001	1.852	0.902	0.862	1.379	1.985
2002	2.015	0.871	0.878	1.357	2.093
2003	2.132	0.840	0.862	1.396	2.156
2004	2.372	0.807	0.862	1.347	2.223
2005	2.494	0.809	0.840	1.350	2.287
2006	2.696	0.779	0.798	1.407	2.359
2007	3.001	0.760	0.777	1.308	2.317
2008	3.249	0.744	0.740	1.333	2.383
2009	3.365	0.707	0.737	1.354	2.371

Even when the period for analysis is set at 1999-2009, the pattern remains similar. The overall effect of the increase in energy consumption rose slightly due to the increase in the effects of industrial structure and value added. The production effect remained unchanged even with generation losses included, while the intensity effect nudged down due to the decrease of energy consumption share of energy-intensive sub-sectors.

<Table II-3> Decomposition of the Rate of Increase in Energy Consumption (Including Generation Losses) (1999 Benchmark)

(Unit: times)

	Production Effect	Structural Effect	Value Added Effect	Intensity Effect	Overall Effect
2000	1.138	0.981	0.888	1.070	1.060
2001	1.188	0.954	0.887	1.064	1.070
2002	1.294	0.918	0.909	1.044	1.128
2003	1.371	0.882	0.892	1.077	1.162
2004	1.530	0.846	0.889	1.041	1.198
2005	1.612	0.848	0.867	1.040	1.233
2006	1.745	0.812	0.823	1.090	1.271
2007	1.943	0.782	0.802	1.025	1.249
2008	2.106	0.762	0.759	1.054	1.284
2009	2.188	0.723	0.758	1.066	1.278

Given the results of this analysis, it is necessary to improve the value added and intensity effects in order to enhance energy efficiency in the future. That is, production increases are inevitable if economic growth is to be pursued, and the energy conservational restructuring of industries has been showing consistently effective results. However, considerable uncertainty exists regarding the sustainability of industrial restructuring and thus its contribution may decline in future. The value added effect measures the energy consumption effect caused by the change of value added ratio, that is value added divided by production value. Increasing the value added effect means, when assuming the same growth rate, less production as well as less energy consumption. This is because with increased value added ratio, we can attain higher economic growth rate at the same production level. In South Korea, the decreasing trend of value added ratio has served as another source of higher energy consumption.

The regression analysis showed that the contribution of energy intensity was significantly impacted by energy price. That is to say, the contribution of energy intensity decreases as the relative price of energy to labor increases: the degree of decrease amounts to 0.79 times for each one-point change in the relative price index. These findings confirm the effectiveness of pricing policies in improving the energy intensity of the manufacturing sector. The impact of price variables on the contribution of the energy intensity of each respective manufacturing sub-sector appeared to vary according to the characteristics of the industry. Those industries which were found to be significantly influenced by relative energy price are lumber and wood products, pulp and printing, petrochemicals, nonmetallic minerals, and fabricated metals. Those which were not are the food and beverage, textile and clothing, and primary metals industries.

<Table II-4> The Effect of Energy Prices on Energy Intensity by Manufacturing Sub-sector

Industry	Dependent Variable	Relative Price of Energy to Wage	Constant	Adj-R square	Prob > F-stat
Manufacturing	Contribution of energy intensity	-0.7908***	1.9046***	0.4709	0.0014***
		(0.001)	(0.000)		
Food & Beverage	Contribution of energy intensity	-0.1835	1.1380***	0.0417	0.2124
		(0.212)	(0.000)		
Textile & Clothing	Contribution of energy intensity	-0.0493	1.1617***	0.0013	0.8924
		(0.892)	(0.001)		
Lumber & Wood Products	Contribution of energy intensity	-0.7679**	1.9209***	0.2393	0.0267**
		(0.027)	(0.000)		
Pulp & Printing	Contribution of energy intensity	-1.0991**	2.2332***	0.1990	0.0414**
		(0.041)	(0.000)		
Petrochemicals	Contribution of energy intensity	-2.5326***	3.7619***	0.6671	0.0000***
		(0.000)	(0.000)		
Non-metals	Contribution of energy intensity	0.8478***	1.1017	0.8506	0.0000***
		(0.000)	(0.137)		
Primary Metals	Contribution of energy intensity	-0.0909	1.0089***	0.0269	0.5291
		(0.529)	(0.000)		
Fabricated Metals	Contribution of energy intensity	0.9254***	-0.0250	0.5201	0.0007***
		(0.001)	(0.886)		

Note: Figures in parentheses are p-values. The signs ***, ** and * refer to statistical significance at the levels of one, five, and ten percent, respectively.

E. Implications

This section decomposed manufacturing energy consumption into four factors, rather than the previously used three factors. For this analysis, we disaggregated production intensity (energy consumption divided by production value) further, which appeared as a single factor in the three-factor analysis by Kim Su-yi and Kim Hyun-seok (2011), into value added ratio (value added divided by production) and value added intensity (energy consumption divided by value added). In addition, we explicitly included in the analysis power generation losses, which had previously been excluded from other analyses centering on end-use energy. The effect of energy pricing policies on the contribution of energy intensity was also explicitly featured.

The analysis revealed that energy consumption has increased in South Korea after 1991 due to the production and intensity effects, and that the changes in the industrial structure and the value added ratio have served as consumption-reducing factors. When power generation losses are considered, the rate of increase in energy consumption rises even further because of higher dependency on electricity. The contributions of each factor remained unaltered in terms of direction; they changed only in degree.

It was found through factor decomposition that a decline in the value added ratio under a given growth rate led to an increase in energy consumption by increasing production level, and that the improvement in the energy intensity of production presented in previous studies was the result of a sharp decrease in the value added ratio. A fall in the value added ratio occurred across all manufacturing industries, and especially significantly in the petrochemicals and primary metals industries. Such a drop-off in the value added ratio in manufacturing will be an obstacle in improving energy efficiency, as well as economic growth. The value added energy intensity has similarly shown a declining trend since 1991. The intensity deteriorated despite ongoing governmental efforts to promote industrial energy efficiency; it improved only in the textile and clothing, fabricated metals and non-metals industries. However, the downward trend has been decelerating since 1999 and the number of industries showing an improvement has swollen to five.

In the regression analysis to examine the price effects on energy intensity contribution, relative energy prices were found to have a significantly negative impact on the contribution of energy intensity.

Above all, these findings highlight the value of developing high value-added industries to the improvement of the overall energy efficiency of the manufacturing sector. High value added reduces the risk of both the expansion of production for a given growth rate and the corresponding increase in energy consumption. Energy intensity by industry should also be managed in a more aggressive manner. While the mechanical management of energy efficiency is important, a strategic approach may be required as well regarding the energy price variable, which features a significant effect on the contribution of energy intensity. The effectiveness of energy pricing policies as a means of mitigating the aggravation of energy intensity can be verified.

2 Household Demand Analysis

Using consumer survey data, a demand analysis was performed for energy products. We selected a linear expenditure system (LES) as our demand analysis model and used source data from Statistics Korea's Household Income and Expenditure Survey for the analysis. An LES analysis essentially utilizes panel data, but there are no available panel data from South Korea that both contain expenditures by product and sufficient time span. Therefore, we will resort to a method that is commonly used when micro-panel data are unavailable—constructing a pseudo-panel data set based on aggregate variables as a substitute for micro-panel data.

A. Construction of Pseudo-panel Data

In order to construct a pseudo-panel set, we used Household Income and Expenditure Survey data of Statistics Korea which provide a set of monthly cross-sectional data surveyed over a variety of detailed income and consumptions. By calculating total or average expenditure per household across expenditure categories and then constructing a time series data set for each category with the calculated values, a form of panel data of combined time series data can be obtained. Panel data is created by collecting cross-sectional data containing information on individual consumers (or subjects) through a series of follow-up surveys. Although it appears to be a panel, a data set established through the above-mentioned method is distinguished from a typical panel data set in that it does not include individual information. It does contain, however, information on total or average amount by (consumption expenditure) category instead, and thus they are referred to as a pseudo panel composed of aggregate variables. Examples of studies utilizing this sort of data include Dargay (2002), Dargay & Vythoulkas (1998, 1999) and Deaton (1985).

The Household Income and Expenditure Survey classifies expenditures into twelve main categories. In accordance with the purposes of this study, petroleum is separated from the categories of transportation and utility expenses and further segmented into three categories—gasoline, diesel and kerosene. In addition, the alcohol and tobacco category is divided into two separate categories, and the housing, fuel, light and water category is also sorted between two categories (housing and others), creating a total of seventeen categories.

1. Food, beverage and non-alcoholic drinks
2. Alcohol (soju, beer, whiskey, etc.)
3. Tobacco
4. Clothing and shoes
5. Housing expenses
6. Fuel, light and water expenses (excluding diesel and kerosene)
7. Household commodities and home maintenance service
8. Healthcare (including medical expenses)
9. Transportation expenses (excluding gasoline, diesel and kerosene)
10. Gasoline
11. Diesel
12. Kerosene
13. Communications expenses
14. Expenses for recreation and cultural enrichment

15. Education
16. Food and accommodation
17. Other consumption expenditures

B. LES Demand Functions

1) Estimation of Prices and Quantities by Expenditure Category

For a demand function analysis with a linear expenditure system (LES), we need to have prices and actual consumption quantities data. However, the Household Income and Expenditure Survey contains only information regarding consumption expenditures, not data on prices or quantities. Therefore, supplemental information is required in order to divide the expenditure information by price and volume (real terms). For the prices of each category, we use the consumer price index for the applicable category. The consumer price index is normalized to one (the year 2010=1) for the sake of convenience. The quantity data can be obtained by dividing expenditure by the consumer price index of the applicable category. We use quarterly data from 1990 1Q to 2011 4Q.

2) Linear Expenditure System[7)]

In this study, we use a linear expenditure system (LES) demand function. This system is derived from consumers' utility maximization process. The essential structure of LES has already been widely known through microeconomic theory and no detailed explanation is consequently required. Therefore, we briefly introduce the basic structure as follows, referring to Phlips (1983).

The underlying utility function of the linear expenditure system is the Stone-Geary direct utility function. The Stone-Geary function is as below:

7) For more details on linear expenditure system, please refer to Chapter IV of Phlips (1983).

$$u^{*}=\prod_{i=1}^{r}(x_i-\gamma_i)^{\beta_i} \tag{1}$$

where $0<\beta_i<1$, $\sum_{k=1}^{r}\beta_k=1$, and $x_i-\gamma_i$. Here β_i and γ_i are constants; x_i is the consumption of the i-th good; and r is the total number of expenditure categories. We also assume that x_i is greater than γ_i. This means that γ_i corresponds to the minimum subsistence level for the i-th good.

Taking logarithm of the equation (1) and then transforming it into a Lagrangian function under budget constraints gives:

$$\pounds=\sum_{i=1}^{r}\beta_i\cdot ln(x_i-\gamma_i)+\lambda\left(y_i-\sum_{i=1}^{r}x_i\cdot p_i\right) \tag{2}$$

Solving the maximization problem, the demand function of each good can be expressed in linear form as follows.

$$x_i=\gamma_i+\frac{\beta_i}{p_i}\left(y-\sum_{i=1}^{r}p_k\cdot\gamma_k\right),\ i=1,\ \ldots,\ r \tag{3}$$

If we set up a regression equation for the demand function by adding error term which indicates statistical relation, the result is as below:

$$x_i=\gamma_i+\frac{\beta_i}{p_i}\left(y-\sum_{i=1}^{r}p_k\cdot\gamma_k\right)+\epsilon_i,\ i=1,\ \ldots,\ r \tag{4}$$

C. Analysis of the Demand Functions of Seventeen Categories

1) Estimation of Parameters of Demand Function

In this study, to perform a demand analysis through a linear expenditure system based on general equilibrium theory, we identified seventeen categories and constructed a pseudo-panel of aggregate variables using source data from the quarterly Household Income and Expenditure Surveys spanning 1990 to 2011 prior to estimating the model with the maximum likelihood estimation method. Under this estimation method, the unit (or scale) of dependent or explanatory variables does not matter in theory. However, because there is a tolerance level or identifiable minimum number for the convergence in statistical programs, the unit of measurement may be critical in getting desired results. In this study, we set the unit of all variables of prices and expenditures at 100,000 won for computational convenience. By modifying the equation (3), the following relation is derived.

$$\beta_i = \frac{p_i(x_i - \gamma_i)}{y - \sum_{k=1}^{r} p_k \cdot \gamma_k} \qquad (5)$$

Here β_i represents the proportion of the consumption expenditure of the i-th category after deducting minimum subsistence level in disposable income, which is calculated by deducting necessary consumption expenditures from total income (or total consumption expenditure). The same logic is applied in this case as with the Cobb-Douglas utility function in which the value of the index of each category refers to the component ratio of the applicable category.[8)] Because β_i has the meaning of the share of each category, the sum of β_i is one. The results of estimation of β_i are presented in the left column of <Table II-5> β_i has a positive value in all seventeen categories and its sum is one.[9)]

The values of β_i were estimated to be in the range of 0.00360 (alcohol) to 0.19793 (food and beverage). Categories with large absolute values were food and beverage (0.19793), other consumption expenditures (0.18017), educational expenses (0.10747), and accommodation and food (0.09837), while the categories with small absolute values include alcohol (0.00360), diesel (0.00512), kerosene (0.01002), and tobacco (0.01025).

As explained above, β_i indicates the proportion of disposable

8) As the Stone-Geary utility function and the Cobb-Douglas function are the same in form except the minimum subsistence level (γ), the index has the same meaning as well.

9) Rather than saying the sum of β_i of the seventeen categories is 1, it would be more accurate to state that the sum became 1 because the estimation was made under the condition that the sum of β_i was constrained to be 1.

income—that income remaining after the minimum required expenditure—allocated to each respective category. According to the estimation results, 19.8 percent of remaining income was then spent on food and beverage, while the shares for education and for accommodation and food were 10.7 and 9.8 percent, respectively. On the contrary, the proportions of additional spending on alcohol and tobacco, which are items of personal preference, are low—0.4 and 1.0 percent, respectively. This is due to basically small spending on them, but the fact that these are sub-categories or sub-sub categories, while the others are larger categories and thus there exist considerable expenditure differences among categories, plays a role. Furthermore, as for expenditures on alcohol, a considerable portion of consumption occurs outside of the home environment—mainly in restaurants and bars—and such consumption of alcohol is not included in the data of the Household Income and Expenditure Survey.

The standard deviations of the estimates of β_i were all estimated to be small. Accordingly, the lowest t-value of the estimates was 18.580 (kerosene), suggesting that the overall estimation results of β_i are statistically highly significant.

As for γ_i, which represents minimum subsistence levels, estimators show positive values except kerosene. A negative value for the minimum subsistence level indicates that it is not an essential consumption item required to maintain the subsistence level. In addition, a negative value indicates that the uncompensated (own) price elasticity of the applicable category is greater than one in terms of absolute value. Therefore, it can be assumed that those categories represent goods whose demand is elastic in terms of the change in own prices.

The value of γ_i by category was estimated to fall within the range of—0.08789 to 1.096043 (educational expenses). The absolute value of t-value, which measures statistical significance, was estimated to be at minimum 3.61648 (fuel, light and water), excluding kerosene (-1.33110) and gasoline (0.69421). This means the γ_i estimates for fifteen categories are statistically highly significant.

The γ_i estimates for education and for food and beverage are 1.96043 and 1.54250, respectively. As the price in 2010 was normalized to one, the physical and monetary units are the same as in 2010. Because the unit of each variable was set for convenience to 100,000 won in the analysis, the quarterly minimum subsistence level (or minimum required expenditure) per capita for education and for food and beverage are approximately 196,000 and 154,000 won, respectively. The yearly figures are calculated as approximately 784,000 and 617,000 won, respectively. What is notable is that in the case of education, the minimum required expenditure is greater than that of food and beverage, but the proportion of consumption expenditures allocated to education from remaining disposable income (β_i) is 10.7 percent, a figure markedly lower than food and beverage's 19.8 percent. This implies that compared to the food and beverage category, the education category accounts for a considerably greater share in terms of a minimum subsistence level but has a smaller marginal propensity to consume over the level.

The quarterly minimum required expenditure per capita on accommodation and food is 66,000 won in 2010 constant won, but its proportion of expenditure out of disposable income is very high, amounting to 9.8 percent (β_i=0.09837). This implies that the share of expenses for travelling and eating out in household expenditure is quite large.

<Table II-5> Estimation Results of LES Coefficients for Seventeen Categories

(Unit: 100,000 won [for ɣ], 2010 price=1)

	β			ɣ		
	Estimate	Standard Deviation	T-value	Estimate	Standard Deviation	T-value
Food and Beverage	0.19793	0.00102	193.55427	1.5421	0.25714	5.9971
Alcohol	0.0036	0.00002	238.67856	0.02835	0.00327	8.66772
Tobacco	0.01025	0.00004	265.14194	0.07838	0.01364	5.74681
Clothing and Shoes	0.02835	0.00066	42.76026	0.46379	0.04794	9.67472
Housing Expenses	0.03695	0.00019	194.85636	0.25024	0.03426	7.30463
Fuel, Light and Water Expenses	0.03986	0.00055	71.99643	0.27146	0.07506	3.61648
Household Commodities and Home Maintenance Service	0.04129	0.00029	140.2245	0.32429	0.03951	8.20829
Healthcare	0.04629	0.00035	132.54156	0.41432	0.05148	8.04813
Transportation	0.0694	0.00035	199.71079	0.52377	0.07295	7.18009
Gasoline	0.04255	0.00022	194.15325	0.04091	0.05893	0.69421
Diesel	0.00512	0.00005	112.80995	0.06601	0.01605	4.11288
Kerosene	0.01002	0.00054	18.57985	-0.08789	0.06603	-1.3311
Communication	0.0357	0.00038	93.59462	0.17892	0.02391	7.48171
Expenses for Recreation and Cultural Enrichment	0.04671	0.00029	160.00191	0.32212	0.03508	9.18333
Educational Expenses	0.10747	0.00282	38.17663	1.96043	0.28206	6.95045
Accommodation and Food	0.09837	0.00031	316.99422	0.66054	0.08115	8.14021
Other Consumption Expenditures	0.18017	0.00206	87.38028	1.00477	0.21397	4.69595
Total	1	-	-	-	-	-

Note: Statistics Korea. These values were estimated by the authors in a linear expenditure system based on the source data of the quarterly household income and expenditure surveys from 1990 to 2011.

2) Results of Elasticity Estimation

Under a linear expenditure system, elasticity values depend upon the point of measurement (or base value). In other words, elasticities can vary according to the level of income, price or consumption. Therefore, coefficients estimated through a linear expenditure system hold the advantage that various analysis by income class can be easily tractable. The following results show the estimates of own-price elasticity and income elasticity derived from two criteria. The first criterion is the average values of quarterly income, expenditure and consumption during 1990-2011, while the second is the values for the fourth quarter of 2011.

A) Compensated Price Elasticity

Compensated price elasticity is calculated by adding income effect to uncompensated price elasticity. When measured on the basis of the quarterly average of the 1990-2011 period, own-price elasticities were negative across all seventeen categories. As for the scale of estimates, only kerosene (-1.17140) showed an absolute value greater than one, while the other sixteen categories fell below one. The category with the lowest compensated price elasticity is educational expenses (-0.48926), followed by food and beverage (-0.62600), other consumption expenditures (-0.68574) and household commodities and home maintenance service (-0.69552), in ascending order. The absolute value of compensated price elasticity proved smaller than that of uncompensated price elasticity in each category. This is due to the positive income effect in all categories.

When compensated price elasticities were measured at the prices and expenditures of the fourth quarter of 2011 rather than of mean values, the estimates were similarly found to have negative values across all categories, and their absolute values were a bit smaller than the prior results measured based on mean values. This happens since x_i increases over time.

Negative compensated own-price elasticities mean that they satisfy one of the four conditions which must be met by demand functions: the condition that the own-price substitution effect of compensated demand be negative, or (See <Table II-6>).

B) Uncompensated Price Elasticity

The uncompensated own-price elasticities were all estimated to be negative. Especially, the uncompensated price elasticity for kerosene is greater than one in absolute value since the minimum subsistence level is negative. This suggests that the demand for kerosene is highly elastic to own-price changes.

The own-price elasticities were smaller in absolute value when measured at the fourth quarter of 2011 than at the average of the 1990-2011 period. This is because these seventeen categories are all normal goods.[10)]

The categories with the smallest uncompensated price elasticities in absolute value are educational expenses (-0.59673) and clothing and shoes (-0.67129) at mean value. Noteworthy, however, is the finding that when we evaluate at the fourth quarter of 2011, the absolute value of the price elasticity of educational expenses plunges to -0.05435, which cannot be found at other categories.

C) Income Elasticity

Income elasticity ($\beta_i \frac{y}{x_i \cdot p_i}$) depends on the expenditure share of an item (β_i) out of disposable income (after deduction of minimum subsistence expenditure) and the reciprocal of the share of actual consumption expenditure on the item out of total consumption expenditure ($\frac{x_i \cdot p_i}{y}$). β_i is less than one, but $\frac{y}{x_i \cdot p_i}$ is greater than one. When other conditions are constant, the smaller the expenditure share of the item among total consumption expenditure may be, the greater the income elasticity becomes. Therefore, whether income elasticity is greater or less than one is determined by the relative size of these two components.

When measured at the mean values of the 1990-2011 period, income

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10) If there had been an inferior good whose income elasticity was negative, the uncompensated own-price elasticity (in absolute value) of the good might have been greater when measured by the values of the fourth quarter of 2011 than in the latter case.

elasticity was greater than one in eight out of the seventeen categories: food and beverage, alcohol, housing expenses, household commodities and home maintenance service, transportation, gasoline, expenses for recreation and cultural enrichment, and other consumption expenditures. On the other hand, in six of the remaining nine categories, excluding the three categories of clothing and shoes (0.66516), diesel (0.71093), and communications (0.80094), income elasticity was found to fall within the range of 0.9 to 1, showing high income elasticity.

According to the results evaluated at the fourth quarter of 2011, income elasticity in eight out of the seventeen categories exceeded one. Income elasticity approached one in the two categories of alcohol (0.937796) and expenses for recreation and cultural enrichment (0.92432) while the remaining seven categories showed much smaller values. Although the estimates of income elasticity varied somewhat by base value, in a number of categories they were close to or greater than one. This indicates that the values of β_i and expenditure share are similar. It also suggests that the share of minimum required expenditure is relatively small.

<Table II-6> Estimates of Own-price and Income Elasticities

	Measured at 1990-2011 Mean Values			Measured at the Values of the Fourth Quarter of 2011		
	Price Elasticity		Income Elasticity	Price Elasticity		Income Elasticity
	Compensated	Uncompensated		Compensated	Uncompensated	
Food and Beverage	-0.626	-0.82393	1.0692	-0.39341	-0.59134	1.30952
Alcohol	-0.74102	-0.74462	1.02645	-0.66006	-0.66366	0.93796
Tobacco	-0.7932	-0.80345	0.97248	-0.56554	-0.57579	1.20048
Clothing and Shoes	-0.64294	-0.67129	0.66516	-0.69945	-0.72779	0.3555
Housing Expenses	-0.74757	-0.78452	1.01162	-0.74278	-0.77973	0.69547
Fuel, Light and Water Expenses	-0.79826	-0.83812	0.94777	-0.6886	-0.72846	0.84912
Household Commodities and Home Maintenance Service	-0.69552	-0.73682	1.04073	-0.59361	-0.6349	1.01001
Healthcare	-0.70952	-0.75581	0.93646	-0.6928	-0.73908	0.6529
Transportation	-0.71488	-0.78428	1.04318	-0.58367	-0.65306	1.04061
Gasoline	-0.92827	-0.97081	1.24197	-0.89248	-0.93503	1.34042
Diesel	-0.82013	-0.82525	0.71093	-0.75337	-0.75849	0.34653
Kerosene	-1.1714	-1.18142	0.94598	-2.32503	-2.33506	2.66137
Communications	-0.78135	-0.81705	0.80094	-0.84092	-0.87662	0.5783
Expenses for Recreation and Cultural Enrichment	-0.70481	-0.75152	1.01491	-0.67065	-0.71736	0.92432
Educational Expenses	-0.48926	-0.59673	0.95177	-0.05312	-0.05435	1.24199
Accommodation and Food	-0.72472	-0.82308	0.97844	-0.67951	-0.77788	0.76047
Other Consumption Expenditures	-0.68574	-0.86591	1.07291	-0.42692	-0.60709	1.80534

D. Implications

In this analysis, we utilized source data from Statistics Korea's Household Income and Expenditure Survey to build a linear expenditure system based on general equilibrium theory in order to estimate demand functions. We specifically divided consumption expenditures into seventeen categories, constructed a pseudo-panel of aggregate variables for each quarter and applied the linear expenditure system using the maximum likelihood estimation method.

The minimum subsistence level, the level of consumption necessary for maintaining a basic subsistence, was found to be relatively high in terms of expenses for education and for food and beverage. In contrast, it was estimated to be very low for tobacco and for alcohol, items of personal preference, as well as for oil products such as gasoline and diesel. The price elasticity of all items was estimated to be below one in absolute value, with the exception of kerosene which is larger than one because of negative minimum subsistence level. In terms of income elasticity, all seventeen consumption categories showed positive values, indicating that they are all normal goods.

The (uncompensated) price elasticity of petroleum products, which make up the main components of household energy consumption, included -0.94 for gasoline and -0.76 for diesel (as of 2011 4Q), suggesting it was almost unit elastic. This result implies that pricing policies on petroleum products can impact demand to a considerable extent. The income elasticities of gasoline and diesel were estimated to be 1.34 (highly elastic) and 0.35, respectively. This suggests that because gasoline is mainly used as fuel for personal automobiles, it has an income-elastic demand structure linked to the purchase of automobiles. On the other hand, although diesel is also used as fuel for personal vehicles, its income elasticity was estimated to be somewhat low due to substitutability between gasoline and diesel.

As the linear expenditure system is based on general equilibrium theory, parameter estimates are highly useful for empirical analysis. For example, they can be used as parameter values of the household sector in a computable general equilibrium model. A further characteristic of the linear expenditure system is that price and income elasticities are estimated differently depending on the values of income, prices, and consumption to be measured. This is a useful feature in that it allows asymmetric consumer behaviors by income class, consequently enabling a more diverse analysis of behavioral changes.

III

Experiences of Other Countries

Energy taxation has played a significant role in a number of countries as a means of raising revenues, even prior to the introduction of carbon taxes. Countries such as Denmark and Sweden, for example, have long raised a substantial amount of revenue from energy taxes, mainly those imposed on transportation fuels. Denmark and Sweden levied taxes on transportation fuel, essentially gasoline, as early as 1917 and 1924 respectively (Speck, 2008). The rationale behind such energy taxes was based on fiscal concerns, but during the 1980s, environmental considerations emerged as an important factor. At this time many governments attempted to lighten the environmental load and achieve both climate-change mitigation and their revenue-raising objectives by imposing energy taxes on household, industrial, and transportation fuels. In this context, they introduced carbon taxes as a response to the growing concern on carbon emissions. However, since new taxation on industry can lead to increased production costs and thereby impair the international competitiveness of domestic industries, carbon taxes levied on industry, in particular, soon became an central issue in carbon taxation. To address this issue, some advanced countries have pursued strategies to coordinate carbon taxes within existing tax structures. The following sections explore experiences of these countries.

The examples considered are the countries which have responded to concern for the environment from quite early on. Among those advanced countries in Europe which have demonstrated a particular interest in global warming and have developed related policies, the Nordic countries—notably Finland and Denmark—reformed energy taxation based on environmental perspective earlier than any other nations, while Germany and the U.K., which are economically large countries among nations that adopted carbon taxes.

1 Finland

Energy taxation in Finland—that is, fuel consumption taxes—was initially aimed at raising revenues and took the form of an excise tax. With a 1986 reform of energy taxation, the country started to consider environmental costs in its fuel consumption tax system, but the scope of application remained limited. The excise taxes are imposed only on gasoline and diesel, and VAT is applied for other fuels.[11)] As environmental considerations continued to rise, a carbon tax was introduced in 1990 in the form of excise tax to reduce energy consumption and the harmful environmental impacts of energy production and consumption. The carbon tax was a distinct component of Finland's excise tax on fossil fuels used for transportation or heating. The country's excise taxes consisted of a basic tax and surtax. Carbon tax was a surtax based on the carbon and energy content of fuels.

From 1997, carbon tax base was changed to net carbon content for transportation and heating fuels, while electricity was taxed per kilowatt and electricity-generating fuels were exempted. The general structure of carbon taxation in Finland was adjusted in January 2011. Taxation of liquid fuels and coal products took into account both the energy content and carbon dioxide emissions, not purely carbon content.[12)] Regarding the carbon tax in Finland, tax exemptions and refunds are rarely provided and all revenues collected from the carbon tax are directly included in the

11) Vehams (2005), p. 2177.
12) www.environment.fi/, "Environmentally related energy taxation in Finland (2012)," 2012.

general government budget.[13)] Tax exemptions and discounts are offered on a limited basis only to fossil fuels used for industrial products and to heavy fuel oil for commercial vessels and aircraft, allowing the country a broad base of tax revenues. As additional revenues ease fiscal status, some of these revenues are used to lower personal income taxes and the burden on low-income consumers.[14)]

13) Ahn Chang-nam (2010), p. 230.
14) National Renewable Energy Laboratory (2009).

<Table III-1> The Composition of Energy Taxes in Finland

Classification		Dates	Excise Tax			Strategic Stockpile Fees	Total
				Basic tax	Surtax		
Gasoline (Unleaded) (euro/l)		Jan. 1, 1989	0.207	0.207	-	0.0072	0.2142
		Jan. 1, 1990	0.215	0.215	-	0.0072	0.2222
		Jan. 1, 1994	0.401	0.389	0.012	0.0072	0.4082
		Jan. 1, 1997	0.519	0.491	0.028	0.0068	0.5258
		Jan. 1, 2008	0.620	0.572	0.048	0.0068	0.6268
Diesel Fuel (Sulphur-free) (euro/kl)		Jan. 1, 1989	0.142	0.142	-	0.0039	0.1459
		Jan. 1, 1990	0.168	0.123	0.045	0.0039	0.1719
		Jan. 1, 1994	0.173	0.160	0.013	0.0039	0.1769
		Jan. 1, 1997	0.275	0.244	0.031	0.0035	0.2785
		Jan. 1, 2008	0.361	0.307	0.054	0.0035	0.3645
Light Fuel Oil (euro/kl)		Jan. 1, 1989	-	-	-	3.87	3.87
		Jan. 1, 1990	3.4	-	-	3.87	7.27
		Jan. 1, 1994	20.5	7.1	13.5	3.87	24.37
		Jan. 1, 1997	48.8	17.5	31.3	3.53	52.33
		Jan. 1, 2008	83.5	29.4	54.1	3.53	87.03
Natural Gas (euro/m^3)		Jan. 1, 1989	-	-	-	-	-
		Jan. 1, 1990	0.0017	-	0.0017	-	0.0017
		Jan. 1, 1994	0.0109	-	0.0109	-	0.0109
		Jan. 1, 1997	0.0119	-	0.0119	0.0840	0.0959
		Jan. 1, 2008	0.0202	-	0.0202	0.0840	0.1042
Electricity (euro/MWh)	Household	Jan. 1, 1996	-	-	-	-	-
		Jan. 1, 1997	4	-	4	0.13	4.13
		Jan. 1, 2008	8.7	-	8.7	0.13	8.83
	Industry	Jan. 1, 1996	-	-	-	-	-
		Jan. 1, 1997	4	-	4	0.13	4.13
		Jan. 1, 2008	2.5	-	2.5	0.13	2.63

Note: Electricity was not taxed in 1990 when Finland introduced a carbon tax as a separate component of excise taxes, but a challenging financial environment in the country led to the temporary introduction of an electricity tax in 1993. The structure of fuel taxation was changed again in 1994 for environmental purposes to a tax based on the content of fossil fuels, but electricity was not taxed. In 1997 an electricity tax was reintroduced to excise taxes. (Source: Leila Juanto, "Excise Duties in Finland in a Historical Perspective," pp. 149-151 & http://www.economicinstruments.com/ "Carbon and Energy Taxes (Finland).")

Source: http://www.stat.fi/, "Appendix <Table 1>: Energy Taxes, Precautionary Stock Fees and Oil Pollution Fees."

Since data on carbon surtax revenues is difficult to obtain, the following section instead assesses revenues on energy taxes, including a carbon tax. Energy taxes in Finland include a fuel consumption tax and a carbon tax, which account for the greatest portion of total environmental tax revenues. The share of energy taxes among total environmental taxes decreased from 72.8% in 1995 to 59.8% in 2006, but increased to 68.1% in 2009. The share of transport taxes, the second-largest class of environmental taxes, showed an increase of about 11.5 %p, from 26.3% in 1995 to 37.9% in 2006, and declined gradually until 2009. Total environmental tax revenues as percentage of GDP were 3.3% in 1995, and this rate was maintained until it dropped to 3.1% in 2001. No change was evident in the succeeding years until 2007, since when it has further decreased to 2.7-2.8%. This means that the carbon tax burden has been fairly stable.

2 The United Kingdom

The U.K. energy tax scheme relies heavily on taxation of transportation fuels, and the country once lacked any comprehensive scheme of taxation of energy products such as natural gas, coal, and electricity.[15]

Under these circumstances, in 1990 the U.K. government introduced a tax on all consumers known as the Fossil Fuel Levy (FFL), which was imposed on the purchase of electricity generated from non-renewable energy. The levy is shared by both suppliers and consumers, but are paid by the suppliers of electricity.[16] This tax, designed as an ad valorem duty, peaked in 1992 at 11% of the end-user electricity price and steadily dropped after that. It has been set at zero since 2003 when the Climate Change Levy (CCL) was imposed. Therefore, the FFL can be said to have been replaced by the CCL, which was first put into effect in 2001. Initially, the majority of the revenues raised by the FFL were used to subsidize

15) Speck (2008), pp. 53-54.
16) Heo Gyeong-seon et al. (2012), pp. 3-4; Wikipedia.

nuclear power generation, with only a small fraction earmarked toward the expansion of renewable energy. After 1998, however, the nuclear industry no longer received subsidies from the FFL and FFL revenues were primarily utilized to support renewable energy projects in their stead.

In April 2001, the U.K. government introduced a carbon tax in the form of the CCL as part of its Climate Change Program directed at greenhouse gas mitigation. The CCL was aimed at improving the efficiency of energy use in business and reducing greenhouse gas emissions. It is levied on imported energy and applied only to commercial and industrial uses, exempting household and transportation use.[17)] The consumption of natural gas, electricity, coal, coke, and LPG is subject to the CCL. LPG falls under both the CCL and the existing energy tax, while only the CCL applies to natural gas, electricity, coal and coke. The government provides tax exemptions to electricity created from electricity-generating fuels, non-energy fuels, and renewable energy such as solar and wind power. The rate for the CCL remained steady from April 2001 to March 2007, and has been increased based on the inflation rate since April 2007. However, energy-intensive industries[18)] are eligible for a CCL discount if they achieve green house gas mitigation objectives or energy efficiency improvement targets after participating in the Climate Change Agreement (CCA).

17) Mineral Oils (Diesel, red diesel, petrol, and paraffin), household refuse, waste paper, sewage gas, landfill gas

18) Aluminum, cement, ceramics, chemicals, food and beverage, metal casting, glass, paper products, steel, farming, hog raising, poultry raising, etc

<Table III-2> Changes in the Rates of the Climate Change Levy

Classification	Apr. 2001 -Mar. 2007	Apr. 2007	Apr. 2008	Apr. 2009	Apr. 2011	Apr. 2012
Electricity (p/kWh)	0.43	0.441	0.456	0.470	0.485	0.509
Coal (p/kg)	0.15	1.201	1.242	1.281	1.321	1.387
Natural Gas (p/kWh)	0.15	0.154	0.159	0.164	0.169	0.177
LPG (p/kg)	0.96	0.985	1.018	1.050	1.083	1.137

Note: 1. The rate of the CCL on natural gas from April 2011 is that of Great Britain.
2. The 2009 rate was applied in 2010 as well.

Source: http://customs.hmrc.gov.uk/, "A general guide to Climate Change Levy: What are the rates of CCL?," November 2011.
"Climate Change Levy (CCL) - rates to rise at 1 April 2007"
"Climate Change Levy (CCL) - rates to rise at 1 April 2008"
http://www.nao.org.uk, "The Climate Change Levy and Climate Change Agreements," August 2007.
http://www.economicinstruments.com/, "Climate Change Program (Climate change Levy and Climate Change Agreement), U.K.," December 2008.

The revenues generated by the introduction of the CCL were small—approximately 0.1% of GDP. They were used to change the tax mix so as to increase the role of environmental taxation, referred to as the Environmental Tax Reform (ETR). The revenues were applied in reducing employers' National Insurance contributions (NICs) by 0.3%p in order to prevent the erosion of the international competitiveness of U.K. industry. Some revenue was directed toward funding energy-efficiency schemes and the Carbon Trust fund for low-carbon development and supply.[19)] Through this levy, the overall tax burden was maintained at a similar level while the share of labor taxation whose distortion effect is relatively large was decreased. Germany, which introduced a similar scheme, used the resulting revenues to reduce both employers' and employees' pension contributions.

19) www.ifs.org.uk, "Environmental taxes," March 2007, p. 4 <Table 1> & Kim Jong-ryool (2009).

3 Germany

Prior to the introduction of a carbon tax, intense political debate took place involving the industrial sector, the government and environmental organizations. The industrial sphere was concerned that the introduction of carbon taxes might impair competitiveness, economic growth and employment. In contrast, environmental agencies within the government and pro-ecology organizations voiced the opinion that carbon taxes would encourage the long-term growth of industrial competitiveness and jobs through technical innovation in environmental technologies. When a coalition of the Social Democratic and Green Parties was created in October 1998, the Green Party enforced an ecological tax reform (ETR)[20] grounded in support from NGOs and the Federal Ministry for the Environment, and began to impose an eco-tax in April 1999. Germany did not apply the term carbon tax, but levied eco-taxes instead on energy consumption and environmentally harmful behaviors.[21] The eco-tax was added on the existing mineral oil tax and a newly-enforced electricity tax in five annual stages. Gasoline, diesel, LPG, natural gas and heating oil have been all subject to the longstanding mineral oil tax. Initially, the eco-taxes were intended to expire in 2003, but they remain in place. Rates are applied differently depending on the types and users of fuels. In general, higher rates are applied to household use than to industrial use.

With eco-taxes appended to the existing mineral oil taxes through a gradual annual implementation, the share of eco-taxes within total energy taxes has increased. Prior to the introduction of eco-taxes, the existing mineral oil tax on gasoline and diesel was imposed at the rate of 50.11 1 € cents/liter and 31.7 1 € cents/liter, respectively. From 1999 to 2003, however, an additional 3.07 1 € cents/liter were added annually as eco-tax. As of 2003, when the imposition of eco-taxes was completed, 15.34 1

20) Ecological tax reform is based on the double-dividend hypothesis which helps preserve the environment through an eco-tax on products' market price to reflect the costs for responding to damage to ecosystems and, at the same time, exempts employment sector taxes through a revenue-neutral approach to spur new employment opportunities (as cited in Park Sangchul (2010), p. 90).

21) http://www.economypoint.org/e/eco-tax-germany.html

€ cents/liter of tax was added to gasoline and diesel taxes, accounting for 23.5% (65.45 1 € cents/liter) and 32.6% (47.04 1 € cents/liter) of the total burden, respectively.

<Table III-3> Change of Mineral Oil Tax with Eco-tax (1999-2003)

Tax Base	Mineral Oil Tax Only	Eco-tax Added to Mineral Oil Tax					Share of Eco-tax 2003
	Until Mar. 31, 1999	Apr. 1, 1999	Jan. 2000	Jan. 2001	Jan. 2002	Jan. 2003	
		1st Stage	2nd Stage	3rd Stage	4th Stage	5th Stage	
High-sulfur Fuel Oil (€ cents/liter)	1.53	1.53	1.79	1.79	1.79	2.5	0.97
Light Fuel Oil (€ cents/liter)	4.09	6.14	6.14	6.14	6.14	6.14	2.05
Diesel (€ cents/liter)	31.7	34.77	37.84	40.91	43.98	47.04	15.34
Gasoline (€ cents/liter)	50.11	53.18	56.25	59.32	62.39	65.45	15.34
Natural Gas (€ cents/liter[2])	6	7	7	8	8	8	2
Electricity (€ cents/kWh)	-	1.02	1.28	1.54	1.8	2.05	2.05

Note: 1) High-sulfur fuel oil refers to heavy heating oil.
2) Light fuel oil is also known as light heating oil.
Source: See <Table> on p. 11 of Damian Ludewig, Bettina Meyer, and Kai Schlegelmilch, "Greening the Budget: Pricing Carbon and Cutting Energy Subsidies to Reduce the Financial Deficit in Germany," October 2010 (http://www.boell.org/web/139-676.html).

The share of energy taxes within total environmental taxes peaked at 87.2% in 2003 when the adaptation of eco-tax was completed, but declined to 84.8% in 2009. Taxes on transport sector accounted for 12.8% in 2003, the smallest single portion of the total environmental taxes, increased steadily through 2007, and then declined from 2008. The share of environmental taxes against GDP was 2.1% in 1998, before the eco-taxes were levied, then increased to 2.7% in 2003 with the full implementation of the eco-taxes, and has gradually decreased along with the economic growth witnessed since 2004 when the tax rate increase was completed.

4 Denmark

The Danish energy tax regime consists of an energy tax, CO_2 tax, and SO2 tax. The energy tax, based on the energy content of fuel, was levied on fossil fuels and oil products before the CO_2 tax was introduced. However, VAT-registered companies—that is, the industrial sector—were exempted from the energy tax from 1996. The taxation was revised in 1998 to obligate industries to pay the full tax for energy used for space-heating purposes.

The CO_2 tax was introduced in 1992 in two stages aimed at the reduction of energy consumption and CO_2 mitigation. The tax rate is determined based on the amount of CO_2 emitted by producing or burning oil, gas, coal and electricity.[22] In the first stage, from May of 1992 the tax was levied on energy sources for household and public use—excepting industrial fuels—at the rate of 100 Danish kroner (approximately 13 euros) per ton of CO_2. The second stage was initiated in January 1993 and energy consumed by VAT-registered companies, in other words, industrial uses of energy, was taxed at the rate of 50 Danish kroner per ton of CO_2, half that of household tax rate. The CO_2 tax led to a change in tax concessions granted to the industrial sector; prior to the CO_2 tax, Danish industries were completely exempted from energy taxes. One of the key characteristics of the 2008 tax reform is that it abolished the policy through which industrial companies were taxed differently according to energy use and voluntary agreement in pollution reduction, and instead taxed all firms uniformly. Furthermore, it increased the existing CO_2 tax rate to a level deemed desirable under the EU Emissions Trading System.[23]

The tax rate was 13 euro / CO_2 ton at its introduction, dropped slightly to 12 euro / CO_2 ton in 2005, and increased sharply to 20 euro / CO_2 ton in 2008, and stands at 21.3 euro / CO_2 ton as of 2011.

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22) Heo Gyeong-seon et al. (2012), pp. 9-11 & Eurostat (2003), pp. 14-16.
23) Ministry of Foreign Affairs of Denmark (2008) & OECD (2012), p. 77.

<Table III-4> Changes in Danish CO_2 Tax Rate

(Unit: euro/CO_2 ton)

Classification	1993	1996	2000 -2004	2005	2008	2011
Household, basic rate	13.1	13.4	13.4	12.1	20	21.3
Industry						
Heating, basic rate	13.1	13.4	13.4	12.1	20	21.3
Light Processes						
without voluntary agreement	6.5	6.7	12.1	12.1	20	21.3
with voluntary agreement	-	6.7	9.1	9.1	20	21.3
Heavy Processes[1)]						
without voluntary agreement	0.7	0.7	3.4	3.4	20	21.3
with voluntary agreement	-	0.4	0.4	0.4	20	21.3

Note: 1) Specially-defined energy intensive processes
Source: OECD, “OECD Economic Surveys: Denmark 2012,” p. 76.

<Table III-5> Changes in Tax Burden by Energy Source

Classification		1985	1990	1996	2000	2002	2005	2007
Light Fuel Oil (euro cent/l)	Energy Tax	4.61	22.4	20.25	23.21	24.63	25.0	-
	CO_2 Tax	-	-	3.67	3.63	3.23	3.23	-
	Total Tax	4.61	22.4	23.92	26.83	28.26	28.23	28.65
Heavy Fuel Oil (euro cent/kg)	energy Tax	5.11	25.2	22.56	26.16	27.72	28.09	-
	CO_2 Tax	-	-	4.35	4.29	4.31	3.9	-
	Total Tax	5.11	25.2	26.9	30.45	32.03	31.99	32.48
Natural Gas (euro cent/nm^3)	Energy Tax	-	-	0.14	21.47	27.19	27.42	
	CO_2 Tax	-	-	2.99	2.95	2.96	2.69	
	Total Tax	-	-	3.13	24.42	30.15	30.11	30.58

Source: www.economicinstruments.com, “Energy Taxation (Denmark).” <Table>-Total tax burden of different energy sources (1985-2005)
Speck, “The Design of Carbon and Broad-Based Energy Taxes in European Countries.” The Reality of Carbon Taxes in the 21st Century, Environmental Tax Policy Institute and Vermont Journal of Environmental Law, 2008, p. 46, <Table 3>-Development of energy and CO_2 tax rates for different users and usages

The revenue share of energy-related taxes among total environmental taxes peaked at 50% in 2003, then sharply declined to 36% in 2006 and increased to 45.8% as of 2009. The considerable jump noted in 2009 was due to a sharp increase in the CO_2 tax rate included in the 2008 tax reform. As the Danish parliament set a goal of tax rate increase by 15% over 2010 to 2019 in 2009, the share of energy tax in total environmental taxes is expected to grow even further. The share of environmental taxes by GDP stood at 3.6% in 1992 when the CO_2 tax was introduced and peaked at 6.3% in 2006. It has declined since 2007. In 2009, in particular, it dropped as much as a full %p year on year. The reason underlying the decrease of the share of environmental taxes since 2007 is the moderate increase in revenues from energy-related taxes despite the Danish government's sharp expansion of the CO_2 tax rate in 2008 and a staggering 40% decrease in revenues from pollution tax year on year in 2009.

5 Implications

Carbon taxation regimes introduced in advanced European nations illustrate the need for effective coordination between existing energy-related taxation and the new carbon taxation, securing of the competitiveness of domestic industries, and the effective integration between carbon taxation and cap and trade systems.

First, in order to coordinate between new carbon taxation and existing energy-related taxation, countries took into account the scope of existing energy taxation and sought strategies to broaden the scope when implementing carbon taxes. Germany, for example, imposed a surtax to utilize the existing energy tax base, since its existing tax base was already been broad and further expansion was unnecessary. Meanwhile, Finland, whose energy tax base was not broad, expanded its tax base when introducing a carbon tax, and the U.K. enforced a carbon tax scheme on those sectors falling outside existing energy-related taxation. Denmark, whose energy-tax base was wide but with industry exempted from energy taxes, drew industrial energy consumption into the tax base after it applied a carbon tax.

<Table III-6> Application of Carbon Taxes to Different Energy Sources in Major Countries

Classification	Finland (CO_2 tax)	U.K. (CCL)	Denmark (CO_2 tax)	Germany (Eco-tax)
Gasoline	√	-	-	√
Diesel	√	-	-	√
Light Fuel Oil	√	-	√ (Household, Industry/Heating)	√
Natural Gas	√	√ (Industry)	√ (Household, Industry/Heating)	√
Coal	√	√ (Industry)	√ (Household, Industry/Heating)	-
Electricity	√	√ (Industry)	√ (Household, Industry/Heating)	√

Note: 1. The UK Climate Change Levy (CCL) does not apply to liquefied fuels such as gasoline, diesel, and light/heavy fuel oil and household fuels.
2. In Denmark, a full refund is extended to fuels used for non-heating purposes by industries, virtually exempting them from any CO_2 tax payments. (This policy is to be abolished in 2013.)

Source: Jenny Summer et al., "Carbon Taxes: A Review of Experience and Policy Design Considerations," National Renewable Energy Laboratory, December 2009, p. 4.

Second, the methods of introducing carbon taxes vary according to the scope of taxation. Countries like Germany and Finland, whose tax bases were already broad, implemented carbon taxes in the form of a surtax which was included within the scope of existing energy-related taxation, while nations such as the U.K. and Denmark, whose tax bases were limited to specific items or sectors, introduced a carbon tax as an independent tax. The former approach is an attempt to reduce the complexity of the related tax regime; if a country has a broad existing tax base, it can add a carbon tax rate to the existing energy tax, thereby implementing it as a single item rather than introducing a new tax. However, the U.K. and Denmark introduced carbon taxes distinct from the existing energy tax base as new tax.

<Table III-7> The Scope of Existing Energy Taxation and Carbon Tax Type

		Scope of Existing Energy Taxation	
		Limited	Broad
Carbon Tax Type	Surtax	Finland[1)]	Germany
	Independent tax	U.K., Denmark	

Note: 1) Finland introduced a carbon tax and broadened the scope of existing energy taxation at the same time.

Third, the revenues generated from carbon taxes have not been significant. This can be observed through a comparison between revenues before carbon taxes were introduced and more recent revenues from total environmental taxes. Denmark, which applied its ETR as a measure to strengthen environmental taxation while reducing labor-related taxation, showed the greatest increase in revenue by GDP at 1.02%p. In the meantime, other countries observed a mere 0.5%p or lower variation. Finland and Germany also took ETR measures, that is, a reorganization of revenue sources, but to a minor extent, which could be due to the relatively low tax burden on their citizens and the consequently reduced need to transition into ETR. The U.K. has yet to announce any plan for the reorganization of revenue sources based on ETR considerations. The U.K.'s carbon tax revenues have not increased. These results suggest that a carbon tax could serve as a meaningful measure for raising revenues, but the amount involved will not be large. This is because, fundamentally, the amount of energy consumption is closely related to tax revenues, and the efficiency which determines the energy consumption improves constantly. Also, the development of renewable energy sources is another factor reducing carbon tax base oriented to fossil fuels.

<Table III-8> The Change in Revenues from Environmental Taxes

	Finland	U.K.	Denmark	Germany
Tax Burden on the Public (%)	43.7	33.4	46.5	36.4
	(1990)	(1992)	(1990)	(1998)
Before the Introduction of Carbon Tax (%)	2.2	3.0	3.6	2.1
	(1990)	(1993[1)])	(1990)	(1998)
Recent Performance (%)	2.7	2.8	4.8	2.3
	(2009)	(2010)	(2009)	(2009)
Variation (%p)	0.5	-0.2	1.2	0.2

Note: 1) Due to the difficulties in accessing more recent data, this table is based on data from 1993 when the Fossil Fuel Levy was introduced. At that time, revenue from the FFL was 6.7% of total environmental tax revenues and as low as 0.2% of GDP.

IV

Implementation of Carbon Tax

1 Potentials for Higher Energy Taxation

A. Absolute Energy Prices

Absolute energy prices are an important reference in terms of domestic industries' international competitiveness. This stems from energy prices affecting industrial costs depending on their relative energy intensity. Transportation energy should also be taken into account as well when determining the prices of energy products, since it affects logistical costs. The price of industrial fuel oil in South Korea remains higher than in major European countries with the exception of Sweden. The nation's low sulfur fuel oil price is 970.6 USD / ton as of the fourth quarter of 2011, which is similar to that of Japan and higher than found in France, Germany, and Italy. The South Korean industrial light fuel oil price in 2010 was 922.9 USD / 1000 liters, higher than in the majority of European countries outside Italy. The household fuel oil price in South Korea is, however, similar to those in advanced European countries. At 1,191.2 USD / 1000 liters as of the fourth quarter of 2011, it approximated the average of the prices posted for major European nations and was close to the OECD member average of 1,169.9 USD / 1000 liters.

Transportation fuel prices are lower in South Korea than in major

European countries. The automotive diesel price is 1.559 USD / liter as of the fourth quarter of 2011, significantly lower than prices reported in major European nations, which approach 2.0 USD / liter. The same can be said of gasoline prices. The price of 95 Ron premium gasoline in South Korea, for example, is 1.91 USD / liter as of the fourth quarter of 2011, lower than the 2.0 USD / liter of European countries, but higher than that found in the U.S. There is no data available for regular gasoline prices in European nations due to the fuel market characteristics, but Korean regular gasoline prices proved to be higher than those in the U.S. and Canada, where relatively low prices are maintained for the fuel.

In most countries, the industrial electricity price is lower than the household rate due to the consideration of international competitiveness and supply costs. South Korea is no exception. Both industrial and household electricity prices in the country are notably lower than those found in many other countries. According to the 2010 data, the industrial electricity price in South Korea in 2009 was 57.8 USD / MWh, even lower than 67.9 USD / MWh in the U.S. in 2010, which is the lowest among major countries. It is close to half of the 110.9 USD / MWh, the average of OECD members' industrial electricity prices in 2010. Low price for electricity is even more evident in Korean household electricity prices. It stood at 84.1 USD / MWh as of the fourth quarter of 2011, much lower than OECD average of 171.2 USD / MWh, the 118.2 USD / MWh of the U.S., and the 280.3 USD / MWh found in Japan.

<Table IV-1> Industrial Low Sulfur Fuel Oil Prices

(Unit: USD / ton)

	2003	2005	2007	2010	2011	2011 4Q
France	228.1	323.9	421.8	544.4	726.9	730.2
Germany	210.5	302.9	393.8	521.2	713.3	719.3
Italy	263.5	382.3	473.4	583.4	781.9	789.0
Japan	310.4	469.2	580.9	742.4	971.6	976.0
South Korea	310.9	429.6	573.9	670.6	928.4	970.9
Sweden	626.1	855.4	1036.8	1155.8	1437.9	1401.2

Source: OECD, "Energy Prices and Taxes," 2012 2Q.

<Table IV-2> Industrial Light Fuel Oil Prices

(Unit: USD/1000 liters)

	2003	2005	2007	2010	2011	2011 4Q
France	332.4	563.3	691.7	748.9	980.8	989.1
Germany	344.3	559.7	677.4	717.3	925.5	948.1
Italy	800.0	1084.4	1273.8	1297.9	1568.3	1560.2
Japan	283.1	439.5	509.2	649.8	857.4	853.6
South Korea	537.4	853.5	1009.4	922.9	n.a.	n.a.
Sweden	339.3	549.4	669.0	705.0	1022.9	1034.9
U.K.	313.4	506.1	690.0	793.0	1026.5	1029.8
U.S.	232.3	427.7	547.6	567.1	773.2	782.5
OECD	304.1	495.0	611.3	670.3	883.3	892.5

Source: OECD, “Energy Prices and Taxes,” 2012 2Q.

<Table IV-3> Non-industrial Automotive Diesel Prices

(Unit: USD/liter)

	2003	2005	2007	2010	2011	2011 4Q
France	0.896	1.271	1.495	1.516	1.859	1.839
Germany	1.001	1.323	1.601	1.624	1.983	1.959
Italy	0.991	1.377	1.593	1.608	2.013	2.076
Japan	0.729	0.911	1.010	1.285	1.579	1.600
South Korea	0.653	1.052	1.367	1.300	1.575	1.559
Sweden	1.004	1.386	1.629	1.732	2.161	2.134
U.K.	1.272	1.652	1.940	1.842	2.222	2.202
U.S.	0.398	0.633	0.761	0.791	1.017	1.023
OECD	0.697	1.001	1.195	1.268	1.565	1.557

Source: OECD, “Energy Prices and Taxes,” 2012 2Q.

<Table IV-4> Regular Gasoline Prices

(Unit: USD/liter)

	2003	2005	2007	2010	2011	2011 4Q
Canada	0.526	0.763	0.949	1.001	1.263	1.188
Germany	1.211	1.494	1.818	1.876	n.a.	n.a.
Japan	0.917	1.131	1.187	1.515	1.826	1.852
South Korea	1.087	1.394	1.640	1.479	1.741	1.719
U.S.	0.412	0.600	0.739	0.735	0.930	0.889
OECD	0.531	0.719	0.856	0.892	1.064	1.028

Source: OECD, "Energy Prices and Taxes," 2012 2Q.

<Table IV-5> Premium Gasoline (95 RON) Prices

(Unit: USD/liter)

	2003	2005	2007	2010	2011	2011 4Q
France	1.149	1.442	1.743	1.780	2.087	2.008
Germany	1.235	1.519	1.837	1.877	2.170	2.095
Italy	1.198	1.515	1.778	1.805	2.162	2.171
South Korea	n.a.	n.a.	n.a.	1.652	1.928	1.910
Sweden	1.164	1.466	1.724	1.809	2.156	2.065
U.K.	1.241	1.576	1.888	1.805	2.135	2.091
U.S.	0.438	0.626	0.768	0.767	0.963	0.925
OECD	0.611	0.814	0.977	0.998	1.214	1.169

Source: OECD, "Energy Prices and Taxes," 2012 2Q.

B. Prices in Purchasing Power Parity Terms

While absolute prices of energy products are meaningful in that they can have an impact on the competitiveness of South Korean products in the international market, real energy prices also present the burden on consumers at home.[24] Energy prices in purchasing power parity (PPP)

24) Of course, products derived from petroleum, which are imports, are subject to the law of one price and therefore their PPP figures have reduced meaning. However, since they are also necessities of everyday life, the public's ability to bear the tax burden, together with the products' international prices, can be considered in the process of determining the amount of tax burden. Household and transportation energy is mainly considered.

show different positioning results from absolute price based outcomes. Korea's industrial fuel oil price is higher in PPP terms than that of any other major country. Also, its industrial low sulfur fuel oil price and light fuel oil price are higher than those of major European nations. Both fuel oil and transportation fuels consumed by households in South Korea are lofty as well. The fuel oil price in PPP terms in the nation for 2011 is 1612.5 USD / 1,000 liters, higher than those of all countries except Italy, where such fuel costs 1698.3 USD / 1,000 liters. This suggests that the burden of heating fuels is higher than that of other countries. The same holds for transportation fuels such as diesel and gasoline. The 2011 diesel price (PPP) in South Korea, for example, is 2.121 USD / liter, higher than in all other comparable countries and far higher than 1.538 USD / liter, the OECD member average. Gasoline as well costs more in Korea than in other nations in PPP terms. This is the case with both regular gasoline and premium (95 Ron) gasoline. The country's 95 Ron premium gasoline price is 2.596 USD / liter (PPP), more than twice as the 1.204 USD / liter average price among OECD members and higher than the 2.022 USD / liter in the U.K. where relatively high energy prices are maintained. The prices of energy in South Korea on a PPP basis listed above show that the country's energy products place a greater burden on its economic agents that do those of other nations.

As for electricity in South Korea, however, PPP figures remain lower than the average among OECD members and other major countries due to its extremely low absolute prices.

<Table IV-6> Industrial Low Sulfur Fuel Oil Prices (In PPP terms)

(Unit: USD / ton)

	2003	2005	2007	2010	2011
France	215.2	282.4	345.0	470.9	602.6
Germany	202.9	281.3	346.4	485.9	642.4
Italy	273.0	355.1	423.2	547.1	703.9
Japan	257.6	398.8	568.6	584.6	725.8
South Korea	466.2	557.8	694.0	939.9	1250.1
Sweden	541.6	681.5	789.0	921.8	1045.6

Source: OECD, "Energy Prices and Taxes," 2012 2Q.

<Table IV-7> Industrial Light Fuel Oil Prices (In PPP terms)

(Unit: USD / 1000 liters)

	2003	2005	2007	2010	2011
France	313.5	491.1	565.7	647.8	813.1
Germany	331.9	519.7	595.6	668.8	833.4
Italy	828.9	1007.2	1138.7	1217.1	1411.8
Japan	235.0	373.5	498.4	511.7	640.5
South Korea	805.8	1108.0	1220.6	1293.1	n.a.
Sweden	293.5	437.7	509.1	562.2	743.8
U.K.	299.3	437.7	534.5	779.1	972.0
U.S.	232.3	427.7	547.6	567.1	773.2
OECD	308.3	476.6	583.4	644.5	812.9

Source: OECD, “Energy Prices and Taxes,” 2012 2Q.

<Table IV-8> Household Light Fuel Oil Prices (In PPP terms)

(Unit: USD / 1000 liters)

	2003	2005	2007	2010	2011
France	415.1	630.6	724.4	816.8	1023.4
Germany	385.1	602.9	708.8	795.9	1022.7
Italy	994.7	1208.7	1366.5	1460.6	1698.3
Japan	342.3	492.6	659.9	684.2	846.8
South Korea	804.2	1103.0	1211.8	1299.0	1612.6
Sweden	744.2	985.0	1130.5	1266.1	1447.9
U.K.	289.8	481.5	620.5	821.5	1033.1
U.S.	369.8	552.4	717.5	819.9	1031.9
OECD	444.0	643.7	764.0	832.8	1034.1

Source: OECD, “Energy Prices and Taxes,” 2012 2Q.

<Table IV-9> Non-industrial Automotive Diesel Prices (In PPP terms)

(Unit: USD/liter)

	2003	2005	2007	2010	2011
France	0.845	1.108	1.223	1.312	1.541
Germany	0.965	1.229	1.408	1.514	1.786
Italy	1.027	1.279	1.424	1.508	1.812
Japan	0.605	0.774	0.988	1.012	1.179
South Korea	0.979	1.366	1.653	1.821	2.121
Sweden	0.869	1.104	1.239	1.381	1.572
U.K.	1.215	1.429	1.503	1.809	2.104
U.S.	0.398	0.633	0.761	0.791	1.017
OECD	0.750	1.008	1.165	1.293	1.538

Source: OECD, "Energy Prices and Taxes," 2012 2Q.

<Table IV-10> Regular Gasoline Prices (In PPP terms)

(Unit: USD/liter)

	2003	2005	2007	2010	2011
Canada	0.601	0.761	0.841	0.846	1.016
Germany	1.168	1.388	1.598	1.749	n.a.
Japan	0.761	0.961	1.162	1.193	1.364
South Korea	1.630	1.810	1.984	2.073	2.344
U.S.	0.412	0.600	0.739	0.735	0.930
OECD	0.552	0.724	0.860	0.878	1.028

Source: OECD, "Energy Prices and Taxes," 2012 2Q.

<Table IV-11> Premium (95 RON) Gasoline Prices (In PPP terms)

(Unit: USD/liter)

	2003	2005	2007	2010	2011
France	1.084	1.257	1.426	1.540	1.730
Germany	1.191	1.411	1.615	1.750	1.955
Italy	1.241	1.407	1.590	1.693	1.946
South Korea	n.a.	n.a.	n.a.	2.315	2.596
Sweden	1.007	1.168	1.312	1.443	1.568
U.K.	1.185	1.363	1.463	1.774	2.022
U.S.	0.438	0.626	0.768	0.767	0.963
OECD	0.650	0.828	0.961	1.018	1.204

Source: OECD, "Energy Prices and Taxes," 2012 2Q.

<Table IV-12> Industrial Electricity Prices (In PPP terms)

(Unit: USD/MWh)

	2003	2005	2007	2010	2011
France	42.2	43.4	75.4	92.5	100.8
Germany	63.1	78.0	95.8	126.6	141.6
Italy	152.2	161.5	211.9	242.0	251.4
Japan	100.9	104.3	113.5	121.6	133.7
South Korea	75.9	76.4	84.0	91.6 (2009)	n.a.
Sweden	n.a.	n.a.	57.7	76.8	75.8
U.K.	52.3	75.0	100.6	118.9	120.6
U.S.	51.3	57.3	63.9	67.9	69.6
OECD	72.7	80.6	93.4	110.2	118.7

Source: OECD, "Energy Prices and Taxes," 2012 2Q.

<Table IV-13> Household Electricity Prices (In PPP terms)

(Unit: USD/MWh)

	2003	2005	2007	2010	2011
France	119.4	123.5	128.0	143.0	155.1
Germany	169.3	197.3	231.4	297.2	316.9
Italy	193.2	183.5	230.2	246.8	251.0
Japan	154.1	160.5	172.8	182.8	194.9
South Korea	110.8	115.4	123.3	116.5	119.4
Sweden	n.a.	n.a.	149.0	173.8	180.5
U.K.	10.6	130.1	158.4	181.0	194.0
U.S.	87.0	94.5	106.5	115.8	117.8
OECD	112.5	120.8	135.1	152.7	163.3

Source: OECD, "Energy Prices and Taxes," 2012 2Q.

<Table IV-14> Industrial Electricity Prices

(Unit: USD/MWh)

	2003	2005	2007	2010	2011	2011 4Q
France	44.7	49.8	92.2	106.9	121.5	116.0
Germany	65.4	84.0	108.9	135.8	157.2	153.5
Italy	146.9	173.9	237.0	258.1	279.3	283.8
Japan	121.5	122.7	116.0	154.4	179.0	194.7
South Korea	50.6	58.8	69.5	57.8 (2009)	n.a.	n.a.
Sweden	n.a.	n.a.	75.8	96.4	104.2	95.8
U.K.	54.7	86.7	129.9	121.1	127.4	130.5
U.S.	51.3	57.3	63.9	67.9	69.6	66.8
OECD	67.6	78.8	93.7	110.9	123.6	122.4

Source: OECD, "Energy Prices and Taxes," 2012 2Q.

<Table IV-15> Household Electricity Prices

(Unit: USD/MWh)

	2003	2005	2007	2010	2011	2011 4Q
France	126.6	141.6	156.4	165.3	187.1	184.5
Germany	175.6	212.4	263.2	318.7	352.0	341.0
Italy	186.4	197.5	257.5	263.2	278.9	278.4
Japan	185.7	188.8	176.5	232.2	260.9	280.3
South Korea	73.9	88.9	102.0	83.2	88.6	84.1
Sweden	n.a.	n.a.	195.8	218.0	248.2	238.4
U.K.	115.8	150.4	204.4	184.2	204.9	215.3
U.S.	87.0	94.5	106.5	115.8	117.8	118.2
OECD	110.9	123.8	140.8	158.5	174.2	171.2

Source: OECD, “Energy Prices and Taxes,” 2012 2Q.

C. Tax Share in Energy Prices

Tax share[25] in energy prices is an important index to evaluate energy prices. By analyzing tax share together with absolute energy prices, the government can have insights on future policy directions and targets, such as the distribution market of products and tax adjustments. If the absolute prices of certain energy products are higher than in other countries but the tax share in prices is smaller, the government will need to examine the domestic distribution structure. If absolute energy prices are lower, and the tax share in prices is also smaller compared to in other nations, the government may raise additional revenues from a revision of taxation.

Taxation of industrial low sulfur fuel oil in South Korea is much higher than in other countries, with the exception of Sweden. The share in the country of taxes in end-use prices of this oil stands at 11% as of the fourth quarter of 2011, higher than in all European countries except Sweden, as well as Japan’s rate of 5%. Taxation of light fuel oil is higher than in other major countries except Italy and the U.K. Meanwhile, the share of taxes in household fuel oil prices in the country is lower than among European nations. The tax share of fuel prices is 16.7% in South

25) The analysis is based on the data of Energy Prices and Taxes (OECD).

Korea as of the fourth quarter of 2011, greatly lower than that in European countries, but not low in comparison to the U.S. and Japan.

The tax share in the nation's transportation fuel prices is also lower than in Europe. The tax share in both gasoline and diesel prices in South Korea is much lower than experienced in European countries, but higher than that of the U.S. and Japan.

A number of nations levy relatively low taxes on electricity. Industrial use of electricity, in particular, is often either exempt or only lightly taxed. Many governments impose higher taxes on household use of electricity than on industrial use, whereas Korea actually exempts it.

A comparison of the share of taxation in fuel prices is similar to that of absolute prices and demonstrates that taxation has a considerable impact on the determination of energy prices.

D. Implications

These analyses provide profound insight into energy price policies in South Korea. Absolute prices of industrial fuel oil are higher and those of transportation fuels are lower than those of other major countries. Household fuel oil's absolute price is similar to that found in other nations. This indicates that there is room to increase the level of taxation imposed on transportation fuels. In contrast, PPP based prices of a majority of energy products are higher than those found in advanced countries, and economic agents therefore appear to be carrying considerable cost burdens. This will serve as an obstacle to raising tax rate on petroleum products. The government may consider taxing coal, on which energy taxes are not currently levied, in light of seeking balanced taxation.

As for electricity, PPP prices as well as absolute prices are much lower than those recorded in major countries. While the absolute prices of petroleum products in South Korea do not particularly differ from those found in other countries, absolute prices of electricity in the nation are distinctly low compared to those found abroad. This demonstrates governmental efforts to maintain the prices at an affordable level. One of the reasons behind the considerable discrepancy between electricity prices in South Korea and other countries is that its electricity industry is monopolistic and based on a closed structure, unlike petroleum products which face the pressure of proper market competitiveness through trade with competitive counterparts abroad. In order for the government to ensure the effectiveness of policies aimed at coping with global warming in the future, it is important to sustain proper price level of electricity.

2 Plans for a Carbon Tax

A. Some Issues in Carbon Tax Design

In order for South Korea to implement a carbon tax that is compatible with both existing energy taxation and a pending emissions trading system, issues such as how to tax, which sectors to tax, and where to set the tax rate should be resolved.

<Table IV-16> Issues for a Carbon Tax

Detailed Issues	Determinants and Alternatives
Methods of Taxation	- Matters such as the scope, level, and public acceptance of existing energy-related taxation - Alternatives: ① (New) Independent tax, ② Amended rates for current energy taxes
Scope of Taxation	- Matters such as the size of untaxed sectors in the current energy-related tax system, discrepancies with international prices resulting from taxation, the level of burden on economic agents, and subjects of an emissions trading system - Alternatives: ① Taxation on all energy products, ② Taxation on currently low-taxed sectors
Level of Taxation	- Matters such as the social cost of carbon emissions, overlap with existing fuel taxes, price discrepancies with other nations, and burdens on economic agents - Alternatives: ① Taxes equal to the level of social externalities, ② Reduced rate tax
Choice of Tax Base	- Matters such as the effects of changes in energy prices and the rationale for taxation - Alternatives: ① Ad valorem duties, ② Specific duties

The first issue is means of carbon taxation. This question regards how to actualize the concept of a carbon tax through specific tax items.

Two options are commonly perceived: One is to create a new tax under the concept of carbon taxation, while the other is to apply the concept within the existing tax system through rate change. In determining means of taxation, it is necessary to review the scope, level, and public acceptance of the existing energy-related tax system. The scope of the system already in place can have an enormous effect on the necessity of a new tax. That is, if the existing energy tax system is broad, a new carbon tax would be merely an additional change factor in the existing energy tax system. As another rationale for taxes on energy products, implicitly embedded surtax is also desirable. Examples can be found in Germany and Finland. In contrast, if the existing energy tax system is narrow, a new tax would be desirable in the sense of levying taxes mainly on untaxed sectors. This is the case of the U.K. Taxpayer acceptance can become an influential factor as well. If the existing tax system is complex and taxpayer tolerance of a new tax is low, it would be preferable to simply raise tax rates on existing taxes. In contrast, if existing energy-related tax rates are not excessive and taxpayer acceptance of implementing environmental policies is supportive, it would be possible to impose a new independent tax. In the case of South Korea, a considerable burden of taxes has already been levied on the energy sector and a wide variety of different taxes exists as well. Therefore, rather than introducing a new tax, it would be preferable to include the concept of carbon taxation in rates on existing taxes. Since assorted taxation purposes already coexist within the transportation, energy, and environment tax and the individual consumption tax, it is possible to absorb the carbon taxation concept on current energy taxes.

<Table IV-17> Strengths and Weaknesses by Method of Carbon Taxation

	Strengths	Weaknesses
Independent Tax	- Autonomous system design - Redirecting the current tax system	- Increase in complexity of energy taxation - Negative effect on tax compliance
Compounded Tax Rates on Existing Taxes	- Simplicity in system design - Easy application	- Possible loss of public trust - Uncertainty in long-term sustainability

The second issue is the scope of carbon taxation. In order to do so, it is necessary to consider matters such as the efficiency of taxation, discrepancies with international prices, and the level of burden placed on economic agents. In terms of efficiency, a carbon tax should improve the efficiency of the overall energy taxation. For efficient taxation, first of all, we need to reduce untaxed sectors: Tax-exempt energy resources such as bituminous coal, anthracite, and electricity should be the next target of taxation in South Korea. The price gap with comparable nations can be reviewed in terms of both absolute prices and revised prices in purchasing power parities. When it comes to the demand for industrial energy, the differences in absolute prices among nations can be an important factor in deciding the scope of taxation since energy costs affect the price competitiveness of the industrial products of respective nations. Whether to introduce an emissions trading scheme that establishes a market price for carbon is also a pressing matter as well. The European Union (EU) has already implemented its Emissions Trading System (ETS) targeting large-scale industries, and South Korea is scheduled to introduce such a system in 2015. Assuming similar conditions, the gap in absolute prices with European nations can serve as a useful reference in determining the scope of carbon taxation in South Korea. The relatively low prices on industrial bituminous coal and electricity demonstrate that there is indeed room for a carbon tax.

Prices measured in terms of purchasing power are an important factor in deciding domestic energy prices since these prices indicate how economic agents will respond to increased energy prices. If energy prices measured in PPP surpass those in other nations, the acceptability of an increase in tax rates for carbon taxation decreases. Prices (in PPP) of transportation and household energy products in South Korea are considerably higher than those in major advanced countries, with the exception of electricity prices. These have contributed to public support for reductions in fuel taxes in times of rising oil prices.

<Table IV-18> Strengths and Weaknesses of Taxation Scope

	Strengths	Weaknesses
All Energy Products	- Consistency in policies and tax rates	- Difficulties in tax rate differentiation based on payment abilities - Decrease in tax rates
Low-taxed Sectors	- Efficiency gain of taxation - Increase in taxpayer acceptance	- A possible resistance from low-taxed sectors

The third issue is tax rates. The simple solution is to impose taxes equivalent to the social cost of carbon emissions. This method is called the Piguvian tax, which induces efficient energy consumption by levying a tax commensurate to the social cost incurred by carbon emissions. The problem, however, is that it is difficult to estimate the social costs involved, not only due to the technical challenges involved in reckoning the effect of carbon emissions on climate change, a global issue, but also because the issue of the evaluation of the subjective value of natural environment is involved. To avoid social costs measuring issues, Kim Seung-rae and Kim Ji-yeong (2010) applied the average price of CO_2 emissions as determined in the EU (ETS). This method can be considered reasonable because the price is accepted as the social cost of CO_2 among European societies. Still, the issue arises that the price volatility of CO_2 emissions stemming from prevailing economic conditions is too extreme. The overall price remained around 15 euro/CO_2 ton, but it plunged to as low as 3 euro/CO_2 ton as a result of the recent economic crisis. One alternative is to append a certain level of tax in the form of surtax on the current energy taxation. We need adequate modification in using the EU ETS carbon price, since there exist differences in both income and development level between Europe and South Korea. In fact, in a public hearing on the timetable for implementing a carbon emissions trading scheme in South Korea, the government announced a plan to allocate free allowances until the end of 2017, but industrial circles continued to request an extension of these free allowances until 2020. This is what we have to deal with in carbon tax discussions. If it is difficult to apply EU prices directly, there is no recourse but to apply appropriately reduced prices.

<Table IV-19> Strengths and Weaknesses of Tax Rate Alternatives

	Strengths	Weaknesses
Social Costs	- Consistency in taxation rationale	- Potential for functional overlap with fuel taxes - Heavy tax burden
Lower Tax Rate	- Flexible level of taxation - Harmony with existing tax system	- Relatively weak taxation rationale

The fourth issue is the choice of tax base. This is a matter of levying a carbon tax either in the form of specific duties based on the volume of energy consumption or of ad valorem duties based on prices. Specific duties, a form of taxation based on the volume of energy products, can be selected when the rationale for levying a tax is tied to the quantity of energy consumed. Existing energy taxes (the individual consumption tax and transportation, energy, and environment tax), which were adopted to meet diverse policy objectives, also take the form of specific duties. On the other hand, if the rationale for levying a tax is securing a particular level of tax revenues and therefore is not particularly related to the volume of energy consumption, ad valorem duties are preferred. Taxes on energy products, including a value added tax (VAT), are ad valorem duties. Regarding a carbon tax, the purpose of taxation is to curb carbon emissions resulting from the consumption of energy products, making it advisable to levy a tax based upon the carbon content of related energy products. That is, levying a carbon tax in the form of specific duties accords with taxation rationale.

B. Designing a Carbon Tax

This following section suggests a plural scenario for a carbon tax. After various factors have been taken into consideration, further taxation on low-taxed sectors and setting a low level of carbon tax rates were identified as the foremost avenues. Increasing taxation on low-taxed sectors is a measure to improve efficiency in the taxation of the energy sector and prevent a distortion of the demand structure being triggered by an imbalanced tax burden. In order to attain fairness, there is no alternative but to apply a low level of carbon tax rates since low-taxed sectors have their own various rationales, hindering substantial taxation at the initial stage. This is also due to prices of energy products in South Korea being generally higher than those found in other countries in terms of both absolute prices and of those measured in purchasing power, leaving little capacity for additional taxation.

For tax rate, we need to change the direct use of the EU ETS price which is used in previous studies. In other words, in previous studies conducted by Kim Seung-rae and Kim Ji-yeong (2010), as well as by Heo Gyeong-seon, Sung Myung Jae, and Kim Seung-rae (2012), a carbon price derived from the EU ETS was considered as a social external cost and was directly applied in South Korea's carbon tax rate scenario. However, adjustments must be made because the EU ETS applies only to industries over a predetermined size. Therefore, in the case of the EU, such prices can be considered carbon tax rates on industrial sectors. In addition, carbon tax rates on such industrial sectors close to, conceptually, marginal costs,[26] since 96.9% of allowances (under the second phase of the EU ETS) are allocated without charge. Furthermore, carbon tax rates on non-industrial sectors, which are not included in the emissions trading system, tend to be set high because the issue of international competitiveness is generally inapplicable, as opposed to with industrial sectors. The scenario is devised after taking these factors into account.

First of all, the scenario is composed of two phases. The first stage is a process of solving the problem of taxation imbalances among existing energy sectors, while the second phase, building upon the first, implements the concept of a carbon tax in earnest. At the same time, the second phase pursues harmony with the emissions trading system to be implemented from 2015.

In the first stage, coal and electricity, tax-exempt items under the current energy tax system, become taxed in order to promote fairness in energy taxation. As electricity begins to be taxed, bituminous coal and anthracite, which are used to generate electricity, are exempted. The second

26) In terms of efficiency, levying a tax at marginal costs is desirable, but since it is not designed to pay the costs of past emissions, this fact needs to be reflected.

phase, which will begin with the implementation of an emissions trading plan, is a measure designed to maintain the balance of taxation between industrial and non-industrial sectors, taking into account international competitiveness, by beginning to include sectors that are not presently the objects of an emissions trading system.

In the first phase, a low tax rate is imposed to improve fairness. The recent carbon price of 3 euro / CO_2 ton[27)] under the EU ETS is applied, together with the price of 7 euro / CO_2 ton, about half the value of the 15 euro / CO_2 ton which was the average price for 2009-2010. The tax rate of 7 euro / CO_2 ton is to address the income gap between South Korea and EU nations. It also echoes South Korea's 2010 per capita GDP of 20,753 USD, amounting to 52.0% of the average of the 24 OECD-member European nations of 39,943 USD.[28)] Tax rates in the second phase must be associated with the pricing trend in carbon permits. Higher tax rates are applied to non-industrial sectors compared to industrial sectors, based on the assumption that the price for industrial sectors, mainly energy-intensive sectors, would stand at a level of 3 euro / CO_2 ton.[29)] In general terms, no research has identified the appropriate gap in tax rates between industrial and non-industrial sectors. As for industrial sectors that produce tradable goods, applying a relatively lower rate is the conventional trend to avoid damages on international competitiveness. Consequently, the second phase levies an additional tax on non-industrial sectors at the rate of nearly half the amount of the estimated price of carbon permits.[30)]

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27) Previous studies, conducted by Kim Seung-rae, Song Ho-sin, and Kim Ji-yeong (2010), as well as by Heo Gyeong-seon, Sung Myung Jae and Kim Seung-rae (2012), used in their analysis the high price of about 25 euros, but this price is excluded in terms of practical applicability because the same level of taxation would act as more of a drag on Korea's economy, given the income gap with the EU and the difference in the rate of increase in energy consumption.

28) Statistics Korea, key indicators of OECD nations

29) Under the actual emissions trading scheme, free allowances are allocated for a lengthy period of time, so despite a lower level of tax rates on non-industrial sectors compared to the projected price of carbon permits, the effect is on average the same as levying high tax rates.

30) A gradual increase in tax rates on non-industrial sectors should be followed as grandfathering of emissions rights decreases. However, this is a task that should be reviewed once again in combination with the issue of how to operate an emissions trading scheme.

<Table IV-20> A Scenario for a Carbon Tax

	First Phase	Second Phase
Scope of Taxation	Restoring equity in taxation - Levying a tax on tax-exempt goods (coal, electricity) and imposing no tax on fuels that used to generate electricity	Balanced taxation on industrial and non-industrial sectors (emissions trading scheme and a carbon tax)
Tax Rate	① €3/TC ② €7/TC	① Objects of an emissions trading scheme: €2/TC (about 60% of the first phase level) ② Non-objects of an emissions trading scheme: €4/TC (about 60% of the first phase level)

Note: An emissions trading scheme applies to energy-intensive sectors.

According to the scenario, existing tax exempted sectors such as anthracite and electricity are taxed marginally in the first phase. Anthracite is levied at 9.16-21.36 KRW/kg depending on the price. Electricity also incurs a tax rate of 2.03-4.75 KRW/kWh and monthly average expenses increase by 609-1,425 won given that the household's average energy consumption in 2010 is about 300 kWh/month.[31)]

The second phase of taxation is scheduled to begin after 2015, when an emissions trading system will be launched. Under the assumption that the carbon price is maintained at roughly 3 euro/CO_2 ton as the emissions trading system is installed on energy-intensive sectors, more than half the level of this price would be levied on other sectors. An increase in tax revenues is expected, despite the low tax rates.

31) Applying the estimated number of households of 17,152,000 to the 2010 household electricity consumption of 61,194 GWh.

<Table IV-21> Tax Rate Changes under Carbon Taxation

	Unit	Existing Tax Rates	First Phase Carbon Tax		Second Phase Carbon Tax	
			Additional Rates	Total	Additional Rates	Total
Gasoline	l	939.62	0	939.62	6.41-12.82	946.03-952.44
Light Oil	l	671.49	0	671.49	7.95-15.91	679.44-687.40
Butane	kg	564.49	0	564.49	8.79-17.59	573.28-582.06
Propane	kg	183.26	0	183.26	8.91-17.82	192.17-201.08
Natural Gas	kg	143.41	0	0.14	8.48-16.96	8.62-17.10
Kerosene	l	207.52	0	207.52	7.52-15.04	215.04-222.56
Heavy Oil	l	89.33	0	89.33	9.25-18.50	98.58-107.83
Anthracite	kg	0	9.16-21.36	9.16-21.36	6.10-12.21	15.26-33.57
Bituminous Coal	kg	0	10.59-24.71	10.59-24.71	7.06-14.12	17.65-38.83
Electricity	kWh	0	2.03-4.75	2.03-4.75	1.36-2.71	3.39-7.46

Note: 1. By applying the 2011 average exchange rate for the euro of 1,541.42 won to the carbon emissions coefficient by energy source, the conversion of carbon tax rates into the unit price per energy quantity is calculated (See Appendix 3).
2. Energy consumption equals final energy consumption after subtracting power generating electricity, a non-object of carbon taxation.

Compiled tax revenues from carbon taxation in the first phase of reform, according to this scenario, amount to 1.3-3.1 trillion won. This comes from the taxation on electricity and coal, whose consumption levels are high. Energy-intensive sectors which will be covered by the emissions trading scheme are responsible for 0.5-1.2 trillion won, while other industries and uses make up the remaining 0.8-1.9 trillion won. In terms of energy sources, it is a structure designed to place a burden on electricity and coal users.

In the second phase of reform, which is implemented together with an emissions trading system, tax revenues are expected to increase by 1.0-2.1 trillion won. This is the result of an increase in tax rates on the sectors which are not under the emissions trading system.

<Table IV-22> Tax Revenues from a Carbon Tax

(Unit: billion KRW)

	First Phase Reform		Second Phase Reform	
	€3	€7	€2	€4
Inside of Emissions Trading System[1)]	517	1,207	0[2)]	0[2)]
Outside of Emissions Trading System	796	1,856	1,033	2,067
Total	1,313	3,063	1,033	2,067

Note: 1) Under the assumption that objects of an emissions trading system are the petrochemical, non-metallic mineral, and primary metal industries, all of which are energy-intensive sectors.

2) It is presumed that even after introducing an emissions trading system, previous emissions permits are allocated 100% free of charge and that there is no increase in consumption. If no free permits are allocated, for instance, additional tax revenues of about 0.6 trillion won (at the rate of two euros) are expected.

V

Economic Impacts of the Introduction of a Carbon Tax

1 Model[32]

A. Basic Structure

The economy presumed in the simulation model of this study is composed of three units: households, firms, and government. A household is formed of individuals who maximize their lifetime expected utility. Living from the age of 21 to 80, each individual makes decisions regarding consumption and labor supply. That is, it is assumed that individuals do not make any decisions as an independent economic agent in infancy (under the age of 20), that they start making economic decisions from the age of 21 (considered age one for this model), and that they survive until their death at the age of 80 (considered age 60 in this model) without any mortality risk.

It is assumed that firms are owned by individuals from households and that each individual's shares are the same as each individual's asset holdings. Also, this model sets a situation where the management of a firm works for firm owners by maximizing firm value. A firm makes decisions

32) This model is based on the model devised by Young Jun Chun (2011), and the roles of the government sector are adjusted to address the policy alternatives in this research. In addition, parameters for model calibration are modified by using recent data and researches.

on production levels, input of production factors, investment in physical capital, and research and development (R&D) investment. Factors of production, which are the inputs to the production process, consist of labor, capital, fossil fuels, and renewable energy. R&D investment is for technology development both in reducing the use of fossil fuels and in developing renewable energy sources. With the amount of available fossil fuels confined to fossil fuel reserves that can at present be extracted, this model presumed a situation where a firm must make a decision as to when and in what amounts to use fossil fuels in the future.

The model assumed that the roles of government are limited to supporting technology development, carbon taxation to curb fossil fuel use, and policies on transfer payments for the public, and that the government maintains a balanced budget.

B. Households

Individuals belonging to households maximize their lifetime expected utility, which is defined as equation (6):

$$U=\sum_{a=1}^{60}(1+\beta)^{-(a-1)}\frac{1}{1-\gamma}\left(c_{a,\,p\,+a}^{1-\alpha}l_{a,\,p+a}^{\alpha}\right)^{1-1/\gamma} \tag{6}$$

Each individual's utility function is the Cobb-Douglas function and the CRRA function. Here, c is consumption, l is leisure, p is year of birth, a β is age, is γ a discount rate, is intertemporal substitution elasticity (or a reciprocal of the risk aversion coefficient), and α is the share of leisure in utility.

Constraint conditions faced by each individual mean that the present value of labor income in a lifetime and the transfer income (tr) from the government must be greater than or equal to that of consumption. This can be defined by equation (7):

$$\sum_{a=1}^{60}\left(\prod_{j=1}^{a}(1+r_j)^{-1}\right)\left(w_{a,\,p+a}e_a(1-l_{a,\,p+a})+tr_{a,p+a}-c_{a,p+a}\right)\geq 0 \tag{7}$$

Each individual makes decisions on labor (leisure) and consumption based on equation (7), and equations (8) and (9) below are obtained from a first order optimality condition, and asset holdings by age is determined by equation (10):

$$l_{a,\,p+a}=c_{a,\,p+a}\frac{\alpha}{1-\alpha}\frac{1}{w^{*}}\quad w^{*}=we+\mu^{*},\ \mu^{*}>0,\ if\ l=1 \tag{8}$$

$$\frac{c_{a+1,\,p+a+1}}{c_{a,\,p+a}}=\left(\frac{1+r_{p+a+1}}{1+\beta}\right)^{\gamma}\left(\frac{w^{*}_{a,\,p+a}}{w^{*}_{a+1,\,p+a+1}}\right)^{\alpha(\gamma-1)} \tag{9}$$

$$a_{a+1,\,p+a+1}=a_{a,\,p+a}\left(1+r_{p+a+1}\right)+w_{a,\,p+a}\left(1-l_{a,\,p+a}\right)+tr_{a,\,p+a}-c_{a,\,p+a} \tag{10}$$

C. Firms

The production function of a firm that maximizes firm value is defined by the Cobb-Douglas function of labor and a compounding of other production factors (capital, fossil fuels, and renewable energy), as in equation (11). The complex composed of other production functions is defined by the CES function:

$$Y_s=\left(K_s^{\rho}+\alpha_1\left(B_{1s}E_{1s}\right)^{\rho}+\alpha_2\left(B_{2s}E_{2s}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}}L_s^{\theta} \tag{11}$$

where Y_s, K_s, L_s, E_1, E_2 and refer respectively to the amount of yield, capital, and labor, fossil fuel input, and renewable energy input, and B_1, B_2, α_1, and α_2 are parameters showing the technology for conserving fossil fuels, th e technology for renewable energy use, the share of fossil fuel use in production, and the share of renewable energy use in production, respectively.

Firm value is the present value of cash flow or current net income flow into a firm and is defined as equation (12):

$$V_t=\sum_{s=t}^{\infty}\left(\prod_{j=t}^{s}\left(1+r_j\right)^{-1}\right)\left(\left(K_s^{\rho}+\sum_{n=1}^{2}\alpha_n\left(B_{ns}E_{ns}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}}L_s^{\theta}-I_s-\sum_{n=1}^{2}\left(1+\tau_{ns}\right)p_{ns}-w_sL_s-\sum_{n=1}^{2}\left(1-\varphi_{ns}\right)y_{ns}\right) \tag{12}$$

where r, p_n, τ_n, I, w, y_n, and φ_n refer respectively to a firm's discount rate, costs of energy use, carbon tax rates on energy use, physical investment, wage rate, energy-related R&D investment, and the government rate of support for R&D investment. When the subscript n is one, it indicates fossil fuels, and when two, it refers to renewable energy.

The equations for formulating physical capital and technology development are as follows:

$$K_{s+1}=I_s+\left(1-\delta\right)K_s \tag{13}$$

$$B_{ns+1}=B_{ns}\left(1-\delta_{nB}\right)\phi_n B_{ns}^{\sigma_n} y_{ns}^{\upsilon_n} \quad n=1,2 \tag{14}$$

where δ and δ_{nB} refer to physical capital and the depreciation of energy-related technologies, respectively, and ϕ_n, σ_n, and υ_n, which are parameters related to the technology development function, respectively reflect the efficiency of R&D technology, the effect of existing technologies, and the efficiency of R&D for production.

Firms are restricted in their use of fossil fuels. The amount they can use in the present and future is confined to fossil fuel reserves that are presently available for extraction (equation (15)), and the amount of fossil fuel use per each period cannot be negative (-) (equation (16)).

$$R_0=\sum_{s=t}^{\infty}E_{1s} \tag{15}$$

$$E_{1s}\geq 0 \tag{16}$$

Conditions to maximize firm value (equation (12)) are made up of first order conditions below and constraint condition equations (13) - (16).

$$\left(\prod_{j=t}^{s}\left(1+r_j\right)^{-1}\right)\left(\left(K_s^{\rho}+\sum_{n=1}^{2}\alpha_n\left(B_{ns}E_{ns}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}}\theta L_s^{\theta-1}-w_s\right)=0 \tag{17}$$

$$\left(\prod_{j=t}^{s}\left(1+r_j\right)^{-1}\right)\left(-1\right)+\mu_s=0 \tag{18}$$

$$\left(\prod_{j=t}^{s}\left(1+r_j\right)^{-1}\right)\left(\left(K_s^{\rho}+\sum_{n=1}^{2}\alpha_n\left(B_{ns}\,E_{ns}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}}\left(1-\theta\right)\,L^{\theta}K_s^{\rho-1}-r_s\right)\mu_s+\mu_{s+1}\left(1-\delta\right)=0 \tag{19}$$

$$\left(\prod_{j=t}^{s}\left(1+r_j\right)^{-1}\right)\left(\left(K_s^{\rho}+\sum_{n=1}^{2}\alpha_n\left(B_{ns}\,E_{ns}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}-1}\left(1-\theta\right)L_s^{\theta}\alpha_1\left(B_{1s}E_{1s}\right)^{\rho-1}B_{1s}-p_{1s}\left(1+\tau_{1s}\right)\right)\eta+\zeta_{1s}=0 \tag{20}$$

$$\left(\prod_{j=t}^{s}\left(1+r_j\right)^{-1}\right)\left(\left(K_s^{\rho}+\sum_{n=1}^{2}\alpha_n\left(B_{ns}\,E_{ns}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}-1}\left(1-\theta\right)L_s^{\theta}\alpha_2\left(B_{2s}E_{2s}\right)^{\rho-1}B_{2s}-p_{2s}\left(1+\tau_{2s}\right)\right)=0 \tag{21}$$

$$\left(\prod_{j=t}^{s}\left(1+r_j\right)^{-1}\right)\left(\left(K_s^{\rho}+\sum_{n=1}^{2}\alpha_n\left(B_{ns}\,E_{ns}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}-1}\left(1-\theta\right)L_s^{\theta}\alpha_2\left(B_{2s}E_{2s}\right)^{\rho-1}E_{ns}\right) \tag{22}$$
$$-\lambda_{ns-1}+\lambda_{ns}\left(1-\delta_{nB}+\phi_n\sigma_n B_{ns}^{\sigma_n-1}y_{ns}^{\upsilon_n}\right)=0$$

$$\left(\prod_{j=t}^{s}\left(1+r_j\right)^{-1}\right)\left(-\left(1-\varphi_{ns}\right)\right)+\lambda_{ns}\left(\phi_n B_{ns}^{\sigma_n}\upsilon_n y_{ns}^{\upsilon_n-1}\right)=0 \tag{23}$$

Equation (17) is a first order condition of labor input, equation (18) is that of physical investment, (19) is of K_{s+1}, (20) is of E_{1s+1}, (21) is of E_{2s+1}, (22) is of B_{ns+1}, and (23) is of y_{ns+1} . μ_s, λ_{ns}, η, and ζ_{1s} are shadow prices regarding constraint conditions defined by equations (13), (14), (15), and (16). Unlike other shadow prices, η is constant. This is because fossil fuel reserves do not vary at time t, but the values of other variables change as time goes.

Equations (17), (19), (20), (21), and (22) can be rewritten as follows:

$$\left(1+\sum_{n=1}^{2}\alpha_n\left(\frac{B_{ns}E_{ns}}{K_{ns}}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}}\theta\left(\frac{K_s}{L_s}\right)^{1-\theta}=w_s \tag{17′}$$

$$\left(1+\sum_{n=1}^{2}\alpha_n\left(\frac{B_{ns}E_{ns}}{K_{ns}}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}-1}\left(1-\theta\right)\left(\frac{K_s}{L_s}\right)^{-\theta}=r_s+\delta \tag{19′}$$

$$\left(1+\sum_{n=1}^{2}\alpha_n\left(\frac{B_{ns}E_{ns}}{K_{ns}}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}-1}\left(1-\theta\right)\left(\frac{K_s}{L_s}\right)^{-\theta}\alpha_1\left(\frac{B_{1s}E_{1s}}{K_{1s}}\right)^{\rho-1}B_{1s}=p_{1s}\left(1+\tau_{1s}\right)+\left(\prod_{j=t}^{s}1+r_j\right)\left(\eta-\zeta_{1s}\right) \tag{20′}$$

$$\left(1+\sum_{n=1}^{2}\alpha_n\left(\frac{B_{ns}E_{ns}}{K_{ns}}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}-1}(1-\theta)\left(\frac{K_s}{L_s}\right)^{-\theta}\alpha_2\left(\frac{B_{2s}E_{2s}}{K_{2s}}\right)^{\rho-1}B_{2s}=p_{2s}(1+\tau_{2s}) \quad (21')$$

$$\lambda_{ns-1}=\lambda_{ns}\left(1-\delta_{nB}+\phi_n\sigma_n B_s^{\sigma_n-1}y_s^{\upsilon}\right)+\left(\prod_{j=t}^{s}(1+r_j)^{-1}\right)\left(\left(1+\sum_{n=1}^{2}\alpha_n\left(\frac{B_{ns}E_{ns}}{K_{ns}}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}-1}(1-\theta)\left(\frac{K_s}{L_s}\right)^{-\theta}\alpha_n\left(\frac{B_{ns}E_{ns}}{K_{ns}}\right)^{\rho-1}E_{ns}\right) \quad (22')$$

Equation (19′) is derived from equations (18) and (19). Equations (17′) and (19′) suggest that a firm equalizes the marginal productivity of labor and capital to the wage, the sum of interest and depreciation rates, respectively. Equations (20′) and (21′) are conditions of fossil fuel and renewable energy usage, respectively. The optimum usage of renewable energy, which is not confined to reserves, is determined by a firm in order to make the marginal productivity of energy (the left-hand side of equation (21′)) equal to the costs of use (the right-hand side of equation (21′)) under given energy-using technology (B_{2s}). As for fossil fuels, however, whose total usage in the present and in the future is restricted to the reserves accessible at the current moment, additional user costs exist. $\left(\prod_{j=t}^{s}(1+r_j)\right)(\eta-\zeta_{1s})$ in equation (20′) implies that there are additiona costs costs resulting from the given amount of reserves. In a case where fossil fuels are used until they are depleted, η has a positive (+) value, and once they are exhausted, equation (15) has no meaning, therefore resulting in a value of zero. The value of ζ_{1s} is positive in cases where fossil fuels are exhausted and therefore unavailable for use, and the value becomes zero when fossil fuels are in use. Therefore, when fossil fuels are in use prior to their depletion, additional costs are $\left(\prod_{j=t}^{s}(1+r_j)\right)\eta$, and is the present value of this term. In other words, costs stemming from the future decrease of reserves change fossil fuel usage of each period like current costs. By using equations (19′), (20′), and (21′), the following equations (20″) and (21″), which determine energy inputs and capital inputs, can be derived:

$$\frac{E_{1s}}{K}=\left(\left((\eta-\zeta_{1s})\left(\prod_{j=t}^{s}(1+r_j)^{-1}\right)+p_{1s}(1+\tau_{1s})\right)\Big/\left((r_s+\delta)\right)\alpha_1 B_{1s}^{\ \rho}\right)^{\frac{1}{\rho-1}} \quad (20'')$$

$$\frac{E_{2s}}{K_s}=\left(\frac{p_{2s}(1+\tau_{2s})}{(r_s+\delta)\alpha_2 B_{2s}^{\ \rho}}\right)^{\frac{1}{\rho-1}} \tag{21''}$$

If λ_n denotes the rate of returns on technology improvement and λ_{ns} is the present value of the rate of returns, the relationship between the two variables would be $\lambda_{ns}=\lambda_n\left(\prod_{j=t}^{s}(1+r_j)^{-1}\right)$. By using this, equation (22′) can be converted into the following:

$$\lambda_n=(1+r)^{-1}\left(\left(\left(1+\sum_{n=1}^{2}\alpha_n\left(\frac{B_{ns}E_{ns}}{K_{ns}}\right)^{\rho}\right)^{\frac{1-\theta}{\rho}-1}(1-\theta)\left(\frac{K_s}{L_s}\right)^{-\theta}\alpha_n\left(\frac{B_{ns}E_{ns}}{K_{ns}}\right)^{\rho-1}E_{ns}\right)\right)+\lambda_n\left(1-\delta_{nB}+\phi_n\sigma_n B_{ns}^{\sigma_n-1}y_s^{\upsilon}\right) \tag{22''}$$

The rate of returns on energy-related technology development can be divided into two terms. The first term in the right-hand side of equation (22″) represents the effect of an increase in production due to the improvement in energy efficiency through technology development, and the second one shows the effect of the improvement in R&D efficiency derived from technology development. The second effect is caused by the fact that the current level of technology impacts the level of future technology, as is demonstrated in equation (14).

The following equation (18′), a reorganized version of equation (18), implies the decision-making rule of a firm regarding technology development:

$$1-\varphi_{ns}=\lambda_n\left(\phi_n B_s^{\sigma_n}\upsilon_n y_{ns}^{\upsilon_n-1}\right) \tag{18'}$$

The left-hand side of equation (18′) refers to R&D investment costs. Real R&D costs are R&D expenses net of government support. The right-hand side is the multiplication of the improvement in technology due to R&D investment $\left(\phi_n B_s^{\sigma_n}\upsilon_n y_s^{\upsilon-1}\right)$ and the rate of returns on technology development, which shows the eventual rate of return on R&D investment.

D. Government

The roles of government include taxation of energy use, transfer of payments for households, and carbon taxation. In this study, it is assumed that governments maintain a balanced budget each term. The formula for a balanced budget is defined by the following equation (24):

$$\sum_{n=1}^{2}\tau_{nt}p_{nt}E_{n}=\sum_{n=1}^{2}\psi_{nt}y_{nt}+\sum_{a=1}^{60}tr_{a,t} \qquad (24)$$

2 Policy Simulation

A. Basic Economy

<Table V-1> and [Figure V-1] present resource allocation in the basic economy where parameters are set based on various data and previous studies. At the start year, capital / GDP ratio stands at 3.60, the rate of working hours to the available time of workers before retirement is 40.5%, and the savings rate is 19.3%. Capital / GDP ratio stands at a similar level as was presented in previous studies, and the ratio of working hours falls more or less below the figure of 45% found in Survey Report on Wage Structure. Given that the rate of working hours declines when irregular, temporary, and daily workers are included compared to the rate for regular workers only, the rate is acceptable. As for the savings rate, the share of depreciation costs to GDP takes up 18.0% (3.60 × 0.05 × 100), so net savings account for approximately 1.3% of GDP, which well represents the recent low rate of private savings.

The rate of renewable energy use to total energy consumption, the rate of increase in fossil fuel energy saving technology, and the amount of fossil fuel use to total production are all close to the recent actual data. According to the Yearbook of Energy Statistics, as of 2008 renewable energy consumption makes up approximately 2.5% of total energy consumption excluding nuclear energy. As of 2010, this rate is reported to stand at 3.0% in the 2010-2014 National Fiscal Management Plan. It is considered that the rate of increase in fossil fuel energy-conserving technology (an annual rate of 4.9%) approaches the actual number. For instance, according to the Energy and Environment Report 2008 and the website of the European Environmental Agency (EEA) (www.eea.europa.eu), the energy efficiency of the 27 EU nations has improved annually by roughly 2% over the past 15 years. In addition, the Korea Energy Economics Institute's estimation of the index for energy efficiency in the transportation sector, based upon the standard of the International Energy Agency (IEA), showed an increase of 5.4% during the four-year period between 1990 and 1993. The annual rate of 4.9% is somewhat higher than the increase rate of energy efficiency among the 27 EU nations, but it is similar to the recent estimates for South Korea. The rate of fossil fuel use to total output (9.8%) is close to the actual number (approximately 10%) in the 2010 input-output table. The use of renewable energy to total output (0.87%) is consistent with the use of fossil fuels and the share of renewable energy use.[33)]

Due to data constraints, R&D costs for the improvement in fossil fuel efficiency (energy saving technology) and for renewable energy technologies presented in <Table V-1> cannot be compared with actual data. At the start year, the annual efficiency rate of fossil fuels and renewable energy due to the investment in R&D stands at approximately 4.9 and 7.3%, respectively.

The main feature of macro-economic variables after the start year of the basic economy is that economic growth depends considerably on the use of fossil fuels. It is shown that the consumption of fossil fuels increases for a particular period of time and then begins to decline, after about 75 years their use stands at a minimal level, accounting for less than 5% of total energy use. It is predicted that renewable energy use, which is currently minimal, will in the future increase together with efficiency of renewable energy and replace fossil fuels. However, when the reserves of fossil fuels decline, making their contribution smaller, and the use and energy efficiency of renewable energy stagnate, there is a delay in GDP growth, or GDP may even decline. Therefore, for the generation living this

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33) The share of renewable energy use refers to the share (B2E2/(B1E1+B2E2) not in terms of its physical aspect but in terms of efficiency.

period, the level of welfare cannot be improved and may even be fallen.[34)] Following this period, however, it is expected that the use and energy efficiency of renewable energy will improve and consequently replace existing fossil fuels, which would then lead to a continuous increase in GDP and an improvement in the level of welfare for the generation living in that future period.

In this model, however, for the purpose of stability and simplicity of a general equilibrium model, fossil energy is not divided by product. Therefore, this study is not fitting for an analysis of differential taxation by each fossil energy source. Despite the absence of classification of energy sources, the overall increase in tax rates including the rates of a carbon tax—the purpose of this study—can be analyzed.

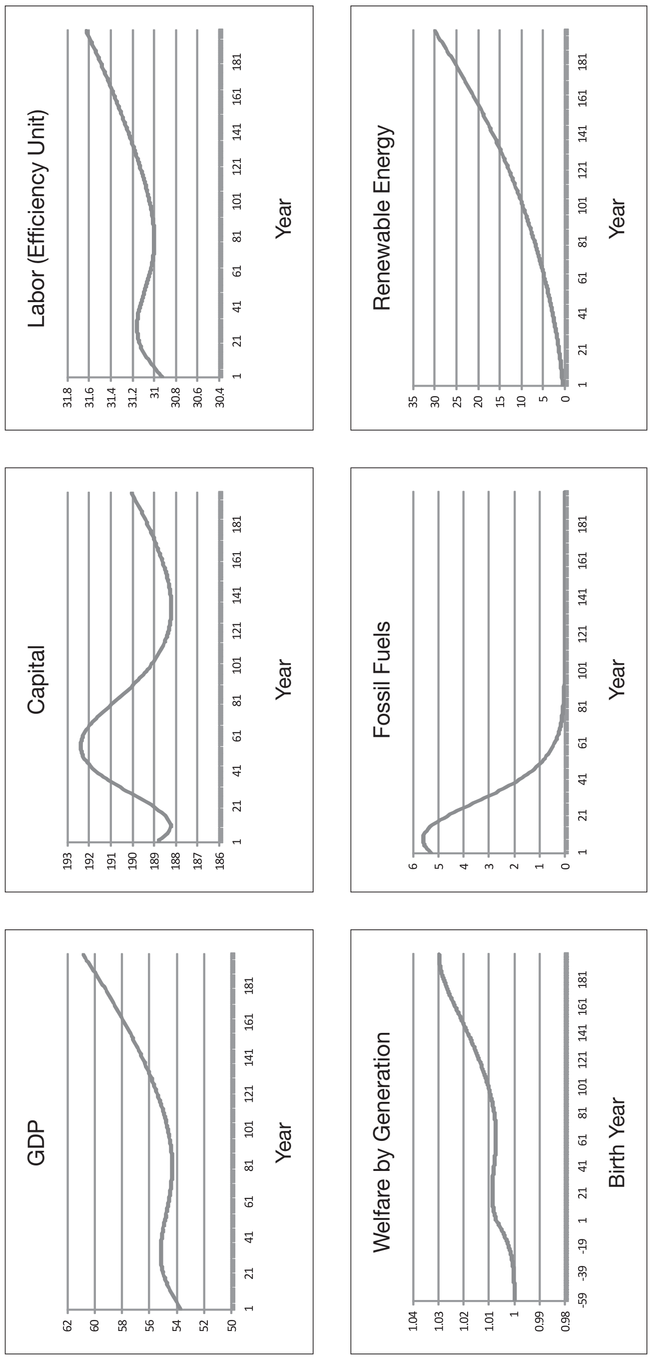
<Table V-1> The Allocation of Resources in the Start Year of Basic Economy

K/GDP	3.60
Average hours of work (worker)	0.405
Savings rate (%)	19.3
Rate of renewable energy use (%)[1)]	3.0
Rate of increase in fossil fuel energy-saving technology (%)	4.9
Use of fossil fuels/total output (%)	9.8
Use of renewable energy/total output (%)	0.87
R&D costs for energy saving technology/total output (%)	0.13
R&D costs for renewable energy technology/total output (%)	0.02

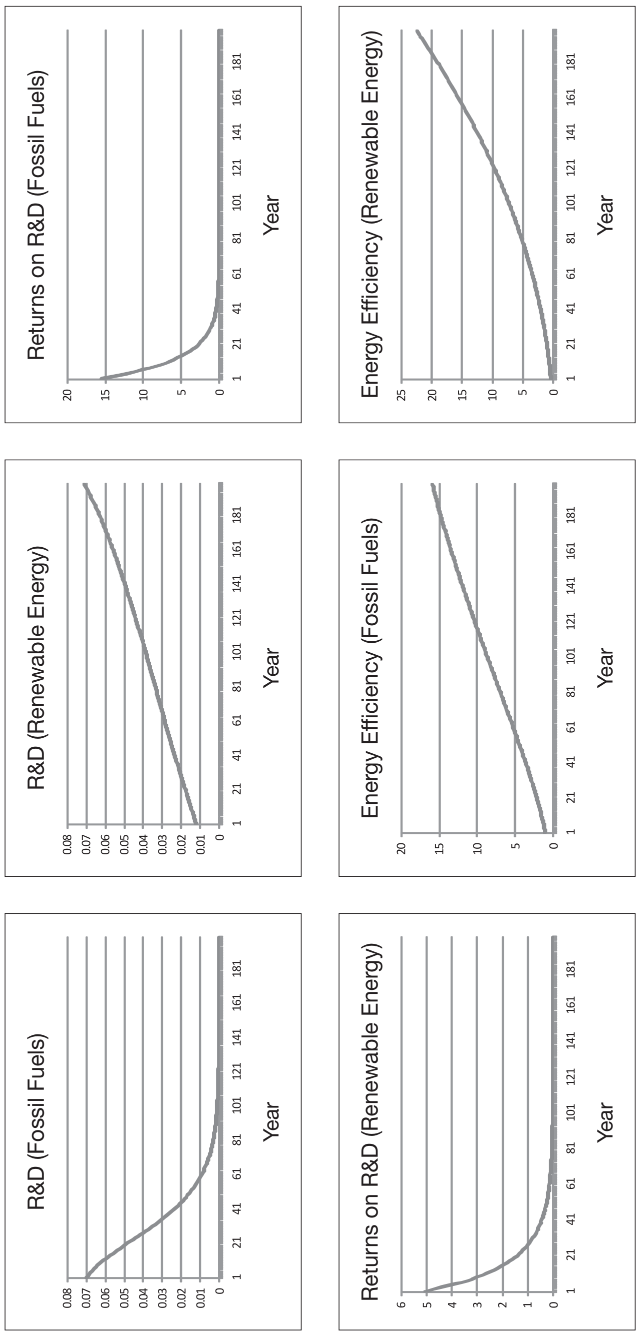
Note: 1) The consumption of renewable energy to total energy consumption

34) Welfare by generation as presented in [Figure V-1] is calculated through the following procedures. First of all, lifetime expected utility of the generation perpetually living at the initial steady state is determined. Next, how much the consumption of this generation should be changed in order to make the lifetime expected utility the same between the perpetually living generation at the initial steady state and other generations living after the initial steady state is calculated. The scale of adjusted consumption, calculated according to these procedures, is then converted into the rate to the level of actual consumption in the initial generation, and this rate is used to ascertain how much higher is each generation's welfare rate compared to the preceding generation.

[Figure V-1] Basic Economy



[Figure V-1] Continue



B. Effects of Policy Reforms

In the following section, we will examine the effects of two policy reforms related to carbon taxation. We will analyze the effect of imposing a carbon tax and distributing the revenues equally among all citizens (policy simulation I), and then the effect of funding up to 50% of R&D expenditures related to the improvement of energy efficiency (policy simulation II).

1) Policy Simulation I

It has been shown that levying a carbon tax is effective in delaying the use of limited fossil fuels into the future. Such a change in the point of use affects returns on R&D investment in enhancing fossil fuel efficiency. As presented in equation (22″), the greater the volume of fossil fuels used, the higher the return on R&D investment. Therefore, R&D investment for the improvement in fossil fuel energy efficiency declines at present but increases in the future. Such an increase in R&D investment improves fossil fuel energy efficiency and contributes to an increase in production. For these reasons, GDP decreases at the present moment while increasing in the future. It is also found that the use of renewable energy decreases in general. Due to the increase in production in the future, returns on R&D investment for enhancing renewable energy efficiency increase somewhat (See equation (22″)). The amount of increased returns on investment, however, is smaller than that with fossil fuels, so the scales of R&D investment and of the improvement in efficiency are smaller compared to those involving fossil fuels. As a result, the use of fossil fuels, whose efficiency is enhanced more compared to that of renewable energy, increases while that of renewable energy slightly decreases.

Despite a decrease in GDP at a present moment, whether the level of welfare for the current generation as well as for future generations increases or decreases, the scale would be insignificant. This is because carbon tax revenues are equally distributed among all citizens in the form of transfer payments. Therefore, the level of social welfare is enhanced, even when carbon tax rates reach a very high level. However, it is worth noting the fact that the effect of welfare improvement through carbon taxation and transfer payments does not last indefinitely due to the decline in fossil fuel reserves and their resulting use leading to an eventual reduction in carbon tax revenues and a consequent reduction in governmental transfer payments. Therefore, it becomes necessary to devise measures to contribute to welfare enhancement for future generations by applying carbon tax revenues in sectors where the effect is more enduring.

2) Policy Simulation II

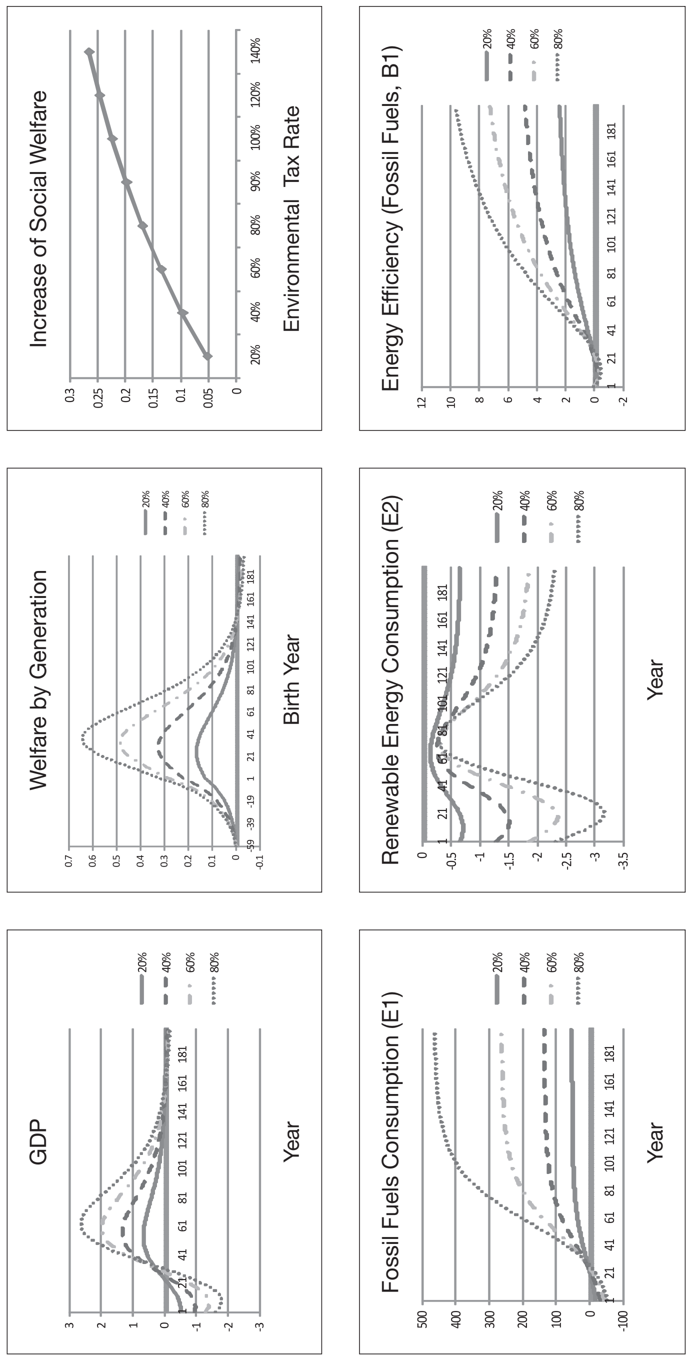
This second policy simulation sets a case of dedicating carbon tax revenues as supportive funding for R&D investment, that is, a scenario of spending them in pursuit of a permanent effect on production and welfare improvement. It then analyzes the effects. This simulation assumes that the government provides up to 50% of R&D investment expenditures for the improvement of fossil fuel and renewable energy efficiency. The simulation also assumes that any funds remaining after R&D support are equally distributed among all citizens as in policy simulation I.

According to [Figure V-3], during the initial periods when the use of fossil fuels is high, the volume of carbon tax revenues is higher than the funding support to R&D investment, allowing considerable transfer payments to be made by the government. As reserves and the usage of fossil fuels decline, leading to a fall in carbon tax revenues, all carbon tax revenues are dedicated to the support of investment. The higher the carbon tax rates, the longer the transfer payment period lasts.

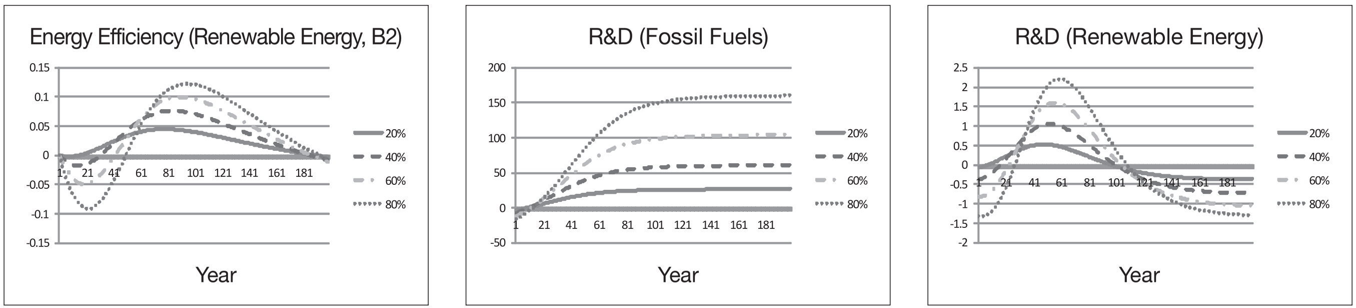
Carbon taxation has the effect of prolonging the use of fossil fuels, as is presented in policy simulation I. Therefore, the impact on production can be summarized as a decline in production at present and an increase in production in the future. Where this scenario diverges from policy simulation I is that its effect on production is permanent due to the enduring effect of the improvement in energy efficiency resulting from the increase in R&D investment leading to a permanent increase in production.

The impact of supporting R&D is first evidenced in the increase in R&D investment. R&D investment for enhancing the efficiency of fossil fuels and renewable energy depends on the rate of support for such investment. During the periods when the subsidy rate is maintained at a high level of 50%, investment increases significantly. As the subsidy rate declines, the rate of increase in investment is reduced. Despite a decrease in R&D investment, the effect of increased energy efficiency due to R&D investment remains, which in turn leads to the lasting effect of an increase in production. In addition, unlike policy simulation I where the effect of welfare improvement on future generations is temporary, policy simulation II features a permanent effect of welfare improvement for future generations.

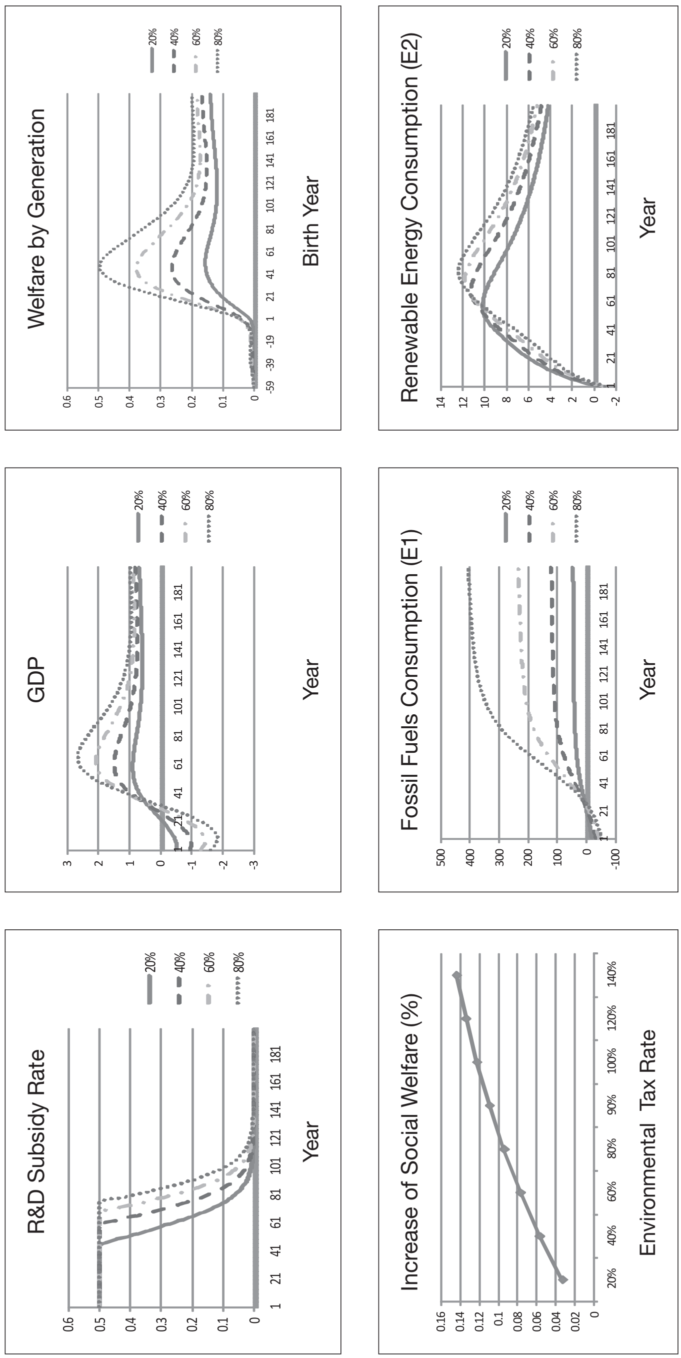
[Figure V-2] Policy Simulation I (Change from Basic Economy under Various Carbon Tax Rates)



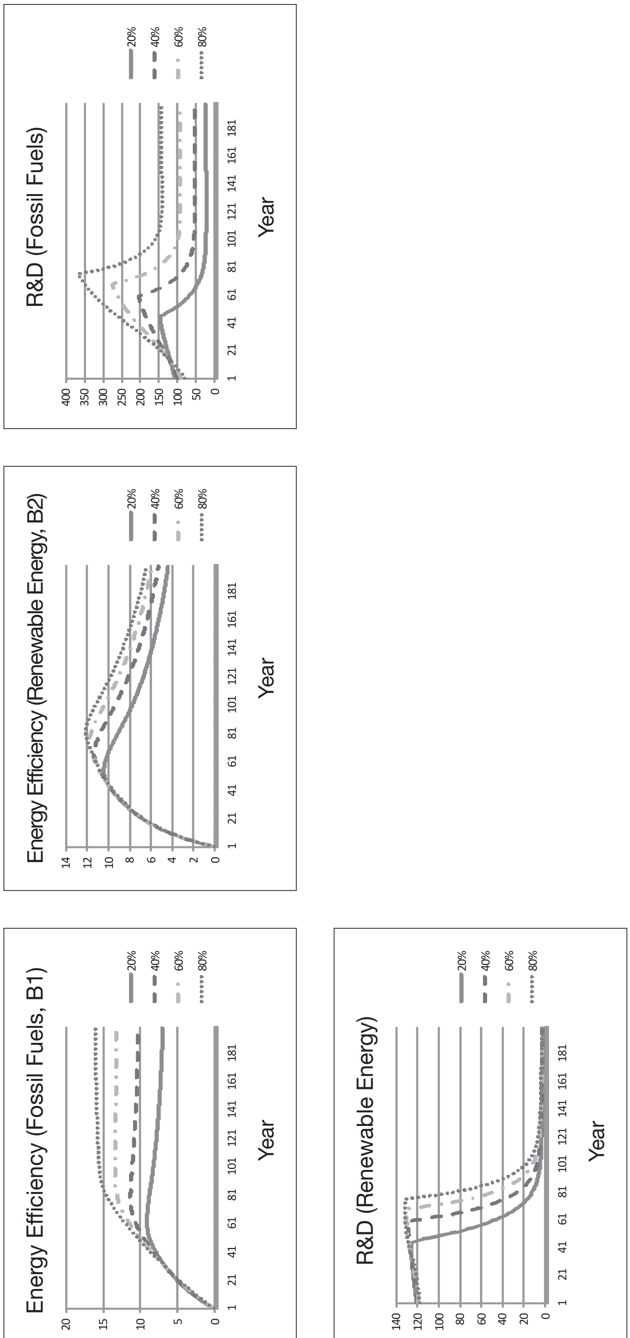
[Figure V-2] Continue



[Figure V-3] Policy Simulation II (Change from Basic Economy under Various Carbon Tax Rates)



[Figure V-3] Continue



3 Implications

In this chapter, the economic impact of levying a carbon tax on fossil fuels is analyzed by means of a general equilibrium model. According to the analysis, carbon taxation affects the period of use of fossil fuels, whose reserves are limited, which in turn brings about an effect of reducing GDP at present but increasing it at a future point. It is also shown that, depending upon the distribution of carbon tax revenues, there is a possibility of lowering the welfare loss due to the decline in production in the initial periods of carbon taxation and of enhancing welfare for nearly all generations. If the government provides citizens with carbon tax revenues in the form of transfer payments, it is possible to enhance welfare, at least by a small margin. In addition, the effect of the improvement in production and in future generations' welfare appears likely to last into the future if some portion of carbon tax revenues is dedicated to support for R&D investment.

We find that supporting R&D investment, in particular, to a certain extent results in mitigating a decrease in production when the use of renewable energy has not entered full swing due to problems of fossil fuel depletion and insufficient renewable energy efficiency remaining underdeveloped, as well as easing the reduction of the current generation's welfare to a degree.

The analysis implies that carbon taxation will significantly contribute to an improvement in production and the welfare of future generations under the condition of excessive amounts of fossil fuels being used without proper consideration for future generations despite the limits of fossil fuel reserves and renewable energy for the future remaining insufficiently developed. The expenses that the current generation would bear are relatively small compared to the future conveniences gained, which indicates it is highly likely that overall social welfare would be improved.

However, there is a limitation in that the analysis model cannot accommodate tax differentiation by energy sources suggested in the first stage of the carbon tax scenario. We did not consider existing energy taxes either. Therefore, the model can better be seen as an impact analysis of the second phase of taxation, which is a broader taxation scenario than of the first phase scenario when the purpose is to restore balanced taxation. Considering that the current proportion of taxes on energy products is 10-20% for industrial and household fuels and approximately 40% for transportation fuels, with the addition of a small margin of an additional carbon tax levied, the tax rates of 20-40% in the analysis can be regarded as the economic effect of tax policies though we cannot separate carbon tax effect from the total. The economic effect of revenue recycling alternatives holds regardless of these limitations.

VI

Conclusions

This paper reviews the feasibility, effectiveness, and specific application plans of a carbon tax as a countermeasure against the climate change. EU nations, in the vanguard of tackling climate change, had adopted the concept of a carbon tax on fossil fuels as early as the 1990s. In addition, the EU Emissions Trading System (ETS) targeting large-scale emitters was launched in 2005 and is currently engaged in its second phase (2008-2012). Despite the recent economic slowdown, EU nations are pushing ahead as planned with extending the ETS to include the airline industry. As part of efforts to secure future growth engines based on the green growth paradigm, the South Korean government has also announced long-term CO_2 reduction targets and, as a more concrete policy measure, elected to implement an emissions trading scheme from 2015.

More specifically, this paper examines key subjects concerning the harmony between a carbon tax and other energy-related taxes. The scope of the research was set so as to focus on major subjects overlooked in previous studies as well as to conduct an in-depth analysis of detailed subjects. Principle research topics include an analysis of energy consumption in the manufacturing and household sectors, international experiences of harmonizing a carbon tax with existing energy taxation, a carbon tax scenario for South Korea, and the economic effects of the implementation of a carbon tax.

According to the analysis of energy consumption, due to low value adding in the manufacturing sector, the efficiency of energy consumption per added value is aggravating. This result contrasts with the recent improvements in the index of energy consumption per production value. That is, when energy consumption per production (energy consumption divided by production value) is decomposed into value added ratio (value added divided by production) and value added energy intensity (energy consumption divided by value added), it decreases due to the sharp decline in the value added ratio and no improvement occurs in energy consumption per value added. It is confirmed that low energy prices significantly impact the aggravation of efficiency in energy consumption. Such results indicate that there is room for improving energy efficiency in the manufacturing sector through a carbon tax. As for household energy consumption, prices and price elasticity are also found to be low. Transportation fuels still show a considerable level of price elasticity, which means there is room to implement pricing policies.

International experiences of harmonizing energy taxation with a carbon tax indicate that effective coordination between the two is necessary, as are securing competitiveness in industrial sectors and integration with an emissions trading scheme. First of all, to harmonize the scope of a carbon tax within the existing energy-related tax system, leading countries have expanded the tax base with the imposition of a carbon tax. In other words, if the scope of existing energy taxation is broad, the need for expanding the scope is not high so that the current tax base is used for a carbon tax (Germany). In contrast, if the scope of the existing energy taxation is narrow, they broaden the base with the implementation of a carbon tax (Finland), or alternatively designing an additional tax on exempt sectors (the U.K.). Denmark, whose scope of existing energy taxation was broadly formed but exempted the industrial sector, expanded its scope of taxation to include energy consumption in the industrial sector after it applied a carbon tax.

Second, a specific form of a carbon tax depends on the scope of existing energy taxes. If the scope of taxation is relatively broad, a type of surtax within existing energy-related taxation is a preferred method

(Germany and Finland). In contrast, if the scope of taxation is restricted to particular sectors, creating a new tax is considered appropriate (the U.K. and Denmark). It seems that these approaches contribute to unraveling the complexity of the tax system. This is because simply adding carbon tax rates to existing energy taxes can work if existing energy taxes are levied on a broad scope of items. In the case of operating a carbon tax on a different tax base, a new tax is created (the U.K. and Denmark).

Thirdly, revenue effects of a carbon tax are not significant. This implies that a carbon tax can be somewhat meaningful as a means of securing new revenues, but the scale of such revenues may not be big due essentially to improved energy efficiency. At the same time, the development of renewable energy is a factor that directly weakens the carbon tax base centered on fossil fuels. Thanks to the application of Environmental Tax Reform (ETR), that is, strengthening environmental taxes while reducing the tax burden on labor, Denmark showed the highest increase in tax revenues to GDP with 1.02%p, while other nations' increases in tax revenues were merely 0.5%p or less.

Energy prices (in absolute and PPP terms), which give room for carbon taxation, vary on usages and energy sources. The absolute price of industrial fuel oils, which affects international competitiveness, is higher than that found outside the country, while the price is relatively low for transportation fuels. As for household fuel oil, however, there is no significant price difference. This indicates that there is room for an increase in the tax burden on transportation fuels. The prices in PPP, which measure the burden on consumers, are higher than those of other countries for most energy products. This implies that economic agents suffer a considerable burden of energy expenses. This, in turn, serves as a barrier to a tax increase on energy products. The current structure of taxation by energy source is preferential to electricity and coal. Coal is not subject to energy-related taxation, so taxing coal should be considered. Electricity prices are also low in both absolute and PPP terms. This can be a good contrast with petroleum products, whose absolute prices show little difference compared to foreign benchmarks. Such results show the government's intentions in managing energy prices. In order to ensure the efficiency of policies, or countermeasures against global warming in the future, it is important to restore electricity prices to a comparable level with other energy sources.

In order to form a complementary relationship with the emissions trading scheme scheduled for 2015, introducing a carbon tax prior to the launch of the trading system is considered desirable. Since the emissions trading scheme applies only to energy-intensive businesses surpassing a given size, it is necessary to apply the concept of a carbon tax primarily to the industrial, transportation, and household sectors which are not in the cap and trade system. When introducing a carbon tax prior to the launch of the EU ETS, EU nations also considered the competitiveness aspect through measures such as imposing low tax rates on industrial sectors. Considering that carbon permits will be allocated free of charge in South Korea until the end of 2016, it is important to set the price properly before the ETS implementation by a carbon tax on non-industrial sectors.

As for a carbon tax, it is desirable to add a type of surtax on broadly-formed existing taxes such as the transportation, energy, and environment tax and the individual consumption tax, rather than a separate tax. The strengths of this method include convenience of system design, simplicity in tax system, and better tax compliance. In terms of the scope of a carbon tax, non-taxed sectors should be minimized in order to improve the efficiency of taxation. Currently tax-exempt energy sources such as bituminous coal, anthracite, and electricity are preferable objects of taxation. The absolute prices of these energy products are relatively low compared to those reported in other nations, allowing considerable room for a carbon tax. It is desirable to adopt the characteristics of the Piguvian tax when introducing a carbon tax, but the measurement of social costs is infeasible. We apply EU ETS prices after proper modification. This is because carbon prices of the EU ETS can be seen as market-evaluated carbon emissions prices. The reason of price adjustment is that the perceived value of the environment largely depends on the income level of a society. As for the base of carbon taxation, it is preferable to have specific duties based on quantity, which is directly related to carbon emissions. This measure matches well with the purpose of carbon taxation, which is the internalization of social costs, and is able to maintain consistency with the existing energy-related tax system.

Based on the previous discussions, we can apply a carbon tax in two stages. The first stage is a process of resolving the issue of imbalances among existing energy taxation, while the second phase, based on the first, is the implementation in earnest of the concept of a carbon tax. At the same time, in the second phase the scope of taxation is adjusted to avoid double taxation on large consumers who will be under the cap and trade system from 2015. In terms of carbon tax rates, the prices of EU carbon permits are used. Considering the income gap between South Korea and the EU, tax rates of 3-7 euro / CO_2 ton are applied in the first phase, while in the second phase, ETS is applied to large consumers in industrial sectors and tax rates of 2-4 euro / CO_2 ton are imposed on non-industrial sectors. The effect of the tax revenues obtained from carbon taxation in the first phase, according to the scenario, amounts to 1.3-3.1 trillion won. This is a structure designed to place a burden on electricity and bituminous coal, of which consumption is high. Objects of an emissions trading system composed of energy-intensive sectors bear an expense of 0.5-1.2 trillion won, while other industries and uses are charged 0.8-1.9 trillion won. In terms of energy sources, economic agents who consume electricity and bituminous coal carry most burden. In the second phase of reform which works with an emissions trading scheme, tax revenues are expected to increase by 1.0-2.1 trillion won, without considering the potential increase in the burden[35] on industrial sectors. This is a result of applying an additional tax rate, which is around 50% of the EU ETS carbon price, on consumers who are not under the emissions trading scheme.

According to the general equilibrium analysis, carbon taxation affects the period of use of fossil fuels, whose reserves are limited, which in turn brings about an effect of reducing present GDP but increasing it at a future point. Carbon taxation on fossil fuels reduces GDP for a while, but after economic adaptation, GDP greatly increases. It is also found that, depending on how carbon tax revenues are distributed, it is possible to mitigate the welfare loss triggered by production decreases in the initial periods of carbon taxation and enhance welfare for most generations. There is a possibility of enhancing welfare for the current generation by at

35) Even though carbon permits are allocated 100% free of charge, the purchase of carbon permits is required at some point as energy consumption increases, thereby incurring a cost burden.

least a small margin if the government provides citizens with carbon tax revenues in the form of transfer payments. In addition, the effects of an improvement in production and the welfare of future generations seem to become permanent if carbon tax revenues are used for R&D investment. What matters here is that carbon taxation causes a reduction in the GDP growth rate in the short term. This period and the growth inhibition effect diminish as carbon tax rates decline, but it is difficult to entirely avoid this impact. However, considering that the current system is unable to maintain sustainable growth due to environmental burden, the negative impact on the economy resulting from a reduction in fossil fuels (that is, a decrease in greenhouse gases) is hard to avoid. The realistic alternative may be the gradual introduction of a carbon tax. The high rate of free allowances under the ETS is another example of gradual implementation.

In conclusion, efforts are required to improve two factors—the manufacturing sector's low value added ratio and energy intensity—which largely drive the economy to consume more energy. It is found that low energy prices significantly affect the aggravation of energy intensity, so a carbon tax can alleviate worsening of energy intensity. Household energy demand has also shown moderate price responsiveness. It has been shown that there is room for additional taxation on energy products based on their absolute prices and prices measured in terms of purchasing power. The implementation of a carbon tax on tax-exempt sectors should be first priority, and then to balance with the emissions trading scheme scheduled for 2015, additional carbon taxation is needed on consumers who are out of the emissions trading scheme. These step-by-step measures are judged preferable because the effectiveness of carbon taxation increases through balanced taxation among sectors. As was seen in other countries' experiences, levying a carbon tax by small margins and securing a broad tax base are important. The implementation of a carbon tax would decrease GDP in the short term, but it will bring about positive effects over the long term. Investment in R&D using carbon tax revenues brings much greater effects. To foster a new growth engine under tightening of worldwide environmental regulations, the introduction of a carbon tax and the productive structure of tax revenue feedback are critical. Active discussions for a carbon tax should begin immediately.

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