The Comprehensive Equity Implications of a Carbon Pricing Policy in South Korea: Based on Environmentally Extended Input Output Analysis Together with Household Expenditure Data*

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국 문 요 약

한국은 2015년부터 총 국가배출량의 60%를 차지하는 탄소 배출권 거래제를 시행하고 있다. 선진국에서 탄소가격정책은 다양한 사회경제적 구성 집단 사이의 소득 불균형을 심화시키는 것으로 밝혀진 바 있다. 현재 한국 사회는 분배적인 문제뿐 아니라, 에너지 안보, 기후변화 대응, 경제 성장 등 다양한 과제에 직면하고 있다. 이런 상황에서 탄소가격정책이 소득 분배적인 측면에 미칠 영향을 분석하고, 이 분석결과를 바탕으로 대응책을 마련할 필요가 있다. 가계동향조사자료와 환경투입산출분석(EEIO)을 이용해 분석한 결과 저소득 가구, 노인가구와 도시가구가 탄소가격정책으로 인해 상대적으로 무거운 부담을 지는 것으로 나타났다. 그러나 세수의 일부가 가구에 재분배 될 경우 이러한 부담은 경감될 수 있을 것으로 분석되었다.

주제어 역진성, 탄소가격정책, EEIO, 분배적 함의, 사회경제적집단

Abstract

A cap and trade program accounting for 60 percent of total national greenhouse gas emissions was launched in South Korea in 2015. Academic literature expects that the implementation of such a policy is likely to adversely impact income distribution among various socioeconomic groups in developed countries. South Korea is challenged by equity issues, as well circumstances, the distributional implications of carbon pricing policies need to be examined and reflected in the design of the program prior to implementation in order not to exacerbate social inequity. Using environmentally

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extended input output analysis together with household expenditure data, this study finds that a carbon pricing policy will be regressive in South Korea, but the extent depends on whether relative burdens of a carbon pricing policy are measured based on current incomes or proxies of permanent incomes. Along with poor households, this paper finds that elderly and urban households will be more adversely impacted in South Korea. These burdens can be relieved if a small fraction of the revenue is redistributed to households.

❙ Keywords ❙ Regressivity, Carbon Pricing Policies, EEIO, Equity Implications, Socioeconomic Groups

Ⅰ. Introduction

South Korea was the world's fifteenth largest economy in both 2011 and 2012, and it was the seventh largest CO_2 emitting country as of 2011, primarily due to its heavy dependence on manufacturing industries (World Bank, n.d.). Emissions have increased by 156.3 percent from 1990 to 2011; this is the fastest growth among OECD member countries (International Energy Agency [IEA], 2013a). In addition, Korean energy self-sufficiency, even taking nuclear power into account, was only 18.04 percent in 2011[1]. At the same time, renewable energy contributes to only 0.7 percent of the Total Primary Energy Supply (TPES), while it contributed an average of 8.1 percent of TPES in OECD countries (IEA, 2013b).

In order to respond to these multifaceted challenges, on August 15, 2008, the South Korean government introduced Low Carbon Green Growth (LCGG) as a new vision for national development for the next 50 years. LCGG pursues sustainable economic growth without adversely impacting the environment by promoting renewable energy technologies and enhancing energy efficiency (Presidential Committee on Green Growth, 2009). In pursuit of the LCGG framework, the government will reduce national greenhouse gas (GHG) emissions by 30 percent compared to business-as-usual (BAU) levels by 2020, which is equivalent to a 4 percent reduction from 2005 levels. To achieve this target, the cap-and-trade program that covers about 60 percent of the national GHG emissions began on January 1, 2015 (IEA, 2012b).

1) This is the ratio of national primary energy output to consumption of primary energy.

While the efficiency of carbon pricing policies has attracted the attention of policymakers across the world, the equity implications of these programs also need our attention. The program affects income distribution, as the costs of mitigation are passed on to consumers in the form of increased prices of non-energy goods as well as energy itself (Fullerton, 2008; Garnaut, 2008). A great deal of literature has found that the impact of the program is likely to be regressive in developed countries. This is attributed to the specific energy consumption patterns observed among lower income households, which spend a larger fraction of their income on energy goods (Grainger and Kolstad, 2010; Hassett et al., 2009; Rausch et al., 2011)[2].

In addition to income levels, the burden of a carbon pricing policy varies depending on demographic factors such as ethnicity/race, location and the age of heads of household. Feng et al. (2010) found that rural households in the UK paid a relatively larger share of their income for a CO_2 or GHG tax because of relatively greater energy consumption for heating and transportation. Rausch et al. (2011) found that households with an African American head bear a relatively heavier burden than other racial groups due to different spending patterns, including a heavier reliance on electricity and natural gas. Their results also show that regions such as the North and South Central parts of the United States, where power plants use more fossil fuels to generate electricity than nuclear or hydropower, will bear heavier burdens than other regions.

Furthermore, a carbon pricing policy is likely to more adversely affect elderly households where energy expenditures are a greater share of income. Dinan (2012) pointed out that elderly households would bear a greater burden in the US if a carbon tax were imposed. Although public transfers such as Social Security, Social Security Income and Supplemental Nutrition Action Payments compensate part of the burdens, they do not cover the entire tax burden. The author argued that a carbon tax would exacerbate distributional inequity without appropriate countermeasures.

2) Since the burden of these programs vary according to energy consumption patterns, which is very different in developing countries, the carbon pricing policies is likely to be progressive in developing countries (Brenner et al., 2011; Yusuf and Resosudarmo, 2007). This means that the implementation of these market-based mitigation approaches can also relieve the social inequity issues in those countries.

However, revenue recycling can relieve the burdens on elderly-headed-households. Blonz et al. (2011) showed that the burden on households where heads are aged 65 or older was relieved through revenue recycling, and elderly households in the bottom quintile would be better off under three cap-and-trade scenarios.

In South Korea, the Gini coefficient for income inequality has increased by almost 17 percent to 0.31 from 1990 to 2012. It peaked in 2009 and then has slightly declined. Furthermore, elderly poverty rate (the poverty rate of the population aged 65 and over) has increased from 44.6% in 2007 to 47.2% in 2010 while rates have decreased from 15.1% to 12.8% on average for the same period in OECD countries (OECD, 2013). In addition, South Korea is an unprecedentedly rapidly aging country. The elderly population was about 3 percent of the total in the 1970s, but it increased to 11.8 percent in 2012 (Lee and Phillips, 2011). According to Korean Statistical Information Service (2012), the proportion of the elderly will exceed half of the total national population by 2048. Under the circumstances, the comprehensive distributional implications of a carbon pricing policy on various socioeconomic groups in South Korea are an important issue to be studied.

Several studies have found that carbon pricing policies would also be regressive in South Korea. However, the scope of these studies is limited to how burdens are distributed among households with different income levels (Kang et al., 2011; Kim, 2009; Shin et al., 2010). In addition, Noh (2009) and Kim and Jeong (2011) explored the distribution of the burden across regions and found that cap-and-trade would exacerbate regional inequity. They argued that the Seoul Capital Area[3)] would bear fewer burdens in spite of greater energy consumption since this area employs electricity that is mainly generated elsewhere.

These studies focused on only one aspect of equity implications, such as income or region. However, it is necessary to comprehensively assess the equity implications of cap-and-trade since cap-and-trade has distributional implications along different dimensions: intergenerational equity, international equity,

3) Seoul Capital Area is the metropolitan area of Seoul, which covers three different administrative districts including Seoul, Incheon and Gyeonggi-do. About half of the total national population lives in this area.

interregional equity, intersectoral equity and interpersonal equity (Kverndokk and Rose, 2008). A few recent studies in other countries have explored the comprehensive or multifaceted interpersonal equity issues of carbon pricing policies. Rausch et al. (2011) evaluated how the burdens of a carbon tax of $20 per ton of CO_2e would be distributed according to regions, ethnicities or races, and income levels in the US. Mathur and Morris (2014) investigated how a carbon tax of $15 per ton of CO_2 would be distributed among households with different income and in different regions of the United States

In order to extend the findings of previous studies, this study aims to evaluate the equity implications of a carbon tax along different dimensions: (1) between different income levels, (2) according to the age of the head of household, and (3) between urban and rural households. The ratio of increased expenditure to disposable income[4)] is compared by household group. This study assesses how revenue recycling relieves the disproportionate distribution of burdens of the implementation. In addition, to avoid the bias of current income, the distribution of burdens among different income households is analyzed using proxies for permanent income. This study conducts meaningful and novel research since the equity implications of a carbon pricing policy have yet not been comprehensively analyzed, and the distribution of burdens has not been assessed using different measurement units in South Korea.

This paper is organized as follows. The methodology section briefly explains input-output analysis along with the datasets that are used. The results section consists of three subsections. 3.1 discusses the distribution of the burdens of a carbon tax among different socioeconomic groups, 3.2 explores the effects of the lump-sum transfer of the tax revenue on distribution, and 3.3 compares the results using proxies for permanent income. The discussion section further explores the results, and the conclusions and policy implications section presents policy implications for the development of cap-and-trade in South Korea based on the results and discussion.

4) Disposable income refers the amount of total income minus non-consumption expenditure including taxes, pensions and etc.

Ⅱ. Methodology: Input-output Analysis with Extensions

1. Data

To assess the equity impacts of a carbon tax, this study conducts Input-Output (IO) analysis. Three datasets are used: (1) IO table of producer prices in 2009[5] (Bank of Korea, n.d.), (2) Household Survey Data (HSD) in 2009[6] (Statistics Korea, n.d.) and (3) table of Energy Balance (Korea Energy Economics Institute [KEEI], 2012). This study reorganizes the original IO table and HSD and constructs the 35-industry-sectors-by-35-industry-sector IO table and three matrixes that describe the expenditure profiles of different socioeconomic groups (expenditures on 26 consumer goods by 10 different income groups, 5 different age groups and 2 different location groups). 35 industries and 26 expenditure categories can be identified in Figure A.1 and Figure A.2.

Figure 1 shows a schematic flow of South Korean economy of 2009. In 2009, domestic industries produced the total output of USD 2,175 billion. The total supply, including imports of USD 401 billion, met the total demand consisting of final demand of USD 804 billion, the intermediate demand of 1,354 billion USD and exports of USD 419 billion. In addition, value-added of USD 821 billion was created in 2009. When the Korean economy is grouped into five aggregated sectors, (primary, manufacturing, utilities and construction, service, and miscellaneous), the

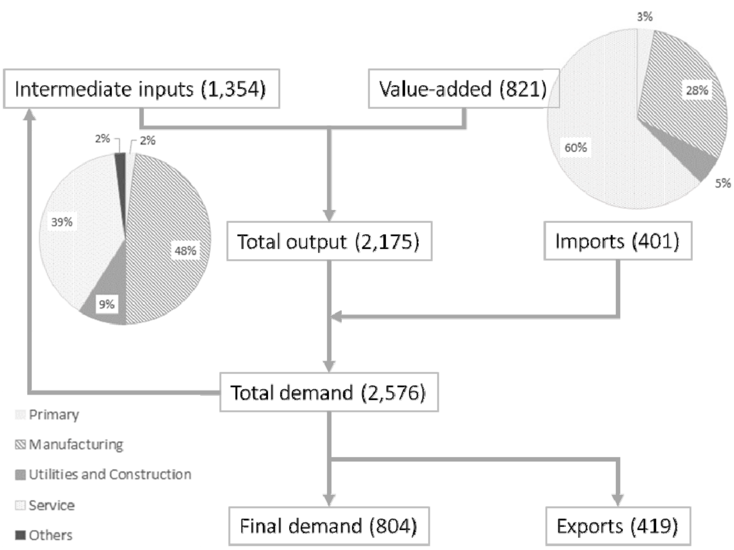
5) The Bank of Korea (BOK) constructs an I-O table. This study uses the most disaggregated I-O table that was provided from the BOK. The most aggregated I-O table has 28 industries. This study disaggregates the oil and coal sector and the electricity, gas and water sector by fuel type, but the primary metal product sector and the metal product sector are integrated into one sector. Finally, this study has built a 35-industry-sectors-by-35-industry-sector I-O table.

6) Similar to the Consumer Expenditure Survey of the United States, every quarter the HSD collects detailed information on demography, income, and expenditure in about 8,700-8,800 households nationwide. The raw data of 2009 HSD has information for 10,881 households. However, the HSD does not include farming, fishing and forestry households because the data for these households are separately collected. Specifically, HSD surveys the expenditure of each sample household on 394 goods and services. HSD summarizes households' expenditure on twelve major categories of expenditures: 1) food, 2) alcohol and tobacco, 3) apparel, 4) housing, 5) household furnishing and equipment, 6) healthcare, 7) transportation, 8) communication, 9) entertainment, 10) education, 11) restaurant and lodging, 12) miscellaneous. This study disaggregates housing and transportation categories by fuel types to more exactly estimate increases in consumer prices induced by a carbon tax. Therefore, this study reorganized HSD to household expenditures on twenty six goods and services.

manufacturing sector contributed the most to output (48%); the service sector contributed the most to the value-added (60%).

Table 1 summarizes the average income and expenditure profile by different household type. In 2009, average monthly household income was USD 2,368, and average consumption expenditure was about 62 percent of gross income. Household expenditures by category show that households, on average, spent the most on food (14 percent of the consumption expenditure) and least on alcohol and tobacco (1 percent). Expenditures on transportation, restaurant and lodging, education, and housing were also large. The expenditure profile varies depending upon household characteristics. For example, the first decile household expenditure pattern is quite different. Expenditures on food and housing contributed to 23% and 20% of the total consumption expenditure, respectively. Therefore, the burden on households induced by a carbon tax varies depending upon existing expenditure patterns.

Figure 1 Flow of South Korean Economy in 2009



Note: Numbers within parentheses are measured in billion USD. The two pie graphs present the contribution of each sector to total output (left) and value-added (right).

Table 1 Snapshot of expenditure patterns by characteristics of household

Unit of Measurement: USD

	House holds	Low-income	High-income	Elderly	Young	Urban	Rural
Gross income	2,368	306	6,006	694	2,322	2,447	2,060
Consumption expenditure	1,479	476	2,830	516	1,439	1,537	1,252
Food	206	108	301	119	164	212	181
Alcohol & tobacco	20	10	22	6	22	20	21
Apparel	93	18	214	17	107	99	71
Housing	163	94	226	118	169	168	142
Household furnishings & equipment	54	17	129	29	65	56	47
Healthcare	98	56	158	90	96	100	91
Transportation	188	37	438	30	193	192	174
Communication	92	29	130	21	97	94	82
Entertainment	74	19	166	19	87	78	61
Education	171	24	393	10	61	185	116
Restaurant and lodging	189	33	361	33	205	198	151
Miscellaneous	131	29	291	25	174	135	114

Note: 'Low-income' means the 1st income decile households while 'High-income' refers to the 10th decile. 'Elderly' means households where heads are aged 75 and over. In contrast, 'Young' heads are younger than 35.

2. Methodology

This study analyzes the distributional impacts of an illustrative carbon price of \$15 per ton of CO_2[7], and additionally assesses how the distribution of the burdens would be different if the revenue were recycled through a lump-sum transfer to households on an equal per capita basis or an equal per household basis. To achieve these research objectives, this study estimates sectoral CO_2 emissions by constructing an environmentally extended IO[8] table (EEIO) rather than using CO_2 intensities

7) Since the Emissions Trading Scheme (ETS) began, the actual price level has been around \$10 per ton of CO_2 according to Korea Exchange. Although the carbon tax level is supposed to be \$15 per ton of CO_2, the distributional implications will remain valid due to the linear nature of the IO.

8) This particular IO table is called a hybrid IO table since the elements of this IO table are presented in different units of measurement. In particular, elements in energy sectors are expressed in physical quantity units such as ton, barrel or TOE while the unit of measurement for elements in non-energy sectors remains in monetary values

estimated by a previous study (Grainger and Kolstad, 2010).

First, 13 energy sectors are specified: anthracite, bituminous coal, LNG, gasoline, kerosene, diesel, heavy oil, jet oil, LPG, naphtha, other petroleum products, hydropower and nuclear power[9]. Second, domestic and imported energy prices are derived, comparing the IO table and the energy balance table[10]. Third, total primary energy consumptions (TPECs) by sector and fuel are estimated by dividing the elements of energy sectors of the IO table, which are originally presented in a monetary unit,[11] by the energy prices. Once sectoral TPECs are estimated, the amount of energy used as raw materials such as naphtha and other petroleum products is subtracted to avoid overstating CO_2 emissions. In addition, since hydropower and nuclear power are considered zero-emission energy sources, the consumption of hydropower and nuclear power is subtracted. Sectoral emissions are calculated by multiplying sectoral TPECs by fuel and IPCC (Intergovernmental Panel on Climate Change) emission factors by fuel (Korea Energy Management Corporation, n.d.). With sectoral CO_2 emissions estimated, the model is ready for the analysis of distributional impacts of a carbon tax (See Figure 2).

In the model, if \$15 per ton of CO_2 were imposed, it is supposed that the burden would be entirely passed on to consumers although the legal incidence falls on industries. The model does not allow input substitution in industries and behavioral changes of consumers according to changes in producer or consumer prices induced by the implementation. In other words, demands for commodities are inelastic to the price change, and the production of every industry is based on a fixed proportion.

Although how burdens of the tax are passed on to consumers is explained in previous studies (Hassett et al., 2009), this study summarizes equations to facilitate readability. The input structure of an IO table can be expressed as a set of linear

such as KRW or USD (Miller and Blair, 2009).

9) To make energy sectors in the IO table better correspond to the energy balance table, this study specifies 13 energy sectors.

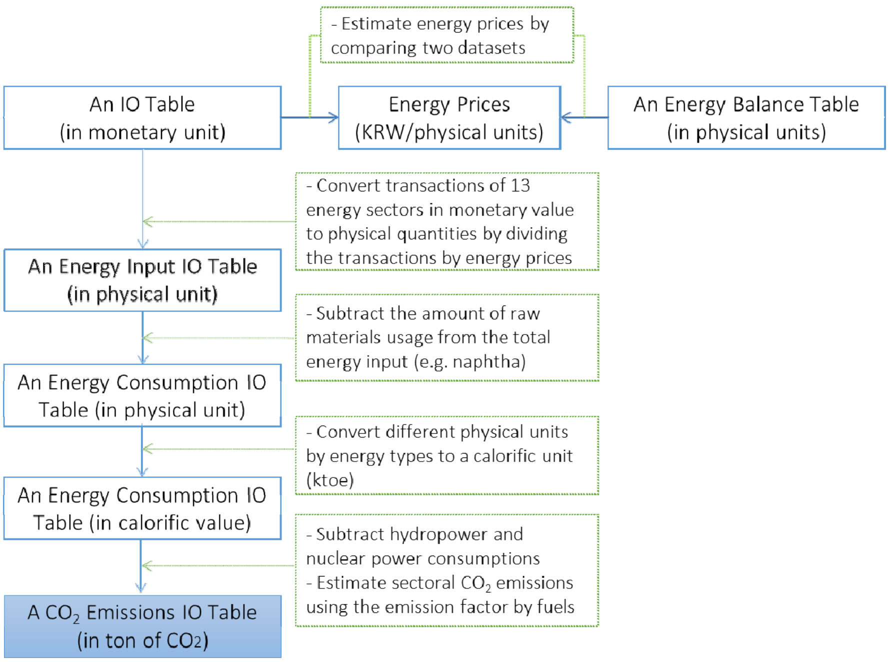
10) It should be noted that different industries are assumed to purchase the same energy at the same prices.

11) In reality, energy price might vary by sector but it is assumed to be the same across sectors in this study.

equations, which illustrates how the output ($x_i p_i$) is produced using intermediate inputs ($\sum_{i=1}^{n} x_{ij} \times p_i$) and value-added ($v_i$).

$$
\begin{aligned}
x_{11}p_1 + x_{21}p_2 + \cdots + x_{n1}p_n + v_1 &= x_1 p_1 \\
x_{12}p_1 + x_{22}p_2 + \cdots + x_{n2}p_n + v_2 &= x_2 p_2 \\
&\vdots \\
x_{1n}p_1 + x_{2n}p_2 + \cdots + x_{nn}p_n + v_n &= x_n p_n
\end{aligned}
\tag{1}
$$

Figure 2 Procedures to construct a CO_2 IO table



Source: modified figure in (Kim, 2006)

This set can be expressed again using input coefficients ($a_{ij} = x_{ij}/x_j$), which explains how much input from sector i is required to produce a unit of output in sector j. Then, the set of linear equations can be expressed in matrix form as follows.

The equation illustrates that a 35X1 producer price vector (P_I) is a product of Leontief inverse ($(I-A')^{-1}$) and a 35X1 value-added coefficient vector (A^V). Here, A is a 35X35 matrix where elements are input coffcients.

$$P_I = (I - A')^{-1}A^V \tag{2}$$

In this model, a carbon tax of \$15 ($Cprice$) is simulated as taxes (t_i) are imposed in proportion to the consumption of nine[12)] fossil fuels ($CO_2\ Emissions_{ff}$) in each sector. The tax rates are equivalent to the ratio of the revenue collected by each sector (CO_2Rev_i) to the total intermediate inputs.

$$CO_2Rev_i = \Sigma_{ff} CO_2\ Emissions_{ff} \times Cprice \tag{3}$$

$$\mathrm{t}_i = CO_2Rev_i / \Sigma_{j=1}^{n} x_{ij} \tag{4}$$

With the carbon tax, the vector of producer prices is expressed as follows. B is a 35x35 matrix, and its elements are $(1+t_j)a_{ij}$.

$$P_I = (I - B')^{-1}A^V \tag{5}$$

The change in producer prices impacts consumer prices. In order to assess the effects on consumer prices, the matrix that links two different data sets, the Z matrix, must be built. The Z matrix is a matrix where elements (Z_{ij}) are coefficients that illustrate how each consumer good consists of different outputs produced by different industry sectors.[13)] Through this Z matrix, the increase in producer prices

12) Four energy sources including naphtha, other petroleum products, hydropower and nuclear power are excluded when CO_2 emissions are calculated.

13) The Z matrix illustrates how producer goods are converted to consumer goods at a fixed proportion (Ballard et al., 1985). Here, the Z matrix is a 35X26 matrix (35 industries and 26 consumer good categories). This matrix can be constructed by aggregating the original IO table into the 35X26 matrix. For rows, 403 sectors are integrated

can be conveyed to consumer prices. The 26X1 consumer price vector (P_c) is a product of the Z matrix and P_I.

$$P_C = Z' P_I \tag{6}$$

The burden resulting from a carbon tax is measured by the ratio of the increase in average monthly expenditure to the average monthly disposable income of households. However, a carbon pricing policy is found to be more regressive in some literature when it is measured on the current income basis rather than on the lifetime income basis (Grainger and Kolstad, 2010; Mathur and Morris, 2014; Poterba, 1991). Current income is a volatile measure, especially for poor households. For example, some households may be temporarily poor because family members are getting higher education, or they are suffering from short-term layoffs (Grainger and Kolstad, 2010). In order to avoid overstating the regressivity, some studies recommend using permanent income to avoid this current income bias. Generally, current expenditure is used as a proxy based on the permanent income hypothesis[14)] (Grainger and Kolstad, 2010; Mathur and Morris, 2014; Poterba, 1991). Alternatively, Rausch et al. (2011) used two proxies for lifetime income: (1) the total income of households where the head is between 40 and 60 years of age[15)] and (2) education levels of households. To discuss how distributional implications vary depending upon the influence of the unit of measurement, this study estimates the distribution of burdens between different income households using three proxies for permanent income.

to 35 industries, but, for columns, 403 sectors are integrated to 25 consumer good categories.

14) According to Friedman (1957), the permanent income hypothesis states that the expenditure level of a consumer has been dependent upon the permanent income which he or she expects to earn for the long term or in a lifetime.

15) Rausch et al. (2011) stated that it is a proper proxy for permanent income because the limitation of age of the heads to 40-60 can "exclude young households who are making consumption decisions in anticipation of higher future income and elderly households who may be drawing down savings in retirement" (p. S26).

Ⅲ. Results

A carbon price of $15 per ton of CO_2 increases producer prices on average by 1.12 percent (See Figure A.1). In turn, increased producer prices impact consumer prices. Increased consumer prices induce increases in households' expenditures, and these increases vary according to the expenditure pattern of each group.

1. Distribution of the carbon tax burdens by income level, age of households' head and location

1) Distribution of the carbon tax burdens by income level

First, HSD has been classified into ten income groups according to the total income/gross income. The first decile refers to households with the lowest income, and the tenth decile is the wealthiest group. The burden on the lowest income group is about three times as much as that on the top income group.

Table 2 presents the composition of burdens in each income group. The total burden consists of a direct burden (Direct) and an indirect burden (Indirect). A direct burden refers to the additional energy expenditures including heating-energy expenditure (Direct_H) and transportation-energy expenditure (Direct T)[16]. The distribution of Direct_H is highly regressive – the average heating burden on the lowest income households is 0.17 percent more than that on the wealthiest households. This result is caused by the different expenditure patterns between wealthy households and poor households – the first decile group (9.31 percent) spends a larger fraction of the total burden on fuels than the tenth decile households (3.13 percent). In contrast, the distribution of Direct_T does not show a big difference between low-income households (2.44 percent of the total burden) and wealthy households (4.92 percent). The indirect burden refers to the increased expenditures on non-energy goods induced by the carbon tax, and it is less

16) The expenditure on heating energy (Direct_H) includes the expenditure on the following fuels: other fuels, electricity, kerosene, diesel, LPG, briquette, multi-housing heating and city gas heating energy. The expenditure on transportation energy (Direct_T) includes the expenditure on diesel, LPG, gasoline and other fuels (See Figure 3).

regressive than the direct burdens.

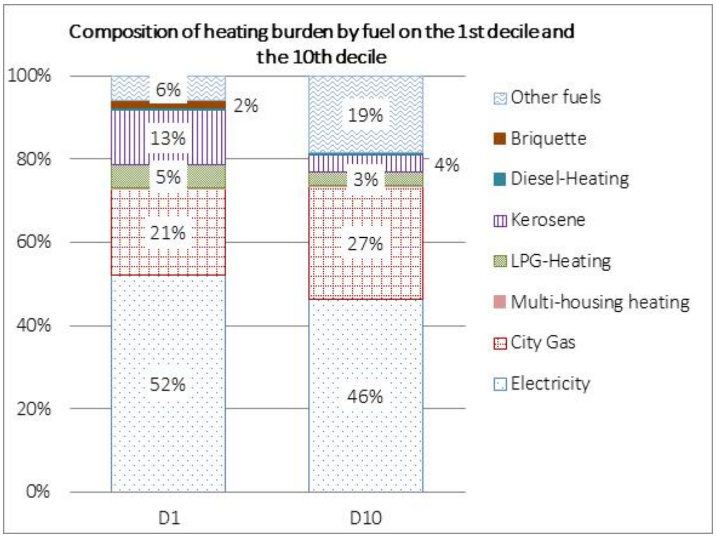
Table 2 Distribution of burden according to household income

Deciles	Direct			Indirect	Total
		Direct__H	Direct__T		
D1	0.24%	0.19%	0.05%	1.80%	2.04%
D2	0.12%	0.09%	0.03%	1.03%	1.16%
D3	0.11%	0.07%	0.04%	0.86%	0.96%
D4	0.10%	0.06%	0.04%	0.80%	0.90%
D5	0.09%	0.05%	0.05%	0.75%	0.84%
D6	0.09%	0.04%	0.04%	0.70%	0.78%
D7	0.08%	0.04%	0.04%	0.67%	0.75%
D8	0.07%	0.03%	0.04%	0.65%	0.73%
D9	0.07%	0.03%	0.04%	0.62%	0.69%
D10	0.06%	0.02%	0.03%	0.56%	0.61%

Note: The table reports the average ratio of carbon tax burdens to disposable income. D1 means the poorest decile and D10 refers to the wealthiest decile. Column heads refer to specific burdens (Direct: energy burden, Direct_H: heating-energy burden, Direct_T: transportation-energy burden, and Indirect: non-energy burden)

Due to the different energy expenditure patterns of each decile, increases in each type of energy expenditure differently contribute to the direct heating burden (See Figure 3). The electricity burden contributes to half of Direct_H in the poorest decile, which is six percentage points lower in the top decile. In addition, increases in expenditures on kerosene, LPG and briquettes contribute to a larger fraction of the heating burden on poor households – about 20 percent in the first decile and about 7 percent in the wealthiest decile.

Figure 3 Composition of heating burden on the 1st and 10th deciles by fuel



2) Distribution of the carbon tax burdens by age of the head of household

This study has sorted households into five groups according to the age of the head of household: under 35, 35-49 group, 50-64 group, 65-74 group, and75+ group[17].

Table 3 presents how carbon tax burdens are distributed among households according to the age of the head of household. The elderly group bears a larger burden than younger groups since elderly households are relatively poorer than other groups – the average income of the 75+ group is only about a quarter of that of the under-35 group (See Table 1). Direct_H on the 75+ group is three times as much as that on the under-35 group. In contrast, Direct_T is larger in the younger groups than in the 75+ group.

17) South Korean statistics classifies people who are aged 65 and older into the elderly. The OECD statistics (2013) divided the elderly into two groups: 65-74 group and 75+ group. Following classifications of previous statistics, this study classifies elderly households into two groups. Except the elderly, other age groups are divided at 15-year intervals.

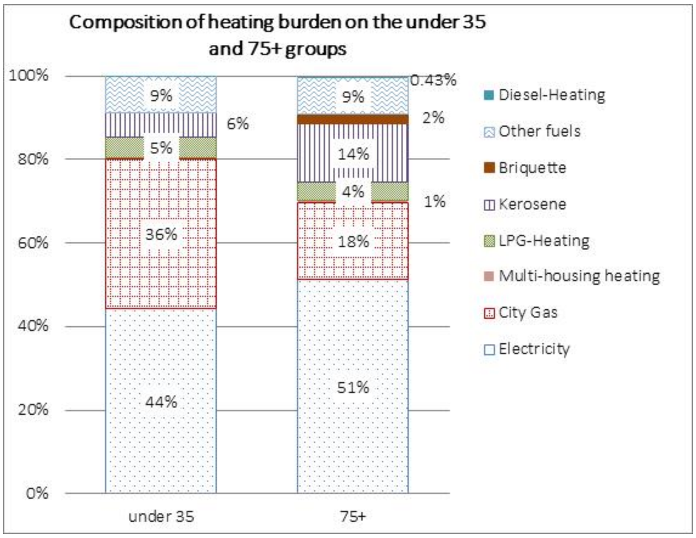
Table 3 Distribution of burden according to the age of head

Age group	Direct			Indirect	Total
		Direct_H	Direct_T		
Under 35	0.08%	0.03%	0.04%	0.68%	0.76%
35-49	0.08%	0.04%	0.04%	0.70%	0.78%
50-64	0.08%	0.04%	0.04%	0.64%	0.72%
65-74	0.10%	0.07%	0.03%	0.75%	0.85%
75+	0.11%	0.09%	0.01%	0.83%	0.94%

Note: The table presents the ratio of the burden to disposable income according to the age of the head of household.

Figure 4 shows that the composition of the heating burden by fuel in the 75 + group is similar to that in the poorest deciles in Figure 3. The increase in electricity expenditures contributes to the largest part of Direct_H in elderly households. Increases in the fuels that are more expensive per calorie, such as kerosene and briquettes, contribute more to the heating burden in elderly households.

Figure 4 Composition of heating burden on the under 35 and 75+ groups



3) Distribution of the carbon tax burdens between urban and rural households

HSD has been sorted into urban and rural households, and households in towns (Eup) and townships (Myeon)[18] are classified into rural households. The burdens on these two groups did not show a significant difference (See Table 4).

Table 4 Distribution of burdens between urban and rural households

	S1					S1-R1	S1-R2
	Direct			Indirect	Total		
		Direct_H	Direct_T				
Urban	0.08%	0.04%	0.04%	0.69%	0.77%	0.44%	0.44%
Rural	0.09%	0.04%	0.05%	0.66%	0.75%	0.39%	0.35%

Note: The table shows the ratio of the increased expenditure due to carbon pricing policy to disposable income in urban and rural households.

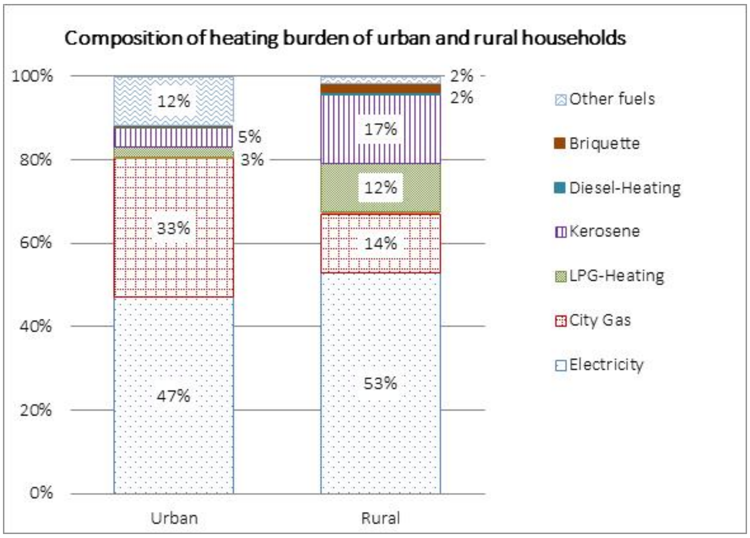
Although the difference between the burdens on urban and rural households is small (0.02%), it increases in a linear fashion according to carbon price levels; therefore, it is still necessary to review the difference. Although the direct burden is slightly heavier on rural households, the heavier indirect burden on urban households leads to this result. The consumption pattern causes the slightly heavier direct burden on rural households – energy expenditure by rural households is on average 2.16 percent higher than that by the urban households (Kim, 2014).

In rural households, about 53 percent of increased heating expenses is attributed to increased electricity expenditures. The contribution of the increase in electricity expenditure is also high in urban households (47 percent). The composition of heating burden by fuel is quite different between urban and rural areas. While increased city gas expenses contribute to more than one third of the increased

18) The South Korean administrative divisions are as follows: cities (Si), counties (Gun), townships neighborhoods (Dong), townships (Myeon), and town (Eup). According to Article 3 of Local Autonomy Act, Dongs shall be established in urban areas (Sis); Eups/Myeons shall be placed in other areas. According to Article 7, the population of Eup shall have a population of not less than 20,000; however, an area may become Eup if it meets following conditions: 1) the office of Gun is located within the area; 2) no Eup exists in the combined form of urban and rural areas

heating expenditures in urban households, it contributes to only 14 percent in rural households (See Figure 5).

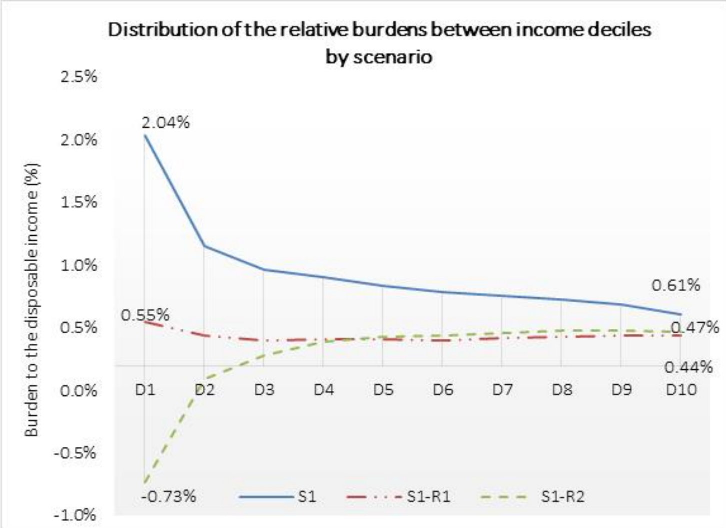
Figure 5 Composition of heating burden of urban and rural households by fuel



2. Effects of lump sum transfer of the proceeds on the distribution

Figure 6 shows how the incidence of the policy changes depending upon revenue recycling measures. Overall, the burden on every decile decreases with the revenue recycling measures. However, the distributional implications are completely different. When a quarter of the proceeds is transferred to the households in the form of equal per capita dividends (S1-R1), the impact is heavier in the first decile, but the burdens are distributed neutrally across other groups from D2 to D10. Under the S1-R2 scenario – where a quarter of the revenue is redistributed to households on the equal per household basis, it became progressive. Scenario S1-R2 is better for the poor deciles than scenario S1-R1. In addition, they can earn additional income rather than paying additional expenditures.

Figure 6 Distribution of the relative burdens between income deciles by scenarios

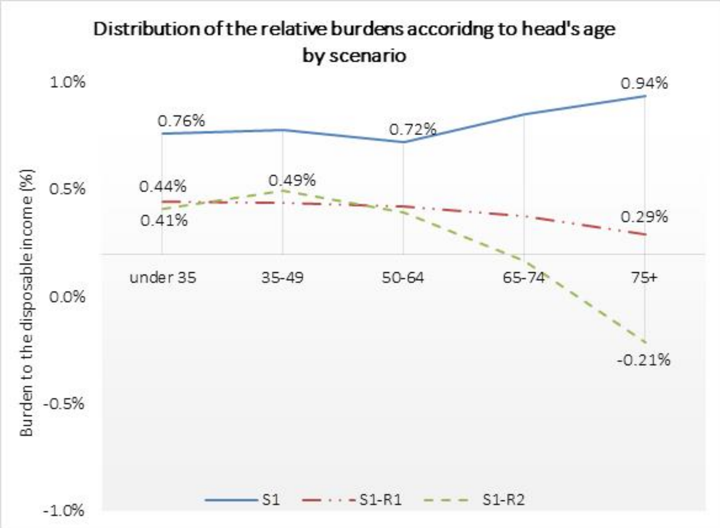


Note: S1: $15 charge on ton of CO_2 and no recycling, S1-R1: 25 percent of the revenue is recycled on the equal per capita dividend basis, and S1-R2: 25 percent of the revenue is redistributed to households on the equal per household dividend basis.

Figure 7 implies that the burden on elderly households effectively declines as a result of revenue recycling measures. Both in scenario S1-R1 and S1-R2, the burden on elderly households is less than that on households with a younger head. The redistribution of the proceeds in the form of equal per household dividends benefits the elderly group more than the equal per capita basis redistribution. In scenario S1-R2, the burden on the eldest group is -0.21 percent, which means that this group benefits from the implementation. In scenario S1-R1, the burden on the 75+ group is relatively lighter compared to that on other groups. In S1-R1, the carbon tax incidence is neutral in other age groups except the eldest group.

Although the difference between the burdens on urban and rural households is small, urban households bear relatively heavier burdens than rural households. In revenue recycling scenarios, the burdens on rural households declined relatively more than those on urban households (See Table 4).

Figure 7 Distribution of the relative burdens according to head's age by scenario



3. The incidence of the burdens based on proxies for permanent income

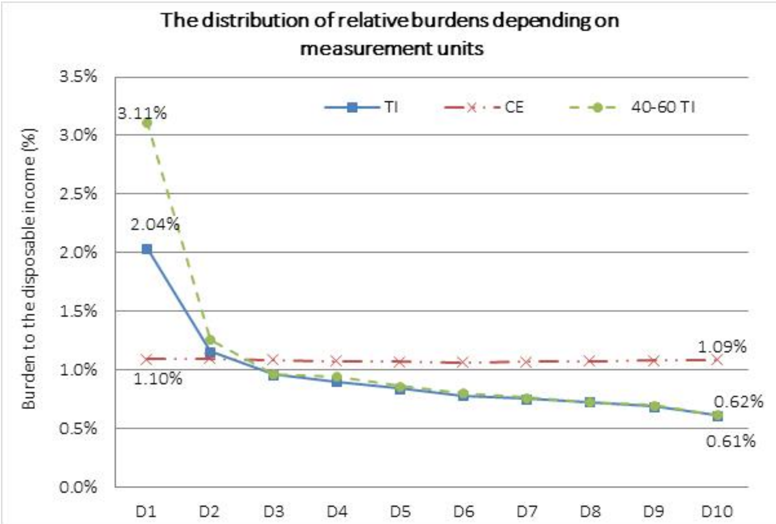
Finally, this study estimates and compares the impact of the tax using several proxies of permanent incomes: (1) current expenditure, (2) the total income of households with heads between 40 and 60, and (3) education levels of households.

Figure 8 shows that the incidence of the carbon tax is neutral when it is measured by current consumption expenditures. However, when it is measured by the total income of households in which the head is aged 40 to 60 (40-60 TI)[19], the regressivity is clearer. The relative burden on the D1 is about 3.3 times as much as that on the D10 when it is measured by the total income (TI), but it is about five times when measured by 40-60 TI.

Based on the assumption that lifetime income is correlated with education levels, the sample of households is arranged according to educational attainment. Figure 9 shows that the heaviest burden falls on households where a head has not had any education opportunities (NS) while households where a head had higher education (such as doctoral and master's degrees) bear fewer burdens.

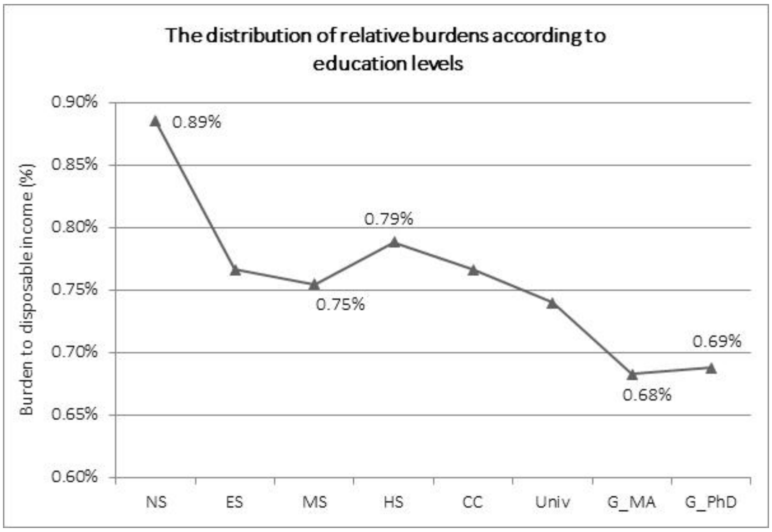
19) Among the total households, the households where the head is aged 40 to 60 are selected as Rausch et al. (2011) did.

Figure 8 The distribution of burdens among ten different income groups



Note: The blue solid line presents the relative burdens on different income groups measured using total income. The green dashed line shows the relative burdens on income deciles measured based on total income of households where heads are aged 40 to 60. The red dash-dot line presents the relative burdens on different income groups on the current expenditure basis.

Figure 9 The distribution of relative burdens according to education levels



Note: Each abbreviation presents the final degree held by the head of households (NS: No School, ES: Elementary School, MS: Middle School; HS: High School, CC: Community College, Univ: University, G_Ma: Master's Degree, and G_PhD: Doctoral Degree)

Ⅳ. Discussion

This study conducted IO analysis to explore the distributional implications of a carbon pricing policy among different socioeconomic groups in South Korea and examine how effectively revenue recycling relieves the regressivity of the tax. Similar to the findings of Hasset et al. (2009), Grainger and Kolstad (2010), Mathur and Moriss (2014), Shin et al. (2010) and Kang et al. (2011), the incidence of a $15 carbon tax is clearly regressive in Korea when it is measured on the basis of current income (ratio of additional expenditures to gross income). The results also reveal that the burdens are relatively heavier in elderly households; this was anticipated by Dinan (2012) who had pointed out that the burden of a cap-and-trade can be heavier on elderly households as well as on low-income households in the US[20). In contrast to the findings of Feng et al. (2010), urban households bear a slightly larger burden than rural households in Korea. This might be because the share of consumption expenditure to total income is about 2 percent higher in urban households (See Table 1). In addition, the result can be attributed to HSD's omission of information on farming and fishing households.

Previous studies attribute the regressivity of carbon pricing policies to the tendency of low-income households to spend a larger share of their income on energy than the wealthier do. In this study, disproportionate increases in expenditures are observed in non-energy goods as well as in energy goods since the carbon tax increases the prices of both energy and non-energy goods[21). Interestingly, transportation energy burdens are heavier in households with younger

20) Similar to Grainger and Kolstad (2010), this study also measured how relative burdens are distributed among different socioeconomic groups using the ratio of per capita increased expenditure to the average monthly equivalent income (which was modified using OECD equivalence scale). In scenario S1, the burdens ranges from 1.80% in the first decile to 0.57% in the 10th decile when measured by the ratio of per capita burden to the average monthly disposable income per adult equivalent. Although the detailed results are not provided here, the distributional implications of this study remain valid even when measured by equivalent income measures.

21) The briquette price is likely to remain constant regardless of carbon price levels. The government has kept the briquette price low to support low-income households and stabilize consumer prices. If the briquette price is supposed to be the same in the model, the burden on low-income households (the first and the second deciles) would decline by 0.01%; and the burdens on other groups remain constant.

heads. This is because the younger use cars more frequently and over longer distances due to trips to work and for child care or family recreational use (Ministry of Transport, 2009).

Besides disproportionate distributions between socioeconomic groups, the results show that dirtier, more expensive, or less convenient fuels account for a larger fraction of the increased heating energy expenditure in the poor, the elderly, and rural households due to different energy expenditure patterns. In Korea, the poor are more reliant on electricity as a heating energy source. Due to cheap electricity prices[22], they often choose to heat a small area with electric heating appliances such as an electric heating pad rather than heat the whole house with electric heating systems or city gas heating systems (Song, 2012). In addition, poor households are often located in hilly or remote areas, where the city gas service is not accessible. As a result, they are dependent on more expensive (based on net heating-value) and dirtier fuels[23].

The more adversely affected groups can be effectively protected or become a beneficiary by recycling a small proportion of the proceeds. The equal per household dividend (S1-R2) is found to be more favorable to the poor, the elderly, and the rural households since these groups will receive a relatively larger support compared to their family size[24].

Similar to findings of Grainger and Kolstad (2010), Mathur and Morris (2014), and Poterba (1991), when the burden is measured on a current expenditure basis, the incidence of carbon tax becomes neutral. However, when it is measured using other proxies including the total income of households where heads are aged 40 to 60 years and education levels, the regressivity remains or becomes stronger[25]. This

22) The residential electricity price is USD 88.643/MWh in 2011. It is half of the average residential electricity price of OECD countries (USD 174.078/MWh) (International Energy Agency, 2012).

23) Using heat-values (International Energy Agency, 2012) and fuel prices by fuel in South Korea in 2009 (KEEI, 2012), energy prices per calorie were calculated. City gas (0.36/Mcal) is the cheapest fuel followed by briquettes (2.68/Mcal), kerosene (10.45/Mcal), propane (12.77 /Mcal), diesel (14.73 /Mcal) and electricity ($89.44/Mcal). Although the heating value is as low as 4,400~4,599 kcal/kg for briquettes, the price per generated heat is low due to the government subsidy to protect the domestic coal industries.

24) The average number of family members is 1.97 persons in the 1st decile and 3.55 persons in the 10th decile, respectively.

result implies that an analysis using a single proxy for permanent income may provide a biased perspective on distributional implications of a policy.

Ⅴ. Conclusions and Policy Implications

This study found that the carbon tax can exacerbate inequity through the disproportionate distribution of the burdens among socioeconomic groups, using environmentally extended IO analysis with a household expenditure dataset. In South Korea, distribution between the poor and the wealthy or the young and the elderly or urban and rural households has been challenging the development and coherence of this society. These results imply that a cap-and-trade can aggravate distributional equity unless it is matched by appropriate countermeasures.

Although this study analyzed the impacts of an illustrative carbon tax of $15 rather than the actual Korean emission trading scheme, the findings can encourage Korean policymakers to consider and take into account the equity implications of cap-and-trade. According to the Korean ETS Act (2014), most allowances are allocated to the participants for free in the first three commitment periods. Although the participants do not need to buy the allowances, the mitigation costs of the program will be passed on to consumers, and the burdens are disproportionately distributed among various socioeconomic groups as this study found. Therefore, distributional implications need to be debated and considered in this program.

The results show that a small proportion of the revenue can help solve this issue. The Australian carbon tax program was designed to redistribute part of the revenue through tax cuts, increases in pensions, increased family payments, etc. to solve the regressivity induced by the implementation. As a result, nine out of ten households were expected to benefit from the increased assistance (Department of Climate Change

25) Since the nature of labor market of S. Korea is different from that of the US, it needs to be cautious to use income of households where the head is aged from 40 to 60 as proxy for permanent income in South Korea. There is no big difference between the degrees of labor stability in S. Korea and the US; however labor mobility of S. Korea is much lower than that of the US.

and Energy Efficiency, 2012). While the Australian carbon tax was abolished due to costs for Australian businesses and households (Department of the Environment, n.d.), the design can be a good example to the South Korean government.

However, this study has some limitations. Due to the assumption built into the IO model that did not allow the substitution of factors and commodities according to changes in prices, the results should be interpreted as a short-term impact. If internal substitution is allowed in the model, the results can be different: for example, the distribution of the burdens can be less regressive.

In addition, Z matrix is used to link IO table with HSD. Although this study has constructed the matrix based on the previous studies (Kang et al., 2011; Joh, 2010; Oh, 2013), it is still not free from being criticized for the arbitrary classification. As research demands for interdisciplinary areas are increasing, reliable Z matrix is being more requested. The Federal Statistical Office of Germany publishes Z matrix, which allows to more accurately analyze the impacts of a policy on households. Kronenberg(2009) uses the matrix to analyze the impacts of demographic change on energy consumption and GHG emissions. The efforts to build the matrix that link these two important datasets are required to be done by Statistics Korea or Bank of Korea.

This study also tested the impacts of revenue recycling scenarios based on lump-sum transfers. However, revenue can be recycled in other ways, for example, assistance for weatherization in low-income households. Energy efficiency improvement and renewable energy deployment are better options for low-income households since the returns on investment are multiyear and comprehensive including a variety of collateral benefits such as job creation, CO_2 emissions reduction in households, etc. (The Energy & Climate Policy Institute, 2010). Therefore, policymakers and further studies need to investigate the effectiveness of various revenue-recycling methods such as investment in energy efficiency enhancement projects or renewable energy facilities, which can result in long-term achievement and accompany additional benefits, and compare these with lump-sum transfer methods.

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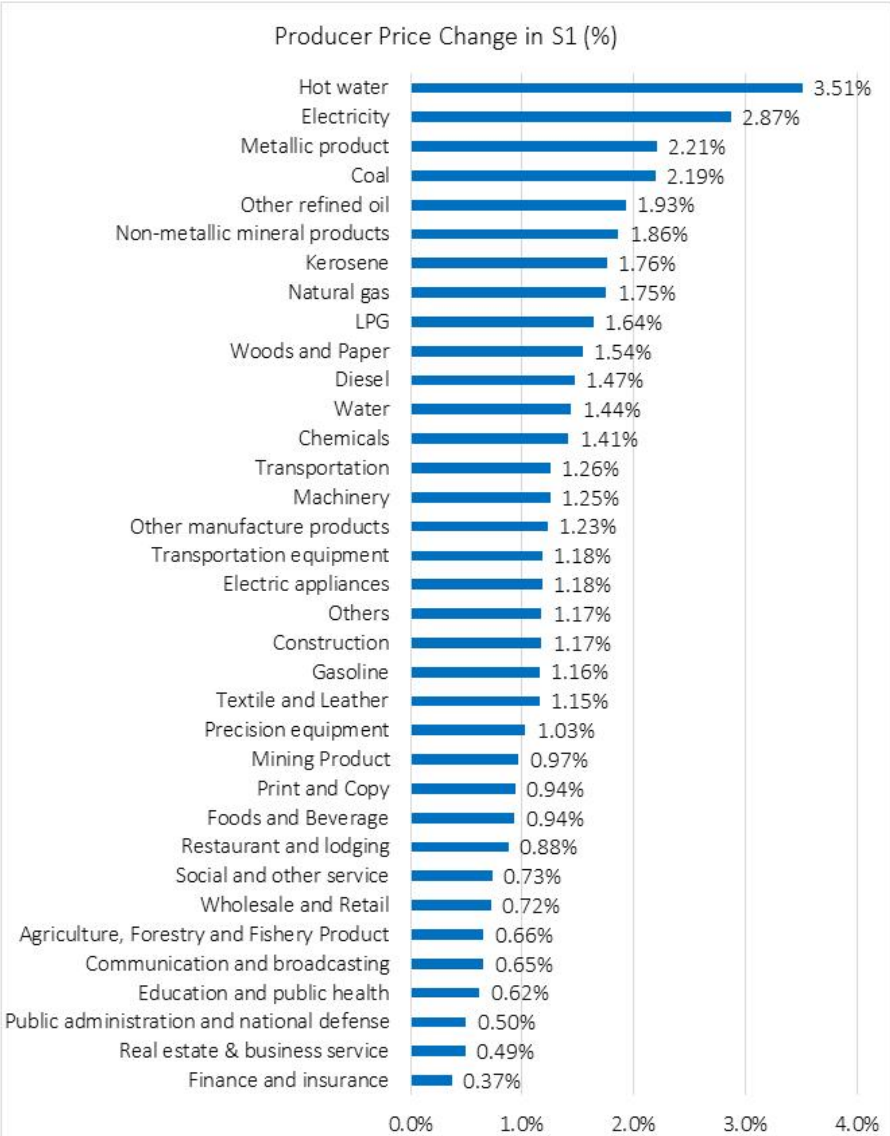
Appendices

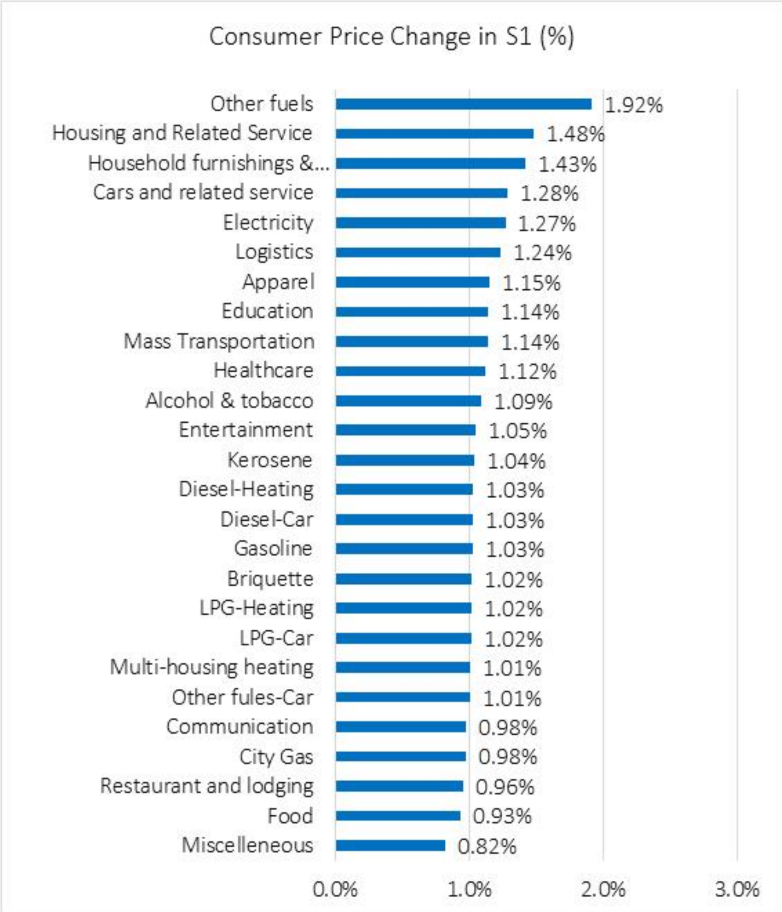
Supplementary table and figures are provided in Appendices.

Figure A.1 Producer Price Change



Note: Each category means the producer product in an industry and the total number of industry sectors is 35.

Figure A.2 Consumer Price Change



Note: Each category refers to consumer goods and services, and the total number of categories is 25.