TOWARDS AN EQUITABLE CAP-AND-TRADE SCHEME IN SOUTH KOREA: BASED ON INPUT-OUTPUT ANALYSIS OF THE DISTRIBUTIONAL IMPLICATIONS OF CARBON PRICING MECHANISMS

by

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A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Energy and Environmental Policy

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ABSTRACT

While the efficiency of cap-and-trade programs has attracted the attention of several countries, equity implications of the programs require equal attention. The programs impact income distribution as the cost of mitigation is passed on to consumers in the form of increased prices. A great deal of literature shows that the incidence of these programs is regressive in developed countries, indicating that this program will exacerbate the distributional equity without appropriate countermeasures.

Facing the impending implementation of cap-and trade schemes in South Korea in 2015, a handful of experts have studied the equity implications of the scheme. The literature often provides a partial analysis on equity implications of the scheme focusing only on regional distribution or on distribution between different income groups. However, this dissertation evaluates the comprehensive equity implications of a carbon pricing policy as well as the impacts on other dimensions.

Input-output analysis (IOA) is employed to assess the comprehensive impacts of a carbon pricing policy in South Korea. Beyond a typical IOA, hybrid IO tables are developed to estimate energy consumption and CO_2 emissions by sector and to analyze the impacts of the implementation on different sectors. In addition, this study makes it possible to assess equity implications by introducing a transition matrix to link Household Survey Data with the IO table.

The analysis of three different carbon-pricing scenarios reveals that a comprehensive participation scenario (S1) impacts economy less adversely than the partial participation case (S2). The S1 more adversely impacts the distribution without revenue recycling. Coal consumption is reduced more in the S2 and the reduction in non-energy use such as naphtha is larger in the S1. Of course, a higher carbon price (S3) can reduce more emissions and energy consumption, but can more adversely affect economy and distributional equity.

Regardless of scenarios, the analysis shows that the households with lower capacity, such as those with low-income or with elderly heads, are likely to be more adversely affected. However, these groups can be beneficiaries if the program is in practice together with revenue recycling through lump-sum transfer. In addition, there is not great difference between the burdens on rural and urban households.

In conclusion, there is no best-case scenario for every dimension. Since the policy impacts economy, energy, environment and equity—important pillars of sustainable development—we need to consider the comprehensive impacts of the policy. In addition, we need to explore a more effective method to recycle the revenue to alleviate the inequity.

Chapter 1

INTRODUCTION

South Korea is located on the Korean Peninsula and bounded by the Yellow Sea and the East Sea[1]. The population is around 50.2 million and the total area is similar to that of US state of Indiana. Even with the small area and the small number of population, South Korea was the world's fifteenth-largest economy in both 2011 and 2012 (World Bank, n.d.). However, due to the heavy dependence on manufacturing industries that produce goods such as semiconductors, automobiles, ships, and other machinery, the CO_2 emissions of South Korea ranked 7th in 2011. The growth rate of the emissions from 1990 to 2011 is highest (156.3% per annum) among the OECD countries (International Energy Agency [IEA], 2013a). In addition, the country heavily depends on imported fossil fuels. The self-sufficiency[2] in 2011 was 18.04%. At the same time, renewable energy contributes to only 0.7% of the TPES in South Korea while it accounts for an average of 8.1% of TPES in all OECD countries (IEA, 2013b) (see Table 1.1).

In response to these multiple challenges, the government introduced Low Carbon Green Growth (LCGG) as a new vision for national development. This strategy pursues

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[1] It is also known as the Sea of Japan.

[2] The ratio of the amount of produced energy to the amount of total primary energy supply (TPES)

sustainable economic growth without impacting the environment through improvements of eco-efficiency by promoting renewable energy technologies and improving energy efficiency (Presidential Committee on Green Growth [PCGG], 2009). In pursuit of the LCGG framework, the government established a national greenhouse gases (GHG) emissions reduction target of 30% by 2020 against the business as usual (BAU) levels. In order to achieve this target, the cap-and-trade scheme that accounts for about 60 % of the national GHG emissions will be launched in 2015.

Table 1.1 General Information of South Korea

Area: 99,720 km^2
Climate: temperate with heavy rainfall in summer
Terrain: mostly hills and mountains
Population: 50.004 million (2012) 49.779 million (2011)
GDP: 1,130 billion USD (15th) (2012) 1,114 billion USD (15th) (2011)
TPES: 260.44 MTOE (2011) Energy Mix: coal 30.8%; oil 36.0%; natural gas 16.0%; nuclear 15.5%; renewable energy 0.7%; waste 1.0% Energy self-sufficiency: 18.04% (2011)
CO_2 emissions: 587 million tons of CO_2 (7th) (2011)

Source: (IEA, 2013a, 2013b; World Bank, n.d.)

A cap and trade program allows a country to reduce emissions in a more cost-effective manner. It limits the total amount of emissions and generally strengthens the cap (the total amount of emissions allowed to be emitted within a nation or from participants). According to the cap, a program distributes permits or allowances to participants that give the right to emit a certain amount of emissions. The participating entities should hold a certain amount of permits equivalent to their GHG emissions and surrender the permits to a regulatory authority or institution at the end of the compliance period or year. In this program, the participants are allowed to trade permits among each other. Entities that reduce their emissions by more than their allowances can then sell these extra permits to other entities that failed to reduce emissions enough to meet their reduction targets. As a result, sellers can gain a profit by selling the permits while buyers can comply with the program requirement at less of a cost than they would incur if they had to reduce the emissions by themselves.

The efficiency of this market-based program is better than a command-and-control measure such as the limitation of the total amount of emissions without allowing the trade of permits. The cost-effectiveness of an emissions trading scheme has been also proven by the cap-and-trade programs for sulfur dioxide (SO_2) in the U.S (Environmental Protection Agency, 2004). Due to its efficiency aspect, the cap-and-trade program has drawn the attention of a number of countries. The European Union Emission Trading Scheme (EU ETS), a well-known emissions trading scheme that has been in operation since 2005, has established a level playing field. Inspired by the practice of the EU ETS, there are some countries including South Korea that will initiate a national or pilot emission-trading scheme. At this point, it is important to more comprehensively examine the impact of the implementation of this program beyond efficiency related impacts.

Much like other environmental policies, cap-and-trade impacts equity. Although the legal incidence of the program falls on emission sources such as large-scale electricity generators or steel manufacturing plants, the burden is finally passed on to the consumers in the form of increased prices (Garnaut, 2008). It has been found in a number of studies that the incidence of the burden induced by carbon pricing policies is generally regressive in developed countries – it is relatively heavier on poorer households. Furthermore, it also more adversely impacts the elderly. This result can be attributed to relatively more energy-intensive expenditure pattern of these groups compared to their capacity/income (as cited in Yusuf & Resosudarmo, 2007). Therefore, it is necessary to explore the distributional implications of the implementation of this program in South Korea.

In addition to the challenges facing energy, economy and environment, South Korea is becoming more unequal in terms of income distribution. The Economist identified that "[j]udging by the relationship between the richest and poorest tenth, Korea is becoming more unequal than it used to be. Worse, the growing number of poor people is disproportionately elderly" ("What do you do when you reach the top?: South Korea's Economy ", 2011). Furthermore, the elderly population aged 65 and over rapidly increased from 9.07% in 2005 to 11.36% of the total population in 2011 (OECD, 2013a). If the program were to be implemented without appropriate countermeasures to relieve the inequitable distribution of the burden, the social equity would be aggravated. With less capacity to respond, the elderly poor will be more adversely impacted. Therefore, the equity implications of this program between different age, income groups or in different locations need to be comprehensively examined.

Several studies explored equity issues related to carbon pricing mechanisms in South Korea (Kang, Kang, & Cho, 2011; Kim, n.d.; Kim & Kim, 2010; Noh, 2009). However, the analyses are too limited to explore comprehensive distributional impacts of the implementation. Several studies focus on the comparison of the compliance costs in different regions. Yet, there has not been a study which has evaluated the equity implications of the program on the elderly group or the households in rural areas. In addition, the interpretation of the results was not enough to reach appropriate policy recommendations.

As this scheme is initiated as the part of the LCGG framework, the equity aspects of the implementation is not likely to weigh against the design of the details in the scheme. Green growth emphasizes a virtuous circle between economic growth and environmental protection by reducing the environmental impact per unit of economic activity through the promotion of renewable energy and the improvement of energy efficiency (PCGG, 2009). According to the definition, the framework inevitably lacks consideration for equity aspects. Therefore, a more comprehensive framework for the analysis is required. This study revisits the concept of sustainable development and analyzes the impact of the policy based on the four essential pillars of sustainable development: economy, energy, environment and equity.

Facing the imminent commencement of the cap-and-trade scheme in South Korea on January 1, 2015, this study aims to evaluate the comprehensive equity implications of the scheme as well as the impacts on environment, energy and economy by conducting an input-output analysis with extensions. An input-output table depicts the interdependence of sectors. The model allows estimating how much change in value-added outputs and employment are induced according to changes in final demands. Specifically, in terms of equity aspects, it will be assessed how the burden will differ by [1] the age of the head of household, [2] income level of household, and [3] between rural and urban households. In addition, this study assesses how revenue recycling relieves the inequity.

The findings of this study can provide insights for policy makers in South Korea. Currently, the details regarding how to operate the policies are being developed. With better understanding of the impacts of the scheme on economy, energy, environment and equity in South Korea, the scheme can be designed in a more balanced manner. Furthermore, these findings can help policy makers in other countries that are considering the implementation of an emission trading scheme understand the impact better.

In order to achieve this goal, this paper will develop as follows. Chapter 2 (Literature Review) will serve as an introductory chapter. It will survey cap-and-trade programs worldwide. Then, it will explore two essential characteristics of this program: efficiency (why this program is efficient) and equity (how and why this program impacts equity). In addition, previous studies on distributional implications of a carbon pricing policy including a carbon tax and a cap and trade program will be surveyed.

Chapter 3 (Conceptual Framework) will explain the conceptual framework. By giving constructive criticism of the current framework of the cap-and-trade scheme of the LCGG in South Korea and revisiting the concept of sustainable development, this study proposes an alternative framework to evaluate a cap-and-trade program comprehensively.

Chapter 4 (Data and Methodology) will explain the data and methodology. I use input-output (I-O) table analyses together with Household Survey Data and Total Primary Energy Balances. In this chapter, how to estimate energy consumption and CO_2 emissions by sectors, how to pass on the changes in producer prices to consumer prices and how to evaluate the impacts on different dimensions are explained in detail.

Chapter 5 (Results) analyzes the results of different scenarios. As the I-O model cannot simulate the operation of cap-and-trade, this study rather evaluates the implications of the program by simulating the different imposition of a carbon tax in the model: [1] comprehensive levy of a carbon tax of $15/t$CO_2$ on every sector; [2] levy of a carbon tax of $18.9/t$CO_2$ on large emitters and [3] comprehensive levy of a carbon tax of $18.9/t$CO_2$.

Chapter 6 (Conclusion) will review the results and the scenarios. The revenue recycling method is reviewed in terms of effectiveness and feasibility to relieve the fuel poverty as well as to relieve the inequity.

Chapter 2

LITERATURE REVIEW

Some countries have either started or plan to implement a cap-and-trade scheme while other countries are considering and discussing the implementation of such a program. South Korea has plans to start the scheme on January 1, 2015. This chapter will briefly survey the current worldwide status of the program by exploring the emission trading programs in force. In the following section, efficiency aspects and equity aspects related to cap-and-trade program will be explored in detail. This will include reasons why the cap-and-trade program is efficient, and how the program has different distributional implications on different groups. The literature that examines the distributional impacts of carbon pricing mechanisms will be surveyed in the last section.

2.1 Cap-and-Trade: World Wide Status

2.1.1 Cap-and-Trade in Force in Other Countries

The effectiveness and efficiency of cap-and-trade was proven in the U.S. The SO_2 emissions trading policy was successful - the emissions have been decreased 5.5 million tons from 1990 levels. In addition, atmospheric concentrations of SO_2 have decreased 30-40% lower than 1990 levels. It was also cost-efficient - the compliance cost was substantially lower than expected. Sulfur dioxide reduction costs $1-2 billion per year, which is just a quarter of the EPA estimates (Environmental Protection Agency, 2004). Supported by the success of the U.S. case, cap-and-trade has begun to proliferate around the world.

Figure 2.1 shows which countries are implementing, planning, or considering a GHG emissions trading scheme (referred to as ETS—emissions trading scheme—in the table). The darkest color refers to areas where the emissions trading scheme is now in force; this includes thirty countries in the EU, New Zealand, Switzerland, Australia, Tokyo, Quebec, and ten states in the U.S. The lighter color refers to areas that have scheduled to implement an ETS, such as South Korea, Kazakhstan, and seven provinces in China. The lightest color shows areas considering the implementation of an ETS , including Brazil, Chile, Turkey, Ukraine, China, Japan, Mexico, three provinces in Canada, and the Brazilian cities of São Paulo and Rio de Janeiro (International Carbon Action Partnership [ICAP], 2012).

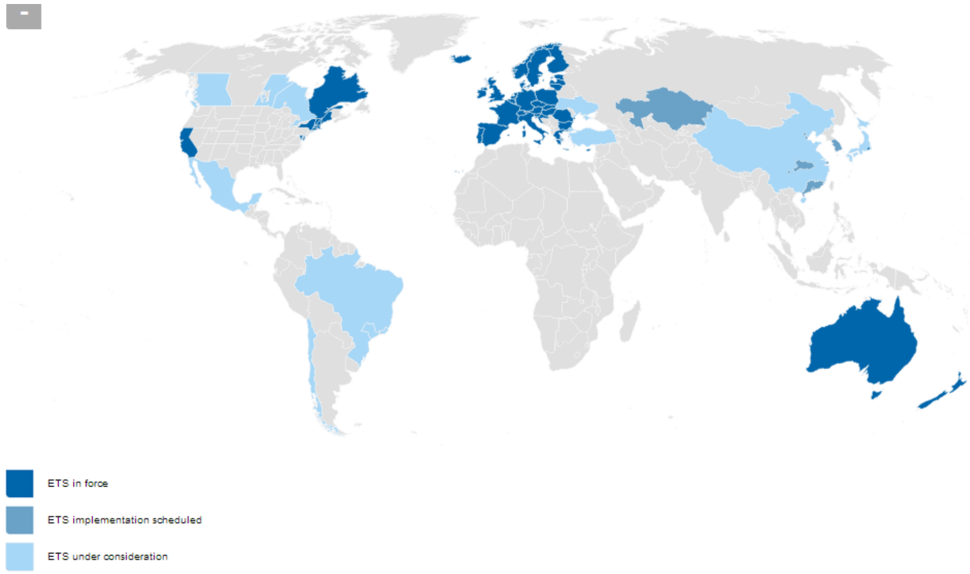

Figure 2.1 Worldwide Cap-and-Trade Program Status

Source: (ICAP, 2012)

The EU-ETS is an international company-level cap-and-trade system across the EU-27 member states, Liechtenstein, Iceland, and Norway. Also, Croatia joined this scheme on January 1, 2013. It covers more than 11,000 energy-intensive facilities, such as power generating plants and large energy-consuming facilities. The scheme expanded to include emissions from aviation in 2012[3]. Currently, in its third phase (2013-2020), the goal is to reduce emission levels by 20% below 1990 levels by 2020. In addition, auctions have become the default method for allocation in this phase; the proportion of auctioned allowances will gradually increase from 40% in 2013. The auction revenue

[3] The EU ETS started to cover CO_2 emissions from flights to and from non-member states as well as between member states in 2012. The aviation sector of Croatia will be included in January 1, 2014.

will be returned to the member states, at which point, each member state will decide how to spend the revenue (European Commission, n.d.-a). Except for ten new member states, 100% of allowances is proposed to be distributed to the electricity sector through auction. In manufacturing industries (not trade-exposed), free allocation will be gradually phased out starting from 80% in 2013 to 30% in 2020. Trade-exposed sectors will receive a higher share of free allowances (European Commission, n.d.-a). The EU ETS recommends that at least 50% of the revenue needs to be used to support GHG reduction activities within member states and developing countries as well. Although there is nothing in the content that indicates support or assistance for low-income groups, among GHG reduction activities "[i]mprovements in energy efficiency and insulation" can support the low-income households which might suffer from the increases in prices (European Commission, n.d.-b).

The EU-ETS has been evaluated as an excellent example of a cap-and-trade system. First, it has created a playing field for multiple entities to participate in the scheme across the EU (European Environment Agency, 2011). Second, it has successfully expanded to include more sectors and has also been strengthened by having auctions as default allocation methods while lowering the cap. Third, the EU-ETS has been proven to be effective for reducing GHG emissions. According to the Commission (2011), the EU-ETS has contributed to a reduction of 8.3% average annual emissions per facility below 2005 levels. The EU-ETS has urged large energy-consuming companies to consider CO_2 reduction responsibility as a part of their long-term business plan. The success of the EU-ETS inspires other countries to seriously consider implementation of cap-and-trade.

Switzerland and New Zealand are also implementing national cap-and-trade programs. Starting on January 1, 2008, the Swiss emissions trading scheme (CH-ETS) has been used as an alternative for companies to avoid paying carbon taxes; energy-intensive or high-emitting industries can choose to join the cap-and-trade system, or pay carbon taxes. As the allowances are distributed to these industries for free according to the benchmark approach[4], emissions trading schemes become more appealing to industries. Currently, four hundred Swiss companies have chosen to join the cap-and-trade system rather than pay a tax, which accounts for about 6.5% of CO_2 emitted. The cap has been set to be lowered in a linear fashion of 1.74% per year. The reduction target of each entity is decided through negotiations between the government and the industry (Council of the European Union, 2010). In the case of non-compliance, the CO_2 tax is retroactively imposed on every ton of CO_2 emitted. The CH-ETS plans to link to the EU-ETS; the Swiss government and the EU started negotiations in March 2011(Federal Office for the Environment, 2010, 2013a; Parliament of Australia, 2010). The tax revenue from the tax levy on CO_2 emissions is redistributed to relieve the burden on the public and the company (about 2/3 of the revenue) and to promote CO_2 reduction in buildings (1/3 of the revenue). In detail, the public will get health insurance premium deductions as a per capita lump-sum rebate and the companies not participating in the

[4] It is also adopted by the EU-ETS. The government is allocating the allowances the average emissions per a unit of a product from 10% of the most efficient installations.

cap-and-trade system will receive the revenue in proportion to the payroll they have paid (Federal Office for the Environment, 2013b).

New Zealand initiated a country-scale emissions trading (NZ-ETS) in 2008. The forestry sector first joined the NZ-ETS to prevent emissions that result from deforestation. Forests have played a principal role in the mitigation policy. Under the Kyoto protocol, New Zealand's reduction target is equivalent to the 1990 emissions level. Besides the amount of emission units assigned from the Kyoto protocol, the amount which can be removed by eligible forests in New Zealand is also significant– about 77.2 million tons of CO_2e for the first commitment period of the Protocol (Ministry for the Environment, 2013).

Since July 2010, the energy, industry and transport sectors have also joined the NZ-ETS. Due to the significant financial impact that it will receive, the agriculture sector will join in 2015. Specifically, the sector accounts for half of all GHG emissions in New Zealand while on average it accounts for only 7% of total GHG emissions in Annex I countries (Branson, Clough, McWha, Layton, & Stephenson, 2007). During the transition phase (July 2010 to December 2012), the price of the New Zealand Unit (NZU) (i.e., one ton of CO_2e) was fixed at $NZ25/NZU. Currently, the permit price is very low around $NZ2/NZU due to both a surplus and weak rules for using external credits (King, 2013). This program also allocates free allowances to emissions-intensive or trade-exposed industries in the proportion of output (Ministry for the Environment, n.d.). In addition, the NZ-ETS is preparing to link with the Australian program.

On November 8, 2011, the Australian Parliament finally approved nationwide implementation of a carbon pricing[5] mechanism (AUS-CPM), which started on July 1, 2012 after rejecting a national emissions trading program two times. The permit price will be annually raised by 2.5%, starting at AUD23 (Australian dollar) per ton of CO_2 for the first three years. The AUS-CPM covers about five hundred large emitters. All facilities that emit at least 25,000 tons of CO_2e, and all landfill facilities that emit at least 10,000 tons of CO_2e, are required to participate in this program. The transition period will last from July 1, 2012 to June 30, 2015; after which it will shift to the cap-and-trade program with a flexible permit price. During this transition period, emissions will not be limited, but they will be capped starting in 2015. In addition, trade-exposed or energy-intensive industries will receive a significant portion of allowances for free, according to their emissions intensity and output; the high energy-intensive group and the moderate energy-intensive group will receive 94.5% and 66% of the emissions for free, respectively (Center for Climate and Energy Solutions, 2011).

The AUS-CPM plans to give assistance to low-income households. The Australian government plans to use a majority of the revenue from this program to support low-income and/or elderly households through tax reforms (Center for Climate and Energy Solutions, 2011). In August 2012, the Australian government and the European Commission announced that they were in the process of linking the EU-ETS to the AUS-CPM in August 2012; it is expected to be established by July 2018 (European Commission, 2012).

[5] The official name of this law is “Clean energy Legislative Package.”

The U.S. government has tried to legislate the federal cap-and-trade system. However, the enactment of the system has continued to fail due to rejection in the U.S. Senate (Hulse & Herszenhorn, 2010). On June 26, 2009, the American Clean Energy and Security Act – often called the Waxman-Markey bill – included a cap-and-trade program; carbon emissions would be capped at 17% below 2005 levels by 2020, and it would gradually strengthen the cap to 83% below 2005 levels by 2050 (Durning, Fahey, Place, Stiffler, & Williams-Derry, 2009).

While a federal cap-and-trade system is absent in the U.S, there are regional cap-and-trade systems in practice. In January 2009, the Regional Greenhouse Gas Initiative (RGGI) began its first phase by aiming to reduce CO_2 emissions from the power sector with a capacity of 25 MW; the goal is a 10% below the 2009 emissions by 2018. The scope of RGGI covers nine states in the Northeast and the Mid-Atlantic (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont) and accounts for 22% of all CO_2 emissions of participating jurisdictions. For the second phase of implementation (January 1, 2012 to December 31, 2014), the cap of the RGGI was equivalent to 165 million tons of CO_2 per annum. The cap will be more stringent in the third phase (2015-2018) by aiming to reduce emissions by 2.5% per annum (RGGI, n.d.). Most allowances will be distributed through auctions and all proceeds collected will be distributed to the states. The total revenue accumulated by 2012 was used as follows: [1] 56% for energy efficiency improvement; [2] 17% for direct bill assistance; [3] 6% for GHG abatement & climate change adaptation; [4] 5% for clean & renewable energy deployment; [5] 5% for administration and [6] 1% for other purposes. As each member state uses its discretion to recycle the proceeds, the specific percentage is different across the states. For example, Connecticut allocated 69% of the cumulative proceeds by 2012 to energy efficiency improvements while Maryland used 67% to assist electricity bill payments (RGGI, 2012). In addition, the RGGI has flexibility provisions such as the use of offsets up to 3.3 % of the entity's emissions and unlimited banking of the allowances, offsets, and early reduction credits (RGGI, n.d.)[6].

The Western Climate Initiative (WCI), established in 2007, is a collaboration of seven U.S. states (Arizona, California, Montana, New Mexico, Oregon, Utah, and Washington) and four Canadian provinces (British Columbia, Manitoba, Ontario, and Quebec). If fully implemented, it will account for about 90% of the total GHG emissions from the WCI partner jurisdictions (WCI, 2010). As of 2013, the program is in operation in California and Quebec; both considered to be linked to each other. Besides RGGI and the WCI, six Midwestern states (Illinois, Iowa, Kansas, Michigan, Minnesota, and Wisconsin) and one Canadian province (Manitoba) signed the Midwestern Greenhouse Gas Reduction Accord (MGGRA) in 2007 to collaborate on reducing GHG emissions. Even though participants are not currently pursuing this accord, the MGGRA has not been officially suspended (Paulman, 2011).

In addition to the U.S., Japan also tried to introduce a nationwide cap-and-trade program. Yukio Hatoyama, a former Prime Minister of Japan, announced at the United

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[6] The RGGI acknowledges early reduction credits achieved by the emitters from 2006 to 2008. In addition, once an applicant filed the early reduction credit by May 1 2009, he or she could bank the credit and then use it in the future (International Emissions Trading Association, 2013).

Nations Summit on Climate Change in September 2009 that Japan would reduce national GHG emissions by 25% below 1990 levels by 2020. To achieve this, the implementation of domestic cap-and-trade was reviewed (Ministry of Environment & Trade Environment Information Network, 2009). However, the government dropped the plan to launch a nationwide cap-and-trade proposal in April 2013 due to strong opposition from industry (Sharp, 2010). Although a national cap-and-trade program is absent, an urban cap-and-trade program has been in practice in Tokyo metropolitan area (TMG ETS) since 2010. It accounts for 18% of all emissions from the Greater Tokyo Area. It is the first urban emissions trading program in Asia. The allowances are distributed free on the basis of grandfathering. In the first phase, office buildings, other facilities and district-heating/cooling plants should reduce emissions by 8% against the average emissions for the past three years. Facilities using large amounts of district-heating/cooling, water/sewage facilities, and waste processing facilities should reduce average emissions by 6% (ICAP, 2012).

Several cap-and-trade programs in force were reviewed. Efficiency was the main reason why aforementioned countries implemented a cap-and-trade program. As a result, every program is trying to be more efficient or more cost effective by providing flexibility or allocating free allowances to industries. A cap-and-trade program inevitably impacts equity, which will be examined in following section. However, every program does not have a countermeasure to solve the equity problem. As explained earlier, both the California and Australia cap-and-trade programs plan to use a proportion of the proceeds of the program to assist low-income households and pensioner. In addition, 17%

of the cumulative revenue of the RGGI was recycled to households as direct bill assistance and 2/3 of the revenue of the CH-ETS was redistributed to the citizens and the companies. However, the EU-ETS scheme, the most mature program, does not discuss much of the issue of equity. It only recommends that at least 50% of the revenues needs to be used to support GHG reduction activities within member states and developing countries.

South Korea will commence the cap-and-trade scheme in the near future. In order to have the scheme balanced in the essential pillars of sustainable development including energy, environment, equity, and economy, equity implications of a carbon pricing policy in South Korea need to be both explored and reflected in the scheme design.

Table 2.1 Summary of Emission Trading Programs in Force

Program	EU-ETS	CH-ETS	NZ-ETS	AUS-CPM
Region	27 EU Member States, Iceland, Liechtenstein, Norway, and Croatia	Switzerland	New Zealand	Australia
Program Status	Began in 2005. Currently, it is in the third trading period from 2013 to 2020. 40% of allowances are auctioned in 2013. The proportion of auctioning will continuously increase. The rest of allowances are freely allocated according to the industry benchmarks	Began in 2008 as an alternative to the CO_2 tax for industries. It is in the second phase from 2013 to 2020. Free allocation according to the benchmarking method.	Began in 2008. Entry dates differ by sectors. Forestry firstly entered the system as of Jan 2008. Transportation, stationary energy, and industrial process entered this system in 2010. Agriculture would enter the program in 2015. During the transition phase, a fixed price for CO_2e emission, NZ$ 25/NZU, would be applied.	Began in July 2012 It is in the transition period with fixed permit price at AUD 23/CO_2e. Significant portions of allowances will be auctioned from July 2013. To support energy-intensive or trade-exposed industry sectors, significant portions of allowances will be allocated for free according to the intensity of emissions.
Program Scope	Gases: CO_2, N_2O, PFCs Sources: Power stations (>20MW) and energy intensive industries, aviation sectors (10,000tCO_2e/yr) Coverage: 40% of 30 countries' CO_2 emissions. (About 11,000 installations) Point of regulation: downstream Benchmark approach	Gases: CO_2 Sources: Large emitters or energy-intensive sectors which want to avoid paying CO_2 tax Coverage: 5% of CO_2 emissions. About 400 companies entered this scheme. Benchmark approach	Gases: All 6 Kyoto gases Sources: Forestry, Agriculture, Stationary Energy, Transportation, synthetic energy, Industrial Process, waste, and Coverage: roughly 50% (forestry, stationary energy, industrial processes and liquid fossil fuels) of total emissions (about 2,250 entities, as of June 2012) Point of regulation: upstream	Gases: Currently CO_2, N_2O, CH_4, and PFCs from aluminum production Sources: Large emitters (>25,000 t of CO_2e or >10,000t of CO_2e) Coverage: 60% of the total Australia GHG emissions.
Reduction Target	2013-2020: 20% reduction from the 1990 levels	2008-2012: 8% reduction from the 1990 levels (Kyoto target) 2010: 10% reduction from the 1990 levels (Swiss target) Each company has a specific target.	Overall GHG reduction target: stabilization at the 1990 GHG levels by 2012. 10% or 20% reduction of the 1990 GHG levels according to the international agreement by 2020. 50% below the 1990 GHG levels. Cap and trajectory: Uncapped	Overall GHG reduction target: 5% reduction of 2000 GHG levels by 2020 Cap and trajectory: Uncapped for transition period; absolute caps after the transition period will be announced in 2014.

Table 2.2 Summary of Emission Trading Programs in Force - continued

Program	TMG-ETS	RGGI	California Cap-and-trade	Quebec Cap-and-trade
Region	Tokyo	Northeastern and Mid-Atlantic States in the U.S.	California Part of the WCI	Quebec Part of WCI
Program Status	Began in 2010 Now, it is in the first phase from FY 2010 to FY 2015. All the allowances are distributed for free.	Began in January 2009. Now, it is in the 2nd phase. About 90% of allowances are distributed through auction. The proceeds are recycled to improve end-use energy efficiency and support renewable energy deployment.	Began in 2013. Now, it is in the 1st compliance period to 2014.	Began in 2012 as transition period (not mandatory). From January 2013 to December 2014, it is in the first compliance period. Electricity and fuel distributor should buy allowances 100% at auction. Other sectors will receive a significant portion of allowances for free.
Program Scope	Gases: Energy related CO_2 (But other Kyoto gases are subject to the MRV requirement. Coverage: 18% of Tokyo CO_2 emissions Point of regulation: downstream	Gases: CO_2 Sources: Fossil-fired power plants (>25MW) (currently 168 installments) Coverage: 22% of the emissions of 9 states Point of Regulation: downstream	Gases: CO_2, CH_4, N_2O, SF_6, HFC, PFC, NF_3 Coverage: 85% of California's GHG emissions Point of Regulation: Mix of downstream and midstream	Gases: CO_2, CH_4, N_2O, SF_6, HFC, PFC, NF_3 Sources: 1st period – electricity and industry sector. (>25,000tCO_2e/yr) 2nd and 3rd periods – fuel distribution and import, building sectors, small or medium-sized businesses (>25,000tCO_2e/yr) will be added. Coverage: 86% of Quebec's GHG emissions
Reduction Target	By 2020: 25% reduction from the 2000 level	2012-2014 : 165 million tons of CO_2/yr 2015-2018 : -2.5% reduction of 165 million tons of CO_2 per annum	-2% by 2013; -2% by 2014; -3% annually from 2015 to 2020 against 2012 emissions level	Starting from 65.3Mt CO_2e in 2015; decreasing 2.1Mt CO_2e annually.

2.1.2 Cap-and-Trade Policy in South Korea

On August 15, 2008, the 60th Anniversary of National Foundation Day, former South Korean President Lee Myung-bak announced *Low Carbon/Green Growth* as a new national vision for the next fifty years. *National Strategy for Green Growth,* which specifies targets and strategies for Green Growth was established the following year. The Strategy has three elements: [1] adapting to climate change and increasing energy self-sufficiency, [2] creating new engines for economic growth, and [3] improving the quality of life and enhancing the national status of South Korea in the world. Ten policy agendas[7] were announced for achieving these three elements; one of them is the efficient mitigation of greenhouse gases emissions (PCGG, 2009).

On November 17, 2009, the Cabinet (the highest body for policy deliberation and resolution in the executive branch of the South Korean government) approved a national GHG emissions reduction target of 30% by 2020 against the BAU emissions, which means a 4% reduction of GHG emissions from 2005 levels. In addition, the sectoral reduction targets (compared to the BAU emissions generated by each sector in 2020) are 18.1% for industries, 26.7% for energy transition/generation, 34.3% for

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[7] The ten agendas are as follows: 1) Efficient mitigation of greenhouse gas emissions; 2) Reduction in the use of fossil fuels and the enhancement of energy independence; 3) Strengthening the capacity to adapt to climate change; 4) Development of green technologies; 5) "Greening" of existing industries and promotion of green technologies; 6) Advancement of the industrial structure to increase the role of services; 7) Engineering a structural basis for the green economy; 8) Greening land and water and building the green transportation infrastructure; 9) Brining the green revolution into our daily lives; 10) Becoming a role model for the international community as a green growth leader (PCGG, 2009).

transportation, 26.9% for buildings, 5.2% for agriculture, forestry, and fishery, 12.3% for waste, and 25% reduction for the public sector (H. Kang & H. Jang, 2011). To achieve this target, the Management of Targets for GHGs and Energy program is in operation, according to the Framework Act on Low Carbon and Green Growth. This program allocates different caps on emissions of energy-intensive companies, but does not allow the exchange of carbon permits. As of 2012, 458 companies and facilities took part in this mandated program, which accounted for about 60% of total GHG emissions (Korea Environment Corporation, n.d.).

The government initially planned to implement this program together with a GHG cap-and-trade scheme at the same time. However, the industries, as well as numerous experts, criticized the duplicate burden on the eligible entities. Also, the industries protested implementation of cap-and-trade because of the heavier burden than that imposed by the Management of Targets for GHGs and Energy program. As a result, Management of Targets for GHGs and Energy was first implemented in 2012, however it will later shift to a GHG emission-trading scheme in 2015.

On May 2, 2012, the ETS bill—officially named the Act on the Allocation and Trading of Greenhouse Gas Emission Permits—was approved by the National Assembly of South Korea. According to this law, the cap-and-trade scheme, which will account for 60% of all national GHG emissions, will begin on January 1, 2015.

The PCGG tried to enact the Act on November 26, 2010, however it was stranded for two years due to strong opposition by the industrial community. In October 2011, fifteen major business interest groups argued in favor of withdrawing the legislation because of the potential for a large financial burden on the industry. For instance, POSCO, one of the largest steel companies in the world, currently emits 63 million tons of CO_2e. If the bill were to pass, POSCO would be obligated to spend about 2 trillion KRW (Korean won) (about $1.85 billion) for the purchase of emission permits (Kwon, 2011). Therefore, the government revised the bill twice in order to facilitate industrial participation. As a result, the final version of the Act became less demanding than prior versions.

According to the Act, an Allocation Committee must be established. The chairperson will be the Minster of Strategy and Finance. The members will consist of the vice minsters of the government department related to the scheme including Ministry of Environment, Ministry of Education, Ministry of Agriculture, Food & Rural Affairs, etc. and other experts. Every five years, the Committee will establish a cap-and-trade basic plan, which is a long-term plan to efficiently achieve the national GHG reduction target/cap. In addition, the Committee will deliberate on and adjust the matters related to: the Allocation Plan, measures for market stabilization, verifications of emissions, assistance in and policy adjustment to offsets, and the linkage with other international carbon markets.

While the Committee is in charge of the development of a comprehensive long-term plan, the Ministry of Environment executes the plan with the detailed regulations in terms of allocation, penalty, etc. The Ministry of Environment shall establish the Allocation Plan to allocate national emission allowances through consultation with ministers of relevant agencies/ministries and the allocation committee for each commitment period. Before the establishment or revision of the plan, the government should hold public meetings and reflect on the opinions of the stakeholders in the plan. The plan shall include guidelines on how to operate the program, including the total number of permits for each commitment period and for each compliance year, the standards for allocation by sectors and by types of business, guidelines for banking, borrowing of the permits, and offsets, etc.

The participation of business entities is decided based on their GHG emissions for the past three years. Specifically, business entities whose emissions for the most recent three years are greater than 125,000 tCO_2e or business entities whose facility's GHG emissions are greater than 25,000 tCO_2e are required to participate in the cap-and-trade scheme. The threshold of the emissions required to join the cap-and-trade is equivalent to those established by the Management of Targets for GHGs and Energy program in 2011[8]. In addition, any entity whose emissions are less than the required criteria can volunteer to participate in this program. However, the specific criteria for allocation have not yet been decided and it is planned that it will be disclosed to the public by the end of 2013.

According to the Act, the majority of emission allowances will be distributed for free although the number will be reduced in subsequent commitment periods. One

[8] The threshold f the emissions required to join the Management of Targets for GHGs and Energy program is gradually strengthened: 125,000 tCO_2e for a business and 25,000 tCO_2e for a facility in 2011; 87,500 tCO_2e for a business and 20,000 tCO_2e for a facility in 2012; and 50,000 tCO_2e for a business and 15,000 tCO_2e for a facility in 2014.

hundred percent will be given away during the first commitment period (January 1, 2015 to December 31, 2017); 97% will be given away during the second commitment period (January 1, 2018 to December 31, 2020)[9]; and less than 90% will be given away during the third commitment period. In addition, the government added an element to the act to protect energy-intensive and trade-exposed industries (Sub-article 4 of Article of the Act)[10], which receive all allowances for free, regardless of what commitment period is in place. Furthermore, the number of allowances can be adjusted due to multiple factors, such as changes in the National Allocation Plan, expansion of facilities, changes in production methods, changes in the amount produced, and changes in the business plan.

The eligible entities can flexibly comply with the scheme by banking and borrowing permits between different commitment periods and different compliance years. The maximum number of permits borrowed from the next commitment period or the next compliance year shall not exceed 10% of the total allowances of an entity. In addition, the Act allows entities to use offsets compatible with international standards to meet the allowances; the offset should not exceed 10% of the total

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9 According to Article 2, the commitment period is five years. However, the Act set up a special case for the first and the second commitment periods in its Addenda.

10 If international trade intensity or additional burden due to the implementation of an entity is larger than 30/100, all emission permits shall be allocated for free. The intensity and additional burden of an entity are estimated as follows: [1] international trade intensity = (average annual export + average annual import)/(average annual sales + average annual import) and [2] additional burden = (average annual emissions x permit price)/ average annual value-added.

number of allowances of an entity. The offsets generated from foreign projects should be no more than half of the total offsets that the entity uses to meet its target.

In addition to the increased free allocation, delayed implementation, and flexible use of banking, borrowing, and offsets, the penalty or fine has also been reduced through revisions of the Act. If the number of permits that the entities surrendered is less than its target, they should pay the penalty surcharge for every ton of CO_2e shortfall, which will not exceed three times the average market price of permits with the maximum surcharge of 100,000 KRW per ton of CO_2e. In addition, anyone who makes a false report of permit exchange and/or the amount of emissions produced by entities is required to pay fines up to 1 million KRW.

Table 2.3 Summary of the Act on the Allocation and Trading of Greenhouse Gas Emission Permits

Items	Explanation
Commencement (Article 2 in Addenda of the Act)	2015.1.1.
The Allocation Committee (Article 7)	Chairperson: the minister of Ministry of Strategy and Finance. The committee consists of 20 members from relevant agencies and ministries, including the Ministry of Strategy and Finance, the Ministry of Education, Science and Technology, the Ministry for Food, Agriculture, Forestry and Fisheries, the Ministry of Knowledge Economy, the Ministry of Environment, the Ministry of Land, Transport and Maritime Affairs, the Prime Minister's Office, the Financial Services Commission, etc.
Entities eligible for allocation (Article 8)	Business entities whose emissions for the recent three years are larger than 125,000 tCO_2e or Business entities whose facility's GHG emissions are larger than 25,000 tCO_2e. Entities who volunteered for this scheme.
Allocation method (Article 2 in Addenda of the Act and Article 14 in the Enforcement Decree of the Act)	1st period (from January 1, 2015 through December 31, 2017): 100% free allocation. 2nd period from January 1, 2018 through December 31, 2020): 97% free allocation. 3rd period: less than 90% of the total number of allowances will be allocated for free.
Assistance to sensitive industries (Article 12 and Article 14 of the Enforcement Decree of the Act)	Trade-exposed industries and energy-intensive industries can receive 100% of allowances for free. Entities with international trade intensity larger than 0.3, entities with additional burden due to the implementation larger than 0.3, or entities with international trade intensity larger than 0.1 and the additional burden larger than 0.05.
Adjustments to Allocation (Article 16)	The amount of allocated permits can be adjusted according to the followings: The total number of allowances increases due to a change in the Allocation Plan, Changes in the range of products, in outputs, in business plan, or in facilities

Source: ("Act on the Allocation and Trading of Greenhouse Gas Emissions Permits," 2012)

Table 2.4 Summary of the Act on the Allocation and Trading of Greenhouse Gas Emission Permits – continued

Items	Explanation
Banking and borrowing (Article 28 and Article 36 in the Enforcement Decree of the Act)	Allowance of banking of extra permits to next commitment period or next compliance period. Allowance of borrowing of permit shortfall from next compliance year within the same commitment period. The maximum number of borrowing shall not exceed 1/10 of total number of permits, which the entity should surrender to the relevant agency.
Offsets (Article 29 and the Article 38 of the Enforcement Decree of the Act)	Offsets in compliance with international standards can be used to meet the number of permits surrendered by an entity. The number of offsets should not exceed 10% of the total permits required to be surrendered. In addition, the offsets generated from projects in foreign countries should not exceed the 50/100 of the total offsets.
Financial Support (Article 35)	Using the proceeds of auctioning allowances, penalty surcharge, and fines, the government will financially support efficiency enhancement, energy savings, new and renewable energy technology development and deployment, GHG storage technology, advanced verification methods, advanced GHG emission statistics systems, etc.
Penalty (Article 33)	The penalty for non-compliance is three times the permit price in the market but the penalty surcharge per ton of CO_2e will not exceed 10,000 KRW.
Fine (Article 31)	A fine of less than 1,000,000 KRW will be imposed on the person who makes a false report on the exchange of permits or the amount of emissions.

Source: ("Act on the Allocation and Trading of Greenhouse Gas Emissions Permits," 2012)

As previously described, when it starts in 2015 the cap-and-trade scheme will be very flexible to facilitate participation of corporate entities. However, specific allocation methods (e.g., grandfathering, benchmarking) have not yet been determined. Based on currently available information, this study will evaluate the comprehensive impacts of the implementation of the cap-and-trade scheme in the future.

2.2 Cap-and-Trade: Conflict of Efficiency and Equity

As discussed in the previous section, emissions trading schemes have proliferated worldwide. Every program pursues maximizing efficiency – reducing emissions with the least cost – by providing assistance for the trade-exposed and energy-intensive industries. However, not every program has measures to relieve the regressivity[11] that results from the implementation of the trading scheme.

In this section, this study will review two principal aspects of cap-and-trade: equity and efficiency. This section explains why the emissions trading program is efficient, and how this program has different distributional implications across different groups.

2.2.1 Cap-and-Trade: Tool of Efficiency

Cap-and-trade programs are one of multiple approaches to internalize the cost of GHG emissions emitted beyond the natural level of emissions (due to anthropogenic interruption). According to Coase (1960), externalities can be eliminated effectively if property rights are appropriately assigned, regardless of who receives the rights. Internalization of the externality can be achieved by clarifying the right to employ a source through imposing a price like a carbon tax or GHG emissions trading. As both approaches recognize the cost of emissions and take the cost into account during the decision-making process, polluters are motivated to reduce their

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[11]The regressivity illustrates that the burden of a tax is greater on the poor than the wealthy. In contrast, progressivity refers to the situation where the burden of a tax is heavier on the wealthy than on the poor.

emissions to the level where the MAC (marginal abatement cost) equals the MAB (marginal abatement benefit) (IEA, 2001). The MAB curve slopes downward because avoided damages would decrease with an additional abatement of GHG emissions. The MAC curve slopes upward because avoided cost would increase with an additional abatement of GHG emissions. It becomes more difficult to reduce GHG emissions according to an additional unit of abatement because emissions easily reduced (low-hanging fruits) are taken first. Therefore, an entity will stop mitigating emissions at some point where the MAB no longer exceeds the MAC.

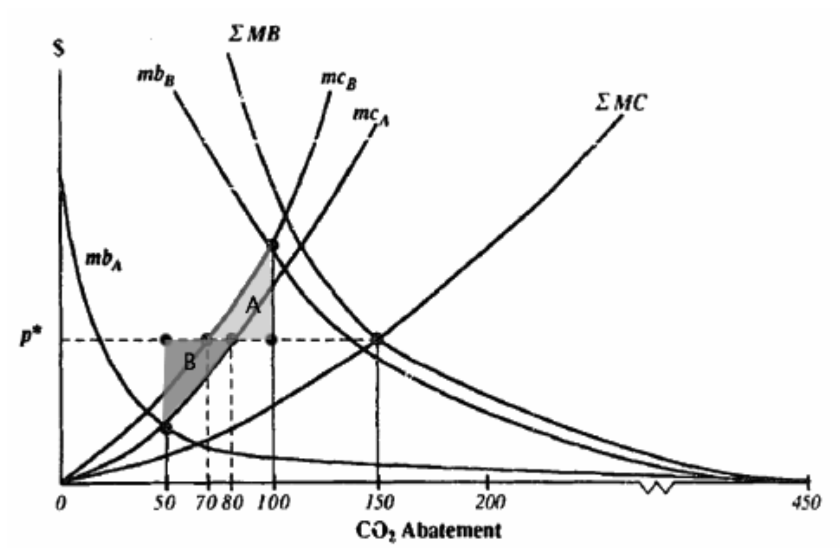

Figure 2.2 An Example of Permit Trading

Source: (Rose & Stevens, 1993)[12] modified

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[12] Suppose that total emissions of country A and country B is 450 (170+280) units.

In this section, the strength of an emissions trading scheme will be illustrated using the example in Rose and Stevens' study (1993). They illustrate the efficiency of cap-and-trade programs, using a two-country example (See Figure 2.2) (which assumes only two nations exist on the planet). The global optimum level of CO_2 abatement is 150 where the global MAB ($\sum$ MB) intersects with the global MAC ($\sum$ MC)[13].

Under an independent participation strategy, each country would cut its emissions by the amount where each nation's MAB equals its MAC. Country A would reduce its emissions by 50 units because its MAB (mb_A) equals the MAC (mc_A) at that point. Country B would reduce its emissions by 100 units because its MAB (mb_B) equals its MAC (mc_B) at that point. Due to the characteristic of the atmosphere as a commons or a public good, the benefit from protecting climate is not exclusive. Country A can enjoy the same amount of benefit with less effort while country B needs to pay more cost in order to protect the atmosphere. It is unfair from the perspective of country B, therefore, it would not elect to participate in this independent participation strategy. In reality, this independent mitigation strategy would not be implemented because it is neither equitable nor efficient.

However, it is possible to achieve the same amount of reduction more efficiently through trading. If emissions trading takes place between country A and country B, it will equalize MAC at the level of p* (market price of the emission

[13] The global MAB is the vertical summation of MAB of two countries and the global MAC is the horizontal summation of MAC of two countries.

permit). As a result, country A abates its emissions by 80 units, and country B abates emissions by 70 units. Country A can sell their additional 30 abatement units to country B. The benefit of selling the permits is indicated on the figure by the triangular area B. Country B can also save costs by buying 30 units of permit at a lower permit price (p*) to meet its original abatement target. The triangular area A represents the cost savings achieved through buying permits. From the perspective of a whole society, the net benefit equals the sum of the areas of triangle A and triangle B. Therefore, cap-and-trade is a more cost-efficient method compared to individual efforts.

This example implies that an increase in comprehensive participation yields higher efficiency. The importance of comprehensive participation, such as an internationally harmonized carbon tax or international cap-and-trade programs, is widely recognized in numerous journals. In developing countries, final energy consumption efficiency and thermal generation efficiency are lower. In addition, environmental regulation is less strict than in developed countries. Therefore, marginal abatement cost is much lower in developing countries. Even though higher-income nations compensate for the participation of the lower-income countries in these efforts, the total cost could be less than that of limited participation (Seidman & Lewis, 2009).

As noted earlier, the efficiency of cap-and-trade programs has also been proven in reality by the success of SO_2 and NO_x cap-and-trade programs in the U.S. According to the EPA (2004), the cost of compliance with these programs has been substantially lower than expected.

2.2.2 Equity Issues related to Cap-and-Trade

According to Kverndokk and Rose (2008), equity issues related to cap-and-trade programs can be examined at different scopes. They can be discussed between different time frames or within a specific time. As the authors indicate, the impacts of climate change can be sizable in the future due to the characteristic of the long atmospheric lives of GHGs. As a result, intergenerational equity issues exist in cap-and-trade programs – how cap-and-trade contributes to relieving the burden of climate change on the future generation. At a specific time, equity issues can be discussed according to dimensional scope: [1] international equity; [2] interregional equity; [3] inter-sectoral equity; and [4] interpersonal equity (Kverndokk & Rose, 2008).

Since climate change is a trans-boundary problem, international emissions trading and/or international carbon taxes can reduce the total cost to reduce GHG emissions. However, it is very difficult to achieve comprehensive participation in the systems due to issues of equity. Developed countries have contributed more to the causes of climate change than developing countries, which need to grow in order to achieve a certain standard of living that is currently enjoyed by developed countries. The mitigation effort can slow down or harm economic activities in developing countries. In order to expand the commitment to GHG mitigation, international programs focus on how to distribute the allowances or targets in a more equitable manner.

The dimensional scope of the equity implications of a cap-and-trade program is dependent on the dimensional scope of the program. Regarding international cap-and-trade programs, the international equity is frequently discussed and debated. In regional emissions trading schemes, such as the RGGI and the WCI, there is a focus on inter-regional equity issues induced by the implementation. When it comes to domestic programs, interpersonal or inter-household equity becomes an important topic of discussion.

Analyses of the inter-sectoral equity implications of cap-and-trade often describe and discuss the uneven distribution of impacts between sectors. Unlike other discussions on equity, this may not have received much sympathy. However, energy-intensive industries will be significantly negatively impacted due to the implementation of carbon pricing schemes. Even though the profit-motivated activities of these industries have been primarily responsible for anthropogenic climate change, the attention to inter-sectoral equity has recently drawn attention since the employees of the industry would be also affected. For example, employees of a coal industry can be laid off due to the increase in production cost after the implementation. The interpersonal equity aspects of cap-and-trade programs describe how the incidence of the burden will be distributed between different socioeconomic groups, different age groups, and/or different races and/or ethnicities.

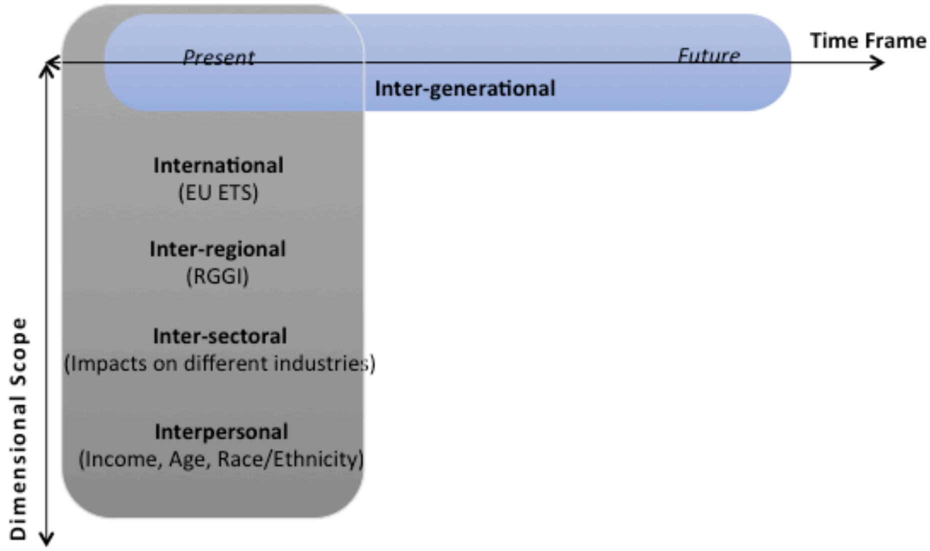

Figure 2.3 The Scopes of Equity Related to GHG Emissions Trading

In addition, the OECD clarified that distributional impacts should be considered in terms of two distinct but inseparable issues: [1] distribution of benefits of the policy and [2] distribution of its cost (as cited in Yusuf & Resosudarmo, 2007). Most literature does not account for the former because it needs a more comprehensive and additional analysis. For example, agriculture or forestry can benefit from the future avoidance of climate change that would result from a mitigation policy. Measuring the benefit would require a tool to analyze the impact on the biosphere, public health, etc. Therefore, it is harder to take into account both the benefits and the costs of the policy simultaneously.

Of course, the best option would be that every equity aspect be considered in a cap-and-trade program along with efficiency. The cap-and-trade scheme, which will begin in South Korea in 2015, is a domestic scheme. Among inter-regional, inter-sectoral and inter-personal equity, distribution of the impacts between different sectors already have been analyzed in several studies although they were not studied or viewed in respect to the equity dimension. In addition, industrial sectors such as the steel industry will be the most adversely affected in South Korea. The sector has taken part in the process to design the scheme by claiming that the impacts will aggravate the industry's competitiveness. As a result, the scheme has become less strict and more flexible.

Unlike the industrial sectors, the interpersonal distributional impacts of cap-and-trade programs have rarely been studied in South Korea. In fact, the public meetings that were held as a part of the legislative process neglected to collect the opinions and interests from a variety of groups. Therefore, in the case of South Korea, the priority of this study falls on the interpersonal equity implications of the scheme. This study will evaluate the distributional implication as well as impacts on economy, energy and environment of the implementation of a cap-and-trade scheme in South Korea in order to suggest a better scheme design in terms of equity as well as efficiency.

2.2.2.1 Cap-and-Trade: How Cap-and-Trade Programs Have Distributional Impacts

Fullerton (2009) discussed six ways that environmental policies may have distributional impacts: [1] if an environmental policy increases production costs, then it may raise a price of output and affect consumers (called forward-shifting), [2] if it reduces the output, then returns to factors such as labor or capital may be reduced; therefore it will affect capital owner and workers (called backward-shifting), [3] due to emission quotas, firms receive scarcity rents[14] and it means additional profit to these firms,[4] the benefit from the policy is disproportionately distributed between different groups, and it is usually progressive because low-income individuals may place more value on other necessities than environmental quality, [5] if the benefit of the policy varies with location, then the benefit is capitalized through land and house prices (capitalization effects), and [6] if a skilled worker in a specific industry is laid off due to the reduced size of the industry caused by a regulation, there will be a loss in human capital (distributional effects of changes in human capital during the transition). Figure 2.4 illustrates how an environmental policy has distributional impacts in these six ways. In general, among these ways, the forward-shifting contributes to a notable part of the incidence of an environmental policy.

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[14] "Any constraint on emissions … will limit those emissions, thereby giving value to the right to emit and creating what economist call scarcity rent. The most familiar example of scarcity rent is the purchase price or rent paid for the use of land. … When a cap is chosen as the means to limit emissions, the scarcity rent is embodied in the allowances …. but we should always remember that the value embodied in allowances reflects the scarcity created by the cap" (Denny, 2010, p. 468).

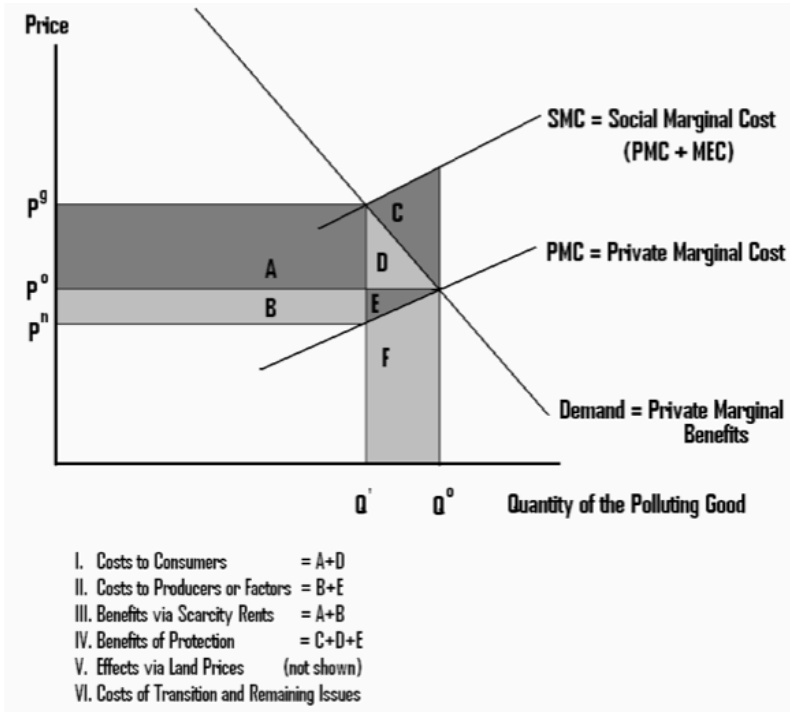

Figure 2.4 Six Ways that Environmental Policies Impacts Distributions

Source: (Fullerton, 2009)

A carbon price will influence patterns of production, consumption and investment. The legal incidence – who or which sector shall reduce its emissions – usually falls on an industry of which emissions exceeds a specific amount. However, the burden is ultimately borne by customers, workers, or shareholders, regardless of who takes legal incidence. "[t]he costs of compliance are passed on through changes in consumer prices, stock returns, wages, and other returns to factors of production" (Grainger & Kolstad, 2010, p. 1). By increasing prices, most sectors will pass most of the compliance cost on to customers, (i.e. the cost to purchase permits).

In multiple industries, production costs can increase due to the legal incidence of a carbon price. For instance, the chart below illustrates how a legal incidence of a cap-and-trade program on industry sectors (such as coal mining, coal-fired electricity generators, petroleum refiners, meat or dairy producers and fertilizer producers) results in a burden on households in the form of higher consumer prices (Garnaut, 2008). Furthermore, the incidence of carbon pricing is disproportionately distributed among different income groups. In general, carbon pricing shows regressivity in developed countries; low-income households would bear more costs than high-income households.

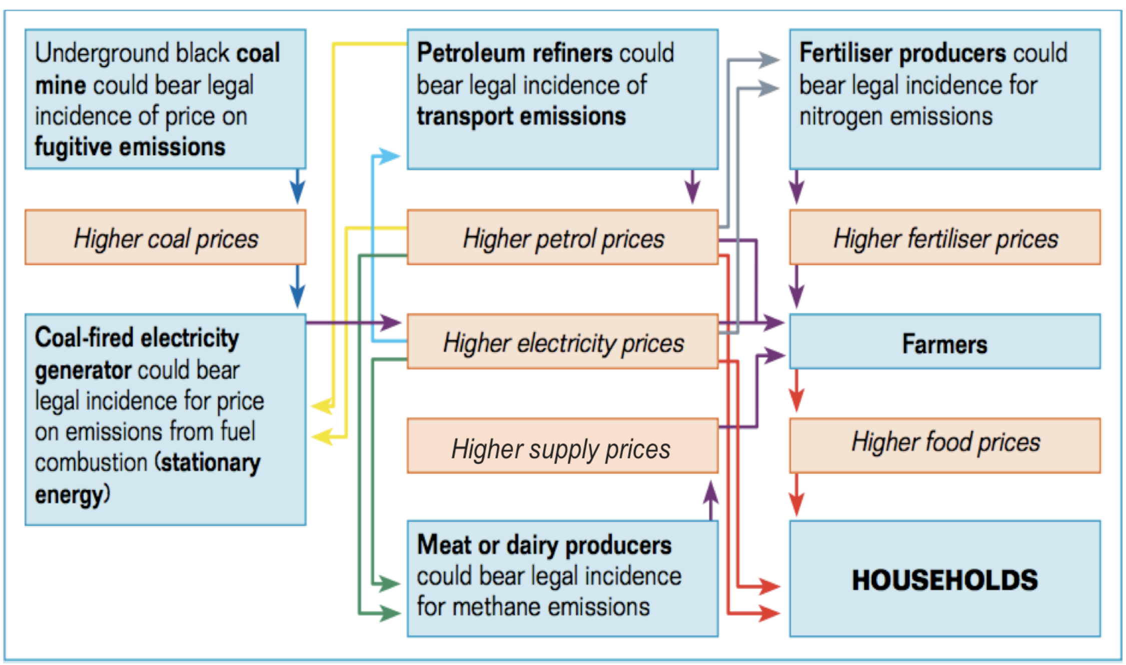

Figure 2.5 Who pays the emissions permit price?

Source: (Garnaut, 2008) modified

This pass-through of the reduction cost through the supply chain is called forward-shifting. The cost of carbon pricing is passed forward to consumers, either in the form of higher energy prices, or in the higher prices of energy-intensive goods and services. Of course, a policy has backward-shifting effects as well as forward shifting effects. While the cost of carbon pricing falls on customers through the supply chain (as mentioned above) under forward-shifting, the cost will rest on producers when customers do not purchase products at increased prices under backward-shifting. At this point, sellers are forced to lower prices and bear the burden of that tax by themselves. The magnitude of forward or backward shifting of carbon pricing depends upon the elasticity of demand for price change[15] as well as the production technology.

If the price elasticity of demand is lower than that of supply – if there are few substitutes, and customers cannot notably change their consumption – the customers will bear more burdens. In Figure 2.4, the area of A and D indicates the burden on customers, and the area of B and E is the burden on producers. If an industry produces output based on fixed proportion technology, there will not be changes in relative factor demands and prices. In that case, every burden is passed on to customers.

[15] Price elasticity of demand for price change explains how sensitively demands change depending on changes in prices. If the price elasticity is greater than one, the change in price impacts greatly demand. When the price elasticity is less than one, the change in price has relatively small impact on the demand. (Since these values are always negative, the sign of these values is often left out.)

According to Bovenberg and Goulder (2001), the producer would bear 10% of the burden of carbon pricing, but the share would increase to 25% in 2050, as customers find substitutes for oil in the long run (as cited in Rausch, Metcalf, & Reily, 2011). Raucsh et al. (2011) did a Computable General Equilibrium (CGE)[16] analysis and found that a significant portion of carbon prices were shifted backward to producers – most notably, the owners of natural resources and capital, which could somewhat offset the regressivity of a carbon price. However, most studies assume the burden of a carbon price is shifted forward (Rausch et al., 2011). In addition, as this study aims to analyze the impacts of a carbon pricing policy in the short run, the incidence shifted backward to producers is likely to be small. Therefore, this study will assume the burden of the implementation is 100% passed on to the customers.

2.3 Interpersonal Equity Implications of Cap-and-Trade

As was noted earlier, the research priority falls on the efficiency as well as the interpersonal distributional impact of the implementation of a cap-and-trade program in South Korea. This section provides a brief and preliminary survey of income distribution impacts of a carbon pricing policy. A literature review can assist us in understanding how the implementation distributes the burden in both developed and developing countries. Studies for South Korea are reviewed in a separate section.

[16] The CGE model is a well-known top-down economic model that consists of a series of equations describing behaviors of agents and finds a new equilibrium depending on the changes in relative prices.

2.3.1 Interpersonal Distributional Implications of Cap-and-Trade in Developed Countries

In general, literature shows regressivity of carbon pricing in developed countries, which means that the impacts are disproportionately distributed across the different income groups. In other words, the poor expect to pay more (or gain less) than the rich due to the implementation of cap-and-trade programs because of the expenditure profile. The poor spend relatively more money on energy than the rich compared to their income level. In contrast, the opposite is true in developing countries. However, revenue recycling can offset the regressivity.

Rather than using a complex model to simulate the cap-and-trade program, an assortment of studies has simulated the introduction of a carbon tax in their model. When the permit price is equivalent to the tax rate, the reduction of emissions is theoretically identical. In the short term, a carbon tax cannot guarantee how much the emissions will be reduced while the abatement cost will be known. Based on this information, a participant will undertake reduction measures until the abatement cost is equivalent to the tax. In contrast, a cap-and-trade cannot guarantee the permit price level to achieve the target while the amount of reduced amount of emissions will be known. In the long term, by increasing the carbon tax, the government can know the tax rate required to meet the reduction target. By changing the amount of allowances or the reduction target, the permit price level can be estimated. Theoretically, when an identical reduction target is pursued by both policy measures, the fully auctioned permit price is equivalent to the carbon tax in the long-term (Rausch et al., 2011;

Seidman, 2009). This study mainly introduces studies that analyze equity implications of carbon taxes.

Grainger and Kolstad (2010) found that the incidence of a carbon tax is disproportionately distributed between different income groups in the U.S and they argued that revenue recycling could offset this regressivity. Using the carbon intensity of each product, the burden of a carbon price of \$15/ton of CO_2 on multiple U.S. households with different incomes in 2003 was estimated by using the Carnegie Mellon Model[17] and the Consumer Expenditure Survey (CEX) survey in 2003. Different units of measurement were used, such as burden to annual income, burden to lifetime income[18], burden to equivalence-scale[19]-adjusted annual income, and burden to equivalence-scale-adjusted lifetime. The incidence of carbon pricing is regressive regardless of which different unit is used. On the basis of the burden to annual income,

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[17] A 1997 U.S. input-output model developed by researchers at Carnegie Mellon University.

[18] Because annual income is volatile – a household's annual income can be reduced temporarily because of education or healthcare costs in a certain year—lifetime income is a better unit of measurement. However, it is difficult to estimate lifetime income. In this study, the authors used annual expenditure as a proxy for lifetime income because current expenditure theoretically reflects expectations for future income.

[19] Due to the different household size, the result can be distorted. The regressivity of a policy can be understated. Cutler and Katz pointed indicated "[s]ince wealthy households are larger, on average, this inflates income of the poorer households, all other things being equal" (as cited in Grainger and Kolstad 2010; p.15). However, a household income should not be divided by its size due to the economies of scale in consumption. Therefore, equivalence scale is used for adjusting household income based on household size, which also accounts for economies of scale.

the burden on the poorest income groups is almost four times as much as that on the wealthiest households. In addition, the degree of regressivity varies with the program design as well as units of measurement. Per capita incidence to equivalence-scale-adjusted income is much more regressive: the burden on the lowest income group is seven times greater than that on the highest income group. If carbon price is imposed only on final energy consumption, it will be twice as regressive as it is applied to all CO_2 emissions.

The results of Feng, et al. (2010) also identified the regressivity of a carbon pricing policy in the U.K. In addition, they also assessed inequitable distribution of the burdens induced by the climate change taxation between different regions. They estimated the effects of a CO_2 tax and a GHG tax on different income groups and different lifestyle groups in the U.K. using an input-output model with specific expense data on a variety of consumption goods by groups. Lifestyle groups were classified by income levels, socioeconomic factors, and physical environment. For instance, the "Rural Isolation" group, which includes people who live just outside of the city or in a remote area, have lifestyles that rely heavily on their community and the natural environment.

The authors estimated the tax rates using the marginal abatement cost curve and the mitigation target in the U.K., while Grainger and Kolstad (2010) externally chose a carbon price of $15/ton of CO_2. 56£ per ton of CO_2e is imposed when the program covers all the GHG emissions (GHG tax) and 93£ per ton of CO_2e is imposed when it targets only CO_2 emissions to reduce the emissions by 122 million tons of

CO_2e. The results show that a GHG tax is more efficient than a CO_2 tax: there was an average price increase of 5.6% under the CO_2 tax, compared to 4.3% under the GHG tax. As there are more available reduction measures in the case of a GHG tax, the marginal abatement cost becomes lower under the GHG tax. However, the authors stated that a CO_2 tax would be favored by the agriculture sector because if a GHG tax were implemented, this sector would have incurred more burdens due to high emissions of methane or N_2O.

Although the GHG tax was more efficient, both taxes were regressive in the U.K. A tax shift from a CO_2 tax to a GHG tax would relieve the degree of regressivity. They also analyzed the impacts of carbon charges on different geographical groups. The results showed that different lifestyle groups have a different capacity to respond to higher prices due to carbon charges. Due to their higher dependence on vehicles for transportation, rural people are more adversely impacted than urban people. In the absence of a change in infrastructure such as low carbon transportation, the emissions of rural people will remain similar. Their findings showed that appropriate compensation for low-income households and investment in low carbon infrastructures would be required to respond to the unequal distribution of the burden.

Blonz, Burtraw and Walls. (2011) confirmed that cap-and-trade programs with revenue recycling could make poor and/or elderly households beneficiaries of the program in the US. Using similar methodology to Feng, et al. (2010), they assessed how the burden of a cap-and-trade program would be distributed depending on g incomes, ages, and regions. They evaluated three scenarios: the Waxman-Markey optimistic case[20], the Waxman-Markey pessimistic case[21], and a cap-and-dividend approach.[22] All of the policy scenarios proved to be effective for protecting poorer households due to the Low-Income Energy Rebate Program in the Waxman-Markey bill and the equal per-capita rebate in the cap and dividend case. Rather than paying the additional cost due to the implementation, the lowest income group would benefit from implementation: 0.21% of income in the optimistic case, 0.13% of income in the pessimistic case, and 0.74% of income in the cap-and-dividend case. Under both Waxman-Markey cases, the middle-income group would take the largest burden, while the lowest income group was protected. The 3rd poorest decile would spend 0.42% of income in the optimistic case, and 1% of the income in the pessimistic case, while the wealthiest group would spend 0.10% of income in the optimistic case and 0.58% of income in the pessimistic case, respectively.

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20 The Waxman-Markey bill, otherwise known as the American Clean Energy and Security Act, was passed by the House of Representatives in 2009, but it did not become a law. This bill attempted to establish an emissions trading scheme similar to the EU-ETS, setting an annual cap on 85% of all U.S. emissions from 2016.

21 The Waxman-Markey optimistic case is different from the Waxman-Markey pessimistic case according to the assumptions of energy efficiency, energy R&D, technology development, and renewables. Whereas the optimistic case assumes benefits from investment in energy efficiency, etc., the pessimistic case does not allow the benefits from those efforts. The benefits from the investment are as follows: reducing electricity demand and changing energy mix, providing substantial benefits to the households.

22 This scenario recycles the proceeds from auctioning as an equal per-capita dividend or refund to each household.

The cap-and-dividend would be progressive. In addition, the older households would be protected successfully under all scenarios, however, the burden on older households was relatively higher under the pessimistic case. Furthermore, the elderly and low-income households would be better protected. In addition, their evaluation of distributional impacts by regions shows that geography matters less than policy scenarios do. A region with more energy-intensive industries does not necessarily mean a heavier burden on households within the area, because those industry products are distributed across the countries.

Rausch, et al. (2011) assessed impacts of a carbon pricing at $20 per ton of CO_2e on 15,588 households in the U.S., either through a cap-and-trade system or a carbon tax. They found that the distributional impact of carbon pricing could be less regressive – or even progressive – if the source-side effects were considered together with use-side effects. Contrasting with previous studies using the partial equilibrium approach, Rausch, et al. (2011) used a static large-open economy CGE model to evaluate the impacts of carbon pricing on different sectors and industries, on different regions, and on different income groups. They tested three different scenarios according to the revenue recycling methods: [1] income tax reduction, [2] equal per capita lump-sum transfers, and [3] lump-sum transfers proportional to capital income.

The net cost would be lowest in the case of income tax reduction along with clear regressivity, while the incidence of the equal per capita rebates case would be progressive. By integrating massive data (such as expenditure patterns, income sources, and information on demographic variables) into the model, they provided comprehensive implications of a carbon tax similar to Blonz et al. (2011). Furthermore, Rausch, et al. (2011) evaluated the incidence of a carbon tax by race/ethnicity; they found that a black person as the head of household would bear a higher burden than a household with a white person (or other race/ethnicity) as the head due to differences in expenditure profiles.

Rausch et al. found that source-side effects of carbon pricing were progressive, while the first three previously reviewed studies assumed the burden would be perfectly passed on to customers. The source-side burden ranges from 0.36% of income for the lowest income group to 0.70% of income for the highest income group. This occurs because returns to capital, consisting of a larger share of income for high-income households, decrease compared to wage. As these source-side effects are strong enough to offset the use-side effect, Rausch et al. indicate that the impacts of carbon pricing would be less regressive or can be progressive in contrast to general findings in a great deal of literature.

2.3.2 Interpersonal Distributional Implications in Developing Countries

Due to a lack of experts and a corresponding lack of data, literature on the distributional impacts of carbon prices in developing countries is much less than that in developed countries. The regressivity of carbon pricing does not hold in developing countries because the expenditure patterns are notably different in such areas.

Yusuf and Resosudarmo (2007) found that the net-impact of a carbon tax is progressive for all scenarios in Indonesia - the rich would bear more burden than the poor. The distributional implication of carbon tax scenarios was evaluated using a CGE model with a massive social accounting matrix including 100 different income centiles in urban and rural areas. The scenarios were divided into no-recycling, uniform tax reduction, and uniform lump-sum transfers based on the revenue recycling method. The impact on households in rural areas is progressive under all scenarios. In urban areas, it depends on tax-recycling scenarios; it is relatively neutral for the no-recycling case and uniform tax rate reduction case, and progressive for uniform lump-sum transfer cases. The authors indicate that the source of the progressivity comes from the lifestyles of Indonesians. The low-income households in rural areas are less energy intensive in Indonesia than in developed countries, because energy demand for heating is low due to a warm climate. Also, passenger cars are luxuries (and not necessities) in that country. Additionally, less energy-intensive industries, such as agriculture or services, account for a greater percentage of the national economy.

Brenner, Riddle and Boyce (2007) found that the incidence of carbon charges with or without equal per capita dividend would be progressive in China and it would contribute to the eradication of poverty. Utilizing carbon intensity estimates of six products and representative households' expenditure surveys in 1995, they assessed distributional implications of a carbon charge of 300 Yuan per metric ton (about 48 USD) of carbon. Similar to the findings of Yusuf and Resosudarmo (2007), the carbon charge is progressive in China because the wealthy group's lifestyle depends on relatively more carbon-intensive products. The poorest decile spends 2.1% of their expenditure on carbon-intensive goods, while the wealthiest decile spends 3.2%. Due to the lower dependence on energy or energy-intensive products in rural households, the burden is lower in rural households; urban households would pay on average 3.3% of their expenditure for carbon charges, while rural households would pay 2%. With an equal per capita payout using the proceeds of carbon charges, every Chinese would get 69 Yuan (about 11 USD) per person, which brings about more progressivity. Seventy percent of the total population would be net beneficiaries from the implementation of this policy. In addition, poverty would be reduced. Due to the socioeconomic characteristic – urban residents' incomes are much higher than rural residents' incomes—this policy would lead to benefits for 90% of rural households, while penalizing 90% of urban households.

As the OECD argued (as cited in Yusuf & Resosudarmo, 2007), the findings by Yusuf and Resosudarmo (2007) and by Brenner et al. (2007) show that the regressivity of carbon pricing policies does not hold in developing countries. Brenner et al. (2007) said that the distributive effects of carbon prices in developing countries in Asia, Africa, etc. should be left as an open question.

Table 2.5 Literature Review on Distributive Implications of a Carbon Pricing Policy

Literature and Country studied	Methodology and Data	Distributive Implications
Grainger and Kolstad (2010) USA	Methodology: An input-output model based on the 1997 US economy (CMU Model) Data: The 2003 CEX Survey	Whichever different units of measurement are used, carbon tax is regressive. The level of regressivity of the carbon price would vary with the breadth of policy. - Carbon price only on final energy consumption is most regressive.
Feng et al. (2010) UK	Methodology: An environmentally extended input-output model Data: geo-demographical database Consumer expenditure data	A shift from a GHG tax to a carbon tax relieves the burdens on different income groups. Due to the different abilities of different lifestyle groups, the burden of carbon charges varies with geo-demographical status.
Blonz et al. (2011)	Methodology: Partial equilibrium method (CO_2 content in households' expenditure in 2016 was estimated, reflecting changes in production and consumption in the future, which was projected by the EIA.) Data: The CEX Surveys from 2004 through 2008	The burdens on households are lower under the optimistic case. Poorer households are protected under all of the policy scenarios.
Rausch et al. (2011) USA	Methodology: A static large-open CGE model (MIT USREP) with detailed data of 15,588 households Data: The 2006 Consumer and Expenditure Survey (CEX) 2006 Social Accounting Matrix Physical energy and price data from 2006 State Energy Data System	Varies with revenue recycling scenarios - Income tax reduction case is regressive but the total net cost is lowest. - Equal per capita rebates are progressive. With a massive data set, finer implications can be achieved. If source-side impact is considered, so the total net cost will be less regressive.
Brenner et al. (2007) China	Methodology: carbon emissions estimates of expenditure of households Data: Representative household income and expenditure survey in 1995 China Statistical Yearbook 1995	A carbon charge is progressive. Equal per capita payout will add more progressivity. - 70% of Chinese population will be beneficiaries: 90% of urban population will be losers while 90% of rural population will be winners.
Yusuf and Resosudarmo (2007) Indonesia	Methodology: CGE model (based on ORANI-G model) with 200 households Data: Indonesian Social Accounting Matrix 2003 Statistics of Indonesian Energy Balance	The national net-impact is progressive for all scenarios. The impact in rural areas would be progressive but it depends on tax-recycling scenarios.

2.3.3 Distributional Impacts of Cap-and-Trade in South Korea

In the previous section I have reviewed several studies, which explored the distributional impacts of carbon pricing mechanisms in both developed and developing countries. The interpersonal equity implications of carbon pricing in South Korea have not attracted much interest of researchers. Only Seung-Rae Kim and his colleagues have continuously studied this issue in South Korea. There are few studies evaluating the impacts of cap-and-trade by regions, however, their studies were not extended enough to discuss the regional equity problem.

S. Kim and J. Kim (2010) concluded that carbon taxes would be regressive. Using the same methodology and data of his previous study (input-output analysis with micro-data of households' expenditure)[23](Kim, Park and Kim., 2008), they evaluated distributional impacts of five different energy tax reform scenarios: [1] imposing a carbon tax of 25 €/tC on the existing energy tax, [2] increasing the existing energy tax by the average OECD tax level, [3] increasing the existing energy tax according to the inflation rate, [4] increasing the existing energy tax to reflect the social cost (except CO_2 avoidance cost), and [5] implementing all four reforms simultaneously. The Gini coefficient[24] was exacerbated under all of the scenarios. In addition, the changes in the Gini coefficient ranged from 0.2% in Scenario No. 3 to 1.2%

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[23] S. Kim et al. (2008) analyzed distributional impacts of a carbon tax of 25€/tC on fuels. The results are exactly the same in their study in 2010.

[24] The Gini coefficient measures the inequality in income distribution. The value ranges from zero (perfect equality where everyone has the same income) to one (perfect inequality where only one person has all the income).

in Scenario No. 5.   They found that the expenditure profile on transportation fuels – the richer spend much more on gasoline – contributed to modest regressivity. This increase in expenditure on gasoline might significantly offset the regressivity generated from the increased expenditure on other fuels.

M.Kang et al. (2011) found that carbon taxes would be slightly regressive in South Korea. Using an input-output model with Household Survey Data in 2009, they evaluated the energy tax reform. With the assumption of a downstream carbon tax, they tested two scenarios according to the tax level: Scenario No. 1 imposed 25€/tC on fuels, and Scenario 2 imposed an average carbon tax of major countries on fuels. The increases in fuel taxes were much less in Scenario 1. Analyzing the distributional implication of scenarios using the Kakwani index[25], the incidence of both scenarios was regressive; but Scenario 2 is less regressive. In addition, they found that expenditure on anthracite coal and kerosene increased most in the lowest income decile. However, the authors did not explore increased costs related to indirect emissions from expenses for goods and services. Therefore, the results of the distributional impacts of carbon taxes are incomplete. While other studies in developed countries used the burden to income /the relative burden (the share of the cost compared to the income) as a unit of measurement to show the distributional

[25] Kakwani Index is utilized to analyze the distributional impacts of a tax. If it is larger than 0, it means the tax is progressive. Vice versa is regressive. If it is 0, the tax is proportional.

impacts of carbon charges, these two studies showed the distributional impacts using the specific indices such as the Gini coefficient and the Kakwani index.

Besides studies on the interpersonal distributional impacts of carbon pricing schemes between different-income households, Noh's (2009) study explored regional equity implications of a cap-and-trade scheme. The author found that the impacts of carbon charges[26] on energy demand would be different across six regions due to the different energy demand elasticity in each region. Using the CGE model, he tested five different carbon pricing scenarios: [1] business as usual (BAU), [2] different carbon taxes by regions in order to achieve 5% emissions reduction compared to BAU emissions by 2020, [3] cap-and-trade with a 5% reduction target, [4] different carbon taxes by regions to achieve a 10% reduction target compared to BAU emissions by 2020, and [5] cap-and-trade with a 10% reduction target.

The costs were unequally distributed between regions. For instance, while the Gross Regional Domestic Product (GRDP) increased in the Jeolla province and Geoyngbuk, the GRDP declined in the Gangwon region, Chungchung region, and Geoyngnam region under cap-and-trade with a 5% reduction target scenario, which resulted from trading permits. The findings show that mitigation scenarios exacerbated regional inequity. Also, most reduction is from outside of the Seoul

[26] The author tested five carbon pricing scenarios: 1) BAU, 2) different carbon tax by regions (5% reduction compared to BAU emissions by 2020), 3) cap and trade (5% reduction), 4) carbon tax by regions (10% reduction compared to BAU emissions by 2020), and 5) cap and trade (10% reduction)

Capital Area, as the area depends less on energy-intensive industries, and depends almost entirely on electricity produced elsewhere.

Other than Noh's (2009) study, J. Kim (n.d.) found that the existing gap in regional economic activities would increase due to the implementation of carbon-pricing mechanisms. Similar to the findings of Noh (2009), the implementation would more adversely impact the regions where energy-intensive industries or electricity plants are located. As a result, the mitigation policy, without appropriate measures to relieve this problem, would aggravate the gaps between regions. In addition, the author also found that a significant proportion of emissions reduction in the Seoul Capital Area would be passed on to other regions when cap-and-trade is implemented. It is important that Noh (2009) and J. Kim (n.d.) explored the regional equity implications of cap-and-trade.

Table 2.6 Literature Review on Impacts of a Carbon Pricing Policy on South Korea

Literatures	Methodology and Data	Main Findings
S. Kim and J. Kim (2010)	Methodology: Input-output model with micro-database Data: Input output table 2007 Household Survey Data 2007	Carbon tax was regressive, but it was relatively less regressive due to the progressivity of carbon taxes on transportation fuels.
M. Kang et al. (2011)	Methodology: Input-output model with micro-database Data: Input output table 2009 Household Survey Data 2009	Carbon tax would be regressive, but it would be less regressive than if the average carbon tax in major countries were applied. The cost increase in dirty fuel such as anthracite and kerosene was much higher in the lowest income decile.
Noh (2009)	Methodology: MARKAL, CGE Data for CGE: 2005 RSAM for 6 regions	The impacts are unequally distributed between regions and scenarios due to the different energy demand elasticity across regions.
J. Kim (n.d.)	Methodology: Dynamic CGE Data for CGE: 2003 RSAM for 6 regions	The impacts are unequally distributed between regions. The emissions that should have been reduced within the Capital area would be passed on to other regions in the cap-and-trade policy.

The regressivity of carbon pricing measures was also identified in South Korea, and the regional impact of the policy was explored in the preceding studies. However, the debate on equity – even in these studies – was not the primary problem; equity aspects of a carbon pricing policy served as supplementary analyses in these studies. While J. Kim (n.d.) mainly focused on regional distributional implications of cap-and-trade schemes, he failed to extend his analysis to suggest political recommendation. Reaching beyond previous studies, this study will explore impacts on economy, energy, and environment, as well as comprehensive distributional implications of carbon charges in South Korea: [1] the distributional implications of the implemenation between different income groups, [2] the distributional impacts between urban households and rural households, and [3] the incidence of the implementation cost, according to the age of the head of household. In order to discuss regional equity issues, it is required to construct regional I-O tables, which is very extensive work. Using the information that can be obtained from a Household Survey Data, analysis on regional distributions of the burden is limited to how the burden is distributed between urban households and rural households.

Chapter 3

CONCEPTUAL FRAMEWORK: THE E4 FRAMEWORK

The current cap-and-trade scheme depends on the "green growth" framework, which pursues environmental conservation together with economic growth. However, as noted earlier, cap-and-trade programs will impact not only economic growth and environmental conservation, but also social equity. Furthermore, its implementation in developed countries is likely to aggravate social equity by disproportionately distributing the burden. Therefore, there is a need to examine the equity implications of this policy and to take the implications into account in the design of the scheme. However, the current framework for the cap-and-trade scheme is too confined or biased to get more comprehensive implications. Therefore, the "green growth" framework needs to be revisited, and an alternative framework is required for comprehensive evaluation of the cap-and-trade scheme into order to provide appropriate suggestions to the existing scheme.

3.1 Criticism of Current Framework for Cap-and-Trade: Green Growth/Growth-biased Framework

On the 60th anniversary of National Foundation Day, 2008, former President Myung-bak Lee announced that *Low Carbon/Green Growth* (LCGG) would serve as a new national vision for the next fifty years. He claimed that Green Growth is a sustainable growth and a new national development paradigm, which can reduce GHG emissions and environmental pollution and create jobs based on green technologies and clean energy. The announcement emphasized the potential of green technologies in terms of economic growth and investments in green energy initiatives.

The OECD recommended green growth not "as a replacement for sustainable development, but rather as a means to achieve it" (as cited in OECD, 2013b : p20). However, the green growth framework in fact replaced the sustainable development framework in South Korea. Prior to the Lee administration, the policy was based on the sustainable development framework during the Moo-Hyun Roh[27] and Dae-Jung Kim[28] administrations. After Agenda 21 was adopted at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992[29], the Presidential Commission on Sustainable Development was organized to advise or consult on sustainable development and suggest reasonable solutions for social conflicts related to the economic development in 2002 (S. Kang, 2006). The Commission served both Kim and Roh's administration. In addition, the Framework Act on Sustainable Development was legislated to provide the legal foundation for both national and local governments in order to develop a basic strategy for

[27] He was the sixteenth President of South Korea from 2003 to 2008.

[28] He was the fifteenth President from 1998 to 2003.

[29] It is the first global environmental conference also called the Rio Summit or the Earth Summit.

sustainable development. The Framework would use sustainable development indices every 20 years in order to evaluate and disclose the status of the sustainability of each region. However, during Lee's administration the status of the Commission was lowered from the Presidential committee to the committee under the Minster of the Environment according to the revision of the Framework Act on Sustainable Development in 2010. In addition, the Framework Act on Sustainable Development was revised to the Sustainable Development Act. The Framework Act on Low Carbon, Green Growth has been legislated, major contents of the Act on Sustainable Development was deleted or absorbed to the Framework Act on Low Carbon, Green Growth. As a result, the Act on Sustainable Development became a law with no meaning (J. Kang, 2012).

The government established a *National Strategy for Green Growth* in 2009 in order to outline the specific goals and strategies for a green growth paradigm. The Strategy has three goals: [1] adapt to climate change and increasing energy self-sufficiency, [2] create new engines for economic growth, and [3] improve the quality of life and enhance the national status of South Korea in the world. The first goal consists of three agendas: [a] effective mitigation of GHG emissions, [b] reduce fossil fuel consumption and promote energy independence, and [c] strengthen the capacity to adapt to climate change. In order to efficiently reduce GHG emissions, several policy measures are outlined including the development of a national mid- or long-term GHG emissions reduction target and a national GHG inventory system, cost-effective sectoral reductions of GHGs, the spread of carbon disclosure and increase in carbon sinks. The cap-and-trade scheme will begin in 2015 in order to achieve the first agenda (Jones & Yoo, 2011; PCGG, 2009).

Figure 3.1 The Vision and the Structure of the National Strategy for Green Growth

Source: (PCGG, 2009)

Paul Ekins first proposed the concept of "green growth" in 1999. Since it was introduced at the Fifth Ministerial Conference of Environment and Development in Asia and the Pacific in 2005 (as cited in Yun, 2012), it has been discussed worldwide. In June 2009, ministers from 34 countries signed a *Declaration on Green Growth* and announced that they will "strengthen their efforts to pursue green growth strategies as part of our response to the current crisis and beyond, acknowledging that green and growth can go hand-in-hand" (OECD, 2011: p3). A growing number of developing countries including low-income countries are adopting green growth as their new development framework. Cambodia adopted a National Green Growth Roadmap, which emphasizes equitable access to natural resources or public services and the Master Plan is being developed to achieve this goal. Ethiopia developed the framework for green growth called the Climate Resilient Green Growth Economy Strategy, which aims to increase per capita GDP by 475% and to reduce GHG emissions by 35% by 2030 (OECD, 2013b). In addition to developing countries, South Korea and Ireland also have adopted green growth as part of their national development plan (OECD, 2009).

The green growth framework was originally suggested as an alternative economic growth model for developing countries, where enhancing the living standards of a growing population is a priority. The green growth framework was originally suggested as an alternative economic growth model for developing countries, where enhancing the living standards of a growing population is a priority. In addition, economic growth without sustainable management of natural resources will undermine the growth in the long term even though it increases growth and creates jobs in the short term. The economies of developing countries are different from those of developed countries. They rely more on the agriculture or fishery sectors, which are more reliant on natural resources. According to an estimation by

UNEP, ecosystem services contribute from 47% to 90% of the income in poor countries. Therefore, inappropriate management of natural resources will result in a more serious consequence in developing countries (as cited in OECD, 2013b). In addition, current exploitation of natural resources is already beyond ecosystem resilience (for example, we are facing climate change). If by 2025 energy use in developing countries approaches that of developed countries, present global energy consumption will increase by factor of five. In addition, if the additional energy demand is supplied with fossil fuel, we will encounter more serious problems than those of which we currently face (WCED, 1987). In order to enable developing countries as well as developed countries to sustainably develop within our planetary ecosystem while avoiding the environmental degradation that results from the economic growth that developed countries have experienced over the past decades and centuries, an economic growth model based on eco-friendly and advanced technologies, and green growth was proposed for developing countries (UN Economic and Social Commission for Asia and the Pacific [ESCAP], 2012).

Green growth aims at pursuing sustainable economic growth without adversely impacting the environment through improving eco-efficiency or decoupling the correlation between economic growth and environmental degradation. Improving eco-efficiency can be achieved by supporting eco-friendly technologies (e.g., making renewable energy technologies more competitive than conventional energy technologies by significantly investing in renewable energy sources). Under the green growth framework, economic growth can protect the environment; thus, environmental protection can result in economic growth (ESCAP, 2012).

The green growth framework is said to be more concrete and more feasible than the sustainable development framework, in that green growth can be achieved by improving eco-efficiency (PCGG, 2009). In addition, the green growth framework is also praised for successfully including all important pillars of the sustainable development framework: economic growth, social equity and environmental protection (ESCAP, 2012). However, there are notable flaws in the LCGG framework.

The principal goals of sustainable development are in reference to environmental protection, social justice, and economic growth; sustainable development pursues these three goals in a balanced manner. Although ESCAP (2012) argues that the green growth framework adds equity to the three aforementioned dimensions, in South Korea the green growth framework is significantly biased towards two dimensions: environmental protection and economic growth. In addition, according to the definition of green growth, it is quite natural that the equity dimension is easily neglected.

Yun (2012) analyzed the green growth framework of South Korea using Connelly's triangular map. Connelly (2007) developed a way to visualize policies or norms or debates on his triangular map where three fundamental priorities including economic growth, environmental protection and social justice are located on each point. A discourse can be located on this triangle based on which point is emphasized.

For example, the growth-only framework located at point A is heavily focused on economic growth, neglecting the other two dimensions of sustainable development.

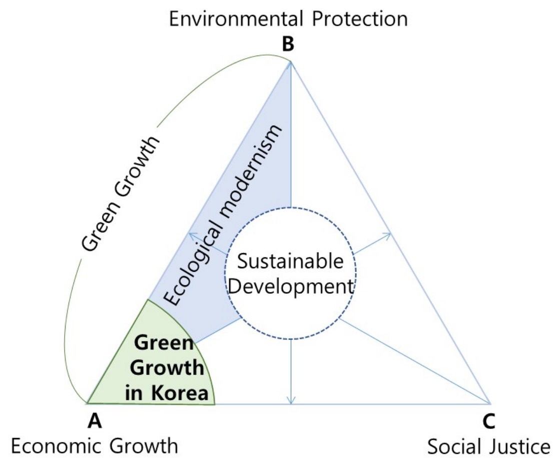

Figure 3.2 South Korean Green Growth Framework

Source: (Yun, 2012)

* She mapped green growth framework of South Korea using Connelly (2007).

Since green growth emphasizes economic growth and environmental protection at the same time, green growth is located on the triangular plane in the same space as ecological modernization. Based on analysis on the allocation of the budget for green initiatives, she found that the green growth framework of South Korea is much closer to a growth-only paradigm. About half of the total budget of 107.4 trillion KRW is allocated to build climate adaptation and enhance energy independence. Of this 56.9 trillion KRW budget, it is planned that 36.3 trillion will be allocated to building climate change adaptation capacity. At first glance it looks attractive, but the reality is different. Yun (2012) pointed out that the 2010 budget executed for climate change adaptation capacity building was mostly (about 93%) spent on the Four River Restoration Project. This project aimed to prevent water shortages and floods, improve water quality and create multi-purpose spaces for residents by constructing new dams, rebuilding old dams, reinforcing riverbanks, and dredging river sediments. In reality, this project has been carried out not for environmental protection, but for economic stimulus. Furthermore, the consequences of the project are frustrating. Algal blooms have been widespread and massive fish deaths have been observed in four rivers. In turn, fishers and farmers adjacent to the project areas are experiencing the adverse impacts (Song, 2013).

Table 3.1 The Budget Plan for Green Growth from 2009 to 2013

Unit of measurement: trillion KRW

Category		09~'13
Climate adaptation & Energy Independence	Efficient Reduction of GHGs	5.7
	Post-oil • Energy self-efficiency	14.9
	Climate change adaptation capacity	36.3
	Sub-total	56.9
Creation of new growth engines	Green technology development	11.3
	Greening industries & Foster green industries	4.6
	Advancement of industrial structure	10.9
	Creation of infrastructure for green economy	1.8
	Sub-total	28.6
Improvement of life quality & Enhancement of national status	Green Land & Transportation system	25.3
	Green revolution in life	1.9
	Global model of green growth	0.7
	Sub-total	27.9
Total		107.4

Source: (PCGG, 2009)

Besides the bias of the green growth framework towards economic growth, improvements of social equity have not been emphasized much. The *National Strategy for Green Growth* also outlines the vision for the vulnerable as follows: [1] reduce energy poor households from 1,230,000 in 2009 to 890,000 in 2013 and [2] improve heating and cooling energy efficiency in low-income homes from 70,000 in 2009 to 365,000 in 2013 (PCGG 2009). The budget for the poor or the vulnerable is negligible compared to the four-river restoration project. As mentioned previously, the current framework does not coordinate the three principal goals of sustainable development.

In addition to the unbalanced consideration for the three objectives of sustainable development, the green growth framework is criticized because the framework was originally suggested as an alternative growth model for developing countries to relieve poverty without environmental degradation. South Korea, a member of the OECD, is not a developing country, thus, it does not apply. Furthermore, the compatibility between environmental protection and economic growth is ascribed to improvements in ecological efficiency. Although efficiency is significantly improved, infinite economic growth is impossible due to the carrying capacity of the environment. However, the green growth framework of South Korea does not consider that capacity (Yun, 2009). From the perspective of South Korea, the green growth framework is not a preferred replacement for the sustainable development framework.

As explored, the current framework is too confined to analyze the comprehensive impacts of cap-and-trade. Therefore, this study returns to sustainable development and suggests an alternative framework, the Economy-Energy-Environment-Equity Framework, to analyze the scheme and to make a meaningful policy recommendation.

3.2 Alternative Framework for Cap-and-Trade: the Economy-Energy-Environment-Equity (E4) Framework

The current cap-and-trade scheme depends on the green growth framework, which is biased towards growth-only discourse. As a result, the current framework is not enough to assess the comprehensive aspects of cap-and-trade, and might not lead to sustainable development. The principal pillars of the green growth framework are economy and environment. Although the implementation of cap-and-trade might expand social inequity, based on the current framework it is considered acceptable unless it hinders economic growth and environmental protection. Therefore, an alternative framework needs to be explored to assess the distributional implications of the implementation.

Connelly (2007) mapped the concept of sustainable development, using a triangular plane with goals at each corner: environmental protection, economic growth, and social justice. Sustainable development is located at the center of the triangle, which implies that all three objectives are considered in a balanced manner.

Rather than three objectives, the Economy-Energy-Environment-Equity framework (E4 framework) clarifies that four important areas/pillars must be considered for true sustainable development. The WCED defined sustainable development not as a steady state, but as a dynamic process of change in energy, economy, society (equity) and environment to conform with sustainability as follows:

> Sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional changes are made consistent with future as well as present needs (WCED 1987: p9).

Wang (2001) and Wang, Byrne, Boo, Yun and Soh (2000) argued that energy, equity, economy, environment are interlocked with each other. Wang (2001)'s description is three-dimensional by extending the timeframe together with interlocking pillars of sustainable development. In the sustainable development path, welfare continuously increases above the welfare level of enjoying basic needs for food, shelter, etc. However, it should be noted that the concept of welfare in Figure 3.4 is different from the increase of utility based on increasing consumption or output. In other words, while the economic growth means the increase in output or consumption, sustainable development can be defined based on "non-declining per capita utility," since utility is determined by not only quantitative consumptions, but also qualitative factors such as environmental quality (Pezzey, 1992: p13).

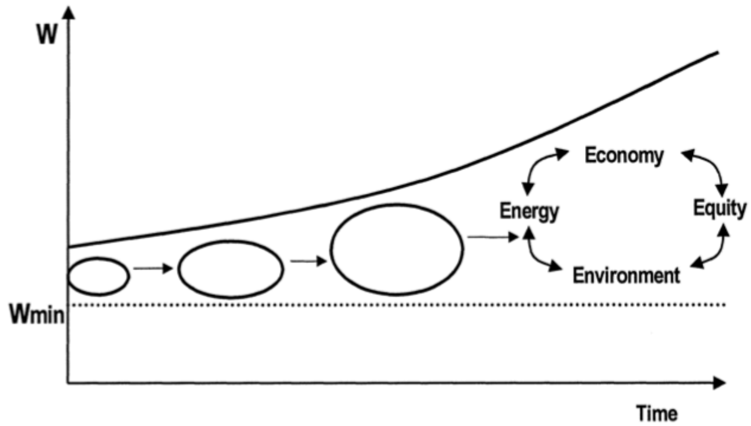

Figure 3.3 A Framework of Sustainable Development: Integration of Time and E4
Source: (Wang, 2001)

Similar to Wang et al. (2000) and Wang (2005)'s description of sustainable development, Dincer and Rosen (2005) refined the definition of sustainable development as the confluence of [1] energy and resources sustainability, [2] economic sustainability, [3] environmental sustainability, and [4] social sustainability. They discussed how the four issues relate to each other, as shown in Figure 3.3. All of the pillars of sustainable development are interdependent of each other (e.g. increasing energy efficiency can contribute to improvements in environmental quality and cost reduction), which shows how these changes will contribute to sustainable development.

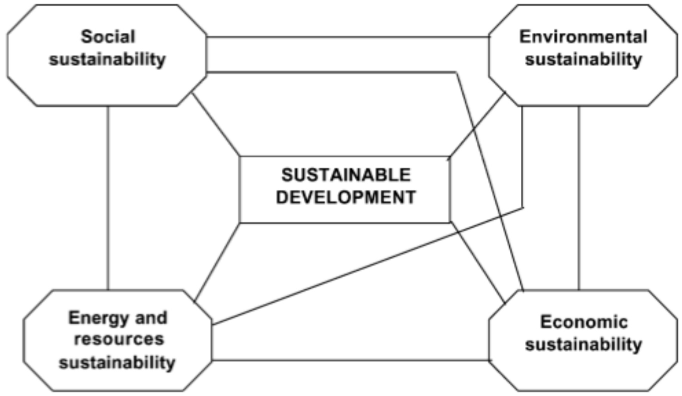

Figure 3.4 The Interdependence of Four Pillars of Sustainable Development

Source: (Dincer & Rosen, 2005)

While the green growth framework focuses on the impacts of a policy in terms of economy and the environment or economy only, the E4 framework allows the cap-and-trade policy to be assessed in terms of four pillars. As each dimension of the framework is too extensive to be assessed, a boundary for each pillar and timeframe needs to be decided.

Wang et al. (2000) identified the principal orientation of each dimension for energy systems under sustainable development by comparing the conventional growth model (CGM) to the sustainable development model (SDM). While an energy system of the SDM uses more alternative energy sources, aggressively improves energy efficiency, simultaneously conserves the environment and aims to improve distributional equity, an energy system of the CGM depends more on fossil fuels, pursues stable and abundant energy supplies, and emphasizes more economic growth rather than environmental protection. This study will use specific indices to evaluate the impacts of the cap-and-trade scheme, rather than evaluate it based on required orientations or norms for each pillar as did Wang et al. (2000).

Table 3.2 Development Orientation: Conventional Growth Model vs. Sustainable Development Model

Conventional Growth Model	Sustainable Development Model
Economy	
Goal: Profit maximization Commodity-oriented Consumption-driven Resources are seen as "factors of production" Resources-intensive, governed by economic priorities Urban/industrial-based centers of production Economic costs are primary	Goal: long-term growth/viability End-use oriented Consumption/conversation in balance Resources are seen as limited, vulnerable requiring stewardship Resource-conserving, governed by multiple priorities Regionally dispersed centers of production Economic costs balanced by social and environmental considerations
Energy	
Fossil fuel-based Goal: to secure abundant, low cost supply Reduce vulnerability by diversifying sources of supply Energy/technology-focused Efficiency in economic production - Scale of economy - Technical efficiency	Greater use of alternative energy sources Goal: to secure end-use efficiency Reduce vulnerability by reducing energy intensity Energy/environmental conservation-focused Efficiency in end-use/energy services - modularity - energy efficiency
Environment	
Ecological assumption: humans dominate the environment Environment is seen as an abundant source of commodities Environmental impacts external to economic choice Use-strategy: intensive, governed by economic profitability	Ecological assumption: humans/environment are mutually dependent Environment is seen as exhaustible, but sustainable resources Environmental impacts central and internal to economic choice Use-strategy: selective, governed by conservation principle to ensure - Long-term economic viability - Non-economic dimensions
Equity	
Short-term utility maximization 'Want'-driven consumption Big-pie-first distribution Expert-dominant decision making Deterioration of rural livelihoods Unevenness of globalization Funding for giant infrastructure projects Efficiency-driven	Intergenerational equity Basic human 'Needs'-driven Distributional equity Public participation based decision making Community & culture based approach Global achievement of environment & development ends Regionalization Funding for health, education, and social priorities Social justice and fair distribution

Source: (Wang et al., 2000)

In this study, the E4 framework will be specified more based on certain indices used to perform a feasible analysis of the impacts on each pillar. First, the time horizon is limited to the short term in this study. Without a limited time frame, impacts on each dimension need to be assessed across the time frame as well, which needs more data and additional complicated methodologies. Consequently, I assess the impacts of a cap-and-trade scheme in the short term. In addition, this study will focus more on quantitative analysis of the impacts. In other words, using specific indices for each dimension, comprehensive impacts of the cap-and-trade scheme will be evaluated.

Environmental impacts will be assessed by CO_2 emissions levels. If the time frame is longer rather than short-term, the reduction in CO_2 emissions results in extensive effects on the environment, such as changes in biodiversity and atmospheric temperature, which need a large and complicated model. This study evaluates the environmental impacts in terms of CO_2 emissions. The impacts on economy will be assessed based on changes in production levels, value-added, employments and imports by sector. In addition, energy impacts will be confined only to primary energy consumption by fuels and sectors. Equity will be assessed in terms of change in income-based distributional equity (equity indices will be discussed in the following section).

Using this E4 framework, I can evaluate the policy with regard to each of the pillars that must be considered for sustainable development. Based on this framework, each policy scenario can be diagnosed: [1] how much energy consumption is reduced;

[2] as a result, how much CO_2 emissions are mitigated; [3] in turn, how this scenario impacts economy in terms of sectoral output production, sectoral employment, sectoral value-added, and imports; and [4] how the burden is distributed across different groups. Based on this analysis, it is possible to diagnose whether a policy scenario especially adversely impacts a dimension and to confirm whether a scenario considers the principal dimensions in a balanced manner while orienting it towards the path for sustainable development.

However, there is a pitfall in this quantitative-factor-based E4 framework. As was previously mentioned, the increase of welfare in the sustainable path does not necessarily result in an increase in outputs or consumption. Consequently, it is hard to measure increases in welfare in the path because quality related judgment is required. Due to the limitations of available data, this study will quantitatively evaluate the impacts on economic dimensions of a carbon pricing policy depending on changes in output. Nevertheless, it should be noted that sustainable development depends not on economic growth, but on economic development.

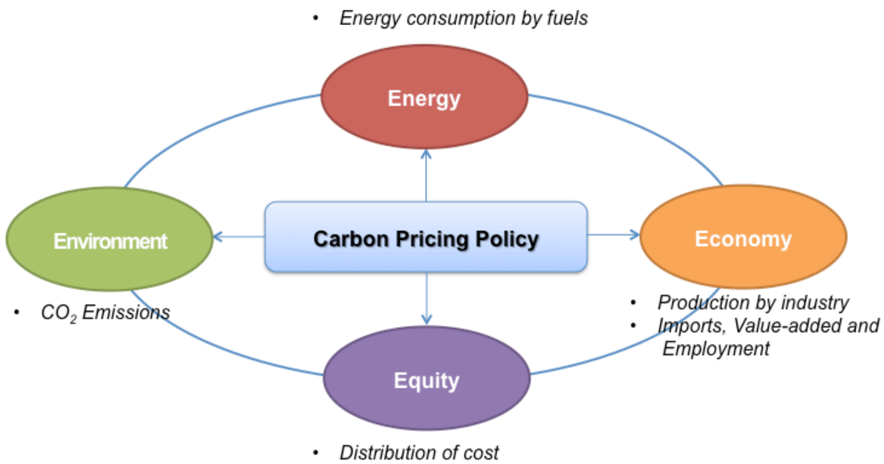

Figure 3.5 The Evaluation Factors of the E4 Framework for Cap-and-Trade

3.3 Definition of Distributional Equity for the Assessment of Equity Implications of Cap-and-Trade

As Ikeme (2003) argued, equity is usually used together with the terms of "environmental justice" and "fairness" when distributional impacts of an environmental policy are discussed in academic or political discussions. A survey of pertinent literature led her to find that those terms are "inconsistently" used in multiple studies. Kverndokk and Rose (2008) also pointed out that many studies were utilizing justice and fairness without distinction. As a result, readers might interpret the arguments and conclusions of those studies in different ways due to the inconsistent use of these terms. Therefore, this study clarifies concepts related to equity through comparison of those concepts, and addresses which concept is used to evaluate the equity implication of a carbon pricing policy in South Korea.

Beginning with equity and equality, it seemed that the difference between the two concepts is well-known and relatively clear. Espinoza (2010) differentiated equity from equality based on an exhaustive literature review. Whereas equality argues for "sameness" in the quantity of benefit or resources distributed, equity involves qualitative aspects as well as quantitative aspects with regard to the distribution. In detail, equality claims for a same amount of resources or benefits, regardless of a person's contribution to the outcome or needs for the outcome. However, equity argues that resources or benefits should be allocated on the basis of a person's contribution to the outcome or needs for outcome.

While Espinoza (2010) considered equity as equal to justice, the concept of justice, in general, is considered a broader concept than equity (Cook & Hegtvedt, 1983; Ikeme, 2003; Kverndokk & Rose, 2008). Kverndokk and Rose (2008) defined justice as: "sometimes taken to be an umbrella term, incorporating all dimensions of evaluation besides efficiency." Although Ikeme (2003) confined her analysis to environmental justice, she stated that environmental justice is a broader concept than equity in the arena of climate change policies.

According to Cook and Hegtvedt (1983), the concept of justice is disaggregated to distributional justice, procedural justice, and retributive justice. According to Eckhoff (1974), distributional justice is defined as a just allocation of resources or benefits, which seems to equate to the concept of equity. However, based on Eckhoff’s explanation of equity and distributive justice, distributive justice is a concept equal to or larger than the concept of equity. He defined equity as a fair exchange, and defined distributive justice as a fair allocation or distribution. And he stated that the exchange or transfer of resources or benefits between two individuals is a special case of allocation or distribution, which means the transfer of resources or benefits from a distributer or allocator to a group of people (as cited in Cook & Hegtvedt, 1983). According to Eckhoff (1974), when we discuss the distribution of climate change mitigation cost, the term "distributive justice" should be used, rather than "equity." Ikeme (2003) found that "equity has largely been confined to dealing with hard distributive choices" (p 200). Hence, distributive justice is a concept equal to or larger than equity.

Put simply, procedural justice involves justice in the procedures – regardless of the distribution of outcomes; if the procedures were unjust (e.g., biased reflection of interest of a specific group in a decision-making process), the distribution of the output can be said to be unjust. Lastly, retributive justice is specific to just compensation for victims, or just distribution of punishment (Cook & Hegtvedt, 1983).

Based on the survey of the literature, a diagram can be made as follows. Equity can be said to be a superset of equality. While equality only considers the sameness of outcomes, regardless of recipients' needs or contributions, equity is involved in qualitative issues related to the distribution of outcomes. In that the concept of distributive justice involves in fairness of distribution of outcomes, the concept of distributive justice can be said to be equal to or larger than equity.

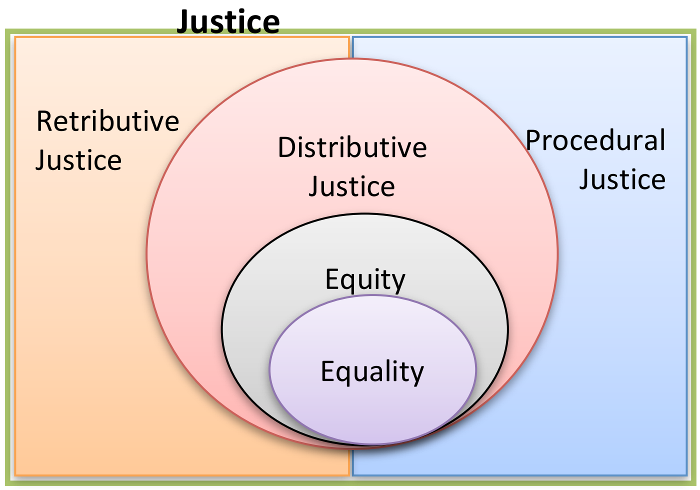

Figure 3.6 The Diagram to Map the Concepts of Justice and Equity

Of course, it would be best if environmental policies – including cap-and-trade – were assessed on the basis of justice. However, in reality, assessment of impacts on all the aspects of justice – including procedural justice – is a very extensive task. This study will limit the scope of assessment to only distributional equity of implementing a cap-and-trade scheme; that means this study will explore how the burden of the policy is distributed between different groups. Although distributional equity or distributional justice is not enough to include all the justice implications of cap-and-trade scheme in South Korea, the assessment of distributional equity or income-based equity will provide more practical implications. Also, distributional equity implications of the cap-and-trade scheme have rarely been studied much in South Korea. As a result, it is meaningful to explore distributional equity aspects.

Chapter 4

METHODOLOGY AND DATA: INPUT-OUTPUT ANALYSIS WITH EXTENSIONS

Input-output (IO) table analysis with extensions is a useful tool to analyze the comprehensive impacts of a policy on energy, economy, environment and equity aspects; this methodology is appropriate to evaluate the impacts of the cap-and-trade policy on South Korea, and explore a better policy design based on the E4 framework.

To conduct the assessment of the comprehensive impacts of the policy on South Korea, it is necessary to construct hybrid IO tables prior to the assessment in order to estimate energy consumption and CO_2 emissions by sector. A hybrid IO table is called as such since the elements of an IO table are expressed in different units of measurement: elements in energy sectors are expressed in physical quantity units while those in non-energy sectors are expressed in monetary value (Miller & Blair, 2009).

After estimating this information, it is possible for us to evaluate the impacts of a carbon charge. The changes in producer prices due to the implementation of cap-and-trade can be evaluated. In turn, final demands will be affected by the changes in producer prices. Based on the changes in final demands, the impacts on economy, CO_2 emissions and energy consumption will be analyzed. In addition, this study can obtain the equity implications of the implementation by taking into account expenditure patterns of different household groups: [1] according to the household income levels; [2] according to the head's age; and [3] according to the location of households.

Once the comprehensive impacts of carbon pricing policy are achieved for the reference scenario case (only with a specific carbon permit price—without revenue recycling), then this paper will also explore additional scenarios of a carbon pricing policy with revenue recycling in order to analyze how revenue recycling helps relieve the regressivity induced by the implementation. The methodology and the data used in this paper will be explained in the following three sections.

4.1 Input-Output Analysis

Since Leontieff developed the Input-Output table (I-O table) analysis, it has been used to analyze economy-wide impacts of policies. Leontief (1986) explained "an Input-Output table describes the flow of goods and services between all the individual sectors of a national economy over a stated period of time; a year" (p. 19). In other words, an I-O table describes interdependency between industries. A row of the table shows how the output of a sector is allocated to final demands, including households' demand, government's demand, and investment and intermediate demands in a specific year. In contrast, a column of the table shows the input structure of the corresponding industry sector; it illustrates how a sector uses/purchases intermediates and value added (labor, capital, and taxes) to produce outputs (See Figure 4.1). These structures can be expressed in a system of linear equations (Bank of Korea, 2012). By modifying the equations, the matrix called the Leontief inverse matrix, of which elements illustrate the "the dependence of each of the gross outputs on the values of each of the final demands" (Miller & Blair, 2009; p. 21) can be obtained. Using this matrix, one can assess how much change in sectoral output, value added or employment will be induced in order to meet the exogenous change in the demands. The detailed equations will be explained in section 4.3.

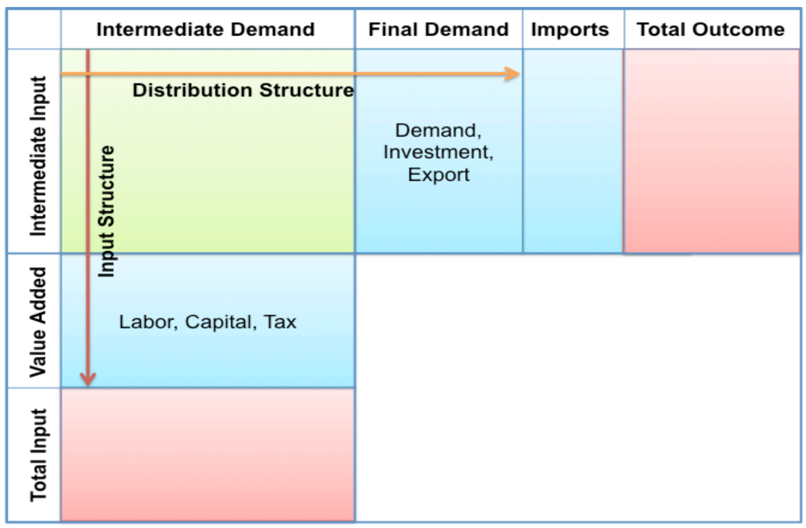

Figure 4.1 The Basic Structure of Input-Output Table

Source: (Bank of Korea, 2012)

In addition, the I-O model is constructed based on several assumptions: [1] once a good is produced, it is sold in a perfectly-competitive market. Here, all price increases will be passed on to consumers; [2] according to the Armington assumption, domestic goods and foreign goods are differentiated by the country of origin; and [3] input substitution is not allowed according to changes in factor prices. This means that every industry produces goods and services based on a fixed proportion of production technology. Therefore, it will produce outputs using inputs at fixed rates even after the prices are increased.

In practice, all elements of the matrix are usually expressed in monetary value and all the units of measurement of transactions are normalized to be one, which allows the construction of a large I-O table. If transactions of goods and services need to be expressed in their own units of measurement, it is impossible to build an I-O table in practice. This is because some industries produce several items with different units; e.g., a refinery industry produces a number of products including gas, butane, petroleum coke, etc. Therefore, it is hard to integrate a range of industries of which products have different units of measurement into one category. Moreover, it would be much harder to get a sum of both rows and columns. In a large I-O table, it becomes more complicated to record data in physical quantities for a number of goods, and to add those numbers together. As a result, an IO table is generally built in monetary units. However, some elements are expressed in forms of their own physical units in a hybrid IO table, which will be detailed later in section 4.2.3.

4.2 Data

This study needs three sets of data from 2009: the I-O table, the Households Survey Data (HSD), and energy statistics. Once all data are obtained, the I-O table and the HSD will be reorganized based on the objectives of the research. As Figure 4.8 illustrates, the I-O table is used to estimate the impacts of a carbon pricing policy on producer prices and to assess the impacts on the four dimensions together with other data sets as well. The HSD is used to understand the comprehensive distributional implications of a cap-and-trade scheme [1] between different income groups, [2] according to the age of the head of household, and [3] between households in rural and urban areas by estimating the impacts on changes in expenditures by a variety of consumer goods of different household groups. Lastly, the energy statistics are used to construct hybrid I-O tables: [1] energy I-O table and [2] environment I-O table. Using the hybrid I-O tables, it is possible to estimate sectoral energy consumption and CO_2 emissions. It allows us to calculate the additional financial burden of each industry due to the implementation of a carbon pricing policy.

The following sections will explain in detail how to reorganize and construct data required for the analysis. In section 4.2.1, the basic characteristics of an I-O table and the classification of industry sectors are explained. In section 4.2.2, the Household Survey Data will be explained: how to reorganize this data according to households' income level, ages of heads of households and location of households (rural or urban). In addition, current expenditure patterns and their implications on the implementation of a carbon pricing policy will be briefly explored. In section 4.1.3, an Energy IO table and an Environment (CO_2) IO table will be constructed in order to estimate both the sectoral energy consumption and emissions. The procedures to construct these hybrid IO tables along with the results will be provided.

4.2.1 Input-Output Table in 2009

The Bank of Korea (BOK) develops an I-O table (actual) every five years, and annually develops an I-O table (estimated) based on the I-O table (actual). The actual I-O table is constructed based on a comprehensive field survey on monetary flows between industries, government, and households. The I-O table (estimated) is indirectly estimated based on the actual I-O table. This study utilizes the most recent I-O table (estimated) in 2009.

The BOK provides three versions of the I-O table: [1] the most specific I-O table with 403 industry categories, [2] the modestly specific I-O table with 78 industry categories, and [3] the most aggregated I-O table with 28 industry categories. In order to analyze the impact of a carbon pricing policy, this study desegregates energy sectors. The overall classification of sectors depends on the 28 categories of the original I-O table (the most aggregated version). The classification of energy sectors is more specific. The "oil and coal" sector is divided into "gasoline", "kerosene", "diesel", "LPG", "coal", and "other refined oil." In addition, "electricity, gas and water" will be separated into "electricity," "gas," "hot water," and "water." However, "primary metal product" and "metal product" will be integrated into one sector. Therefore, the sectors of the original I-O table are reorganized into 35 industry sectors, as follows in Table 4.1.

As this study targets to analyze the impacts of a carbon pricing policy, it reorganizes 403 industry sectors to include eight energy sectors: [1] coal, [2] diesel, [3] electricity, [4] gasoline, [5] kerosene, [6] LPG, [7] city gas, and [8] other refined oil (See Table 4.1). The constructed I-O table can be found in the Appendix.

Table 4.1 I-O Table Industry Sector Classification

No	Industry Sector Classification (35)	IO Industry Classification	Description on IO table
1	Agriculture, Forestry & Fishery Product	1 ~ 29	Rice ~ Agriculture, forestry & fishery service
2	Mining Product	30 ~ 44	Anthracite ~ Other non-ferrous metals
3	Foods and Beverage	45 ~ 84	Unprocessed meat ~ Tobacco
4	Textile and Leather	85 ~ 113	Wool ~ Other leather products
5	Woods and Paper	114 ~ 128	Lumber ~ Other paper products
6	Print and Copy	129 ~ 130	Print, Publication and copy
7	Coal	131 ~ 132	Briquettes, Other Coal Product
8	Gasoline	134	Gasoline
9	Kerosene	136	Kerosene
10	Diesel	137	Diesel
11	LPG	139	LPT
12	Other refined oil	133, 135, 138, 140~141	Naphtha, Jet oil, Heavy oil, Lubricant oil, Other refined oil
13	Chemicals	142 ~ 171	Primary petroleum products ~ Other rubber products
14	Non-metallic mineral products	172 ~ 187	Primary glasses ~ Other earths and stones
15	Metallic product	188 ~ 219	Pig iron ~ Other metallic product
16	Machinery	220 ~ 239	Internal combustion system & turbine ~ Other specific purpose machinery
17	Electric appliances	240 ~ 267	Generator & Motor ~ Other domestic electric appliances
18	Precision equipment	268 ~ 273	Health equipment ~ Clocks
19	Transportation equipment	274 ~ 287	Passenger car ~ bicycle & other transportation equipment
20	Other manufacture products	288 ~ 297	Wood furniture ~ Other manufacture products
21	Electricity	298 ~ 301	Hydropower ~ Other electricity generation
22	City gas	302	City gas
23	Hot water	303	Steam & hot water
24	Water	304	Water
25	Construction	305 ~ 320	Housing construction ~ Other construction
26	Wholesale and Retail	321 ~ 322	Wholesale, retail
27	Restaurant and lodging	323 ~ 326	Restaurant ~ Lodging
28	Transportation	327 ~ 340	Rail passenger transportation ~ Other transportation service
29	Communication and broadcasting	341 ~ 347	Mail ~ Cable & satellite broadcasting
30	Finance and insurance	348 ~ 353	Bank ~ Finance & insurance service
31	Real estate & business service	354 ~ 371	Housing service ~ Other business service
32	Public administration & national defense	372 ~ 373	Central government, local government
33	Education and public health	374 ~ 383	Public education organization ~ Industrial sanitation service
34	Social and other service	384 ~ 400	Newspaper ~ Other personal service
35	Others	401 ~ 403	Staples ~ Non-classified products

4.2.2 Households Survey Data (HSD) in 2009

Similar to the Consumer Expenditure Survey of the U.S., the HSD collects income and expenditure information every quarter on about 8,700-8,800 households nationwide, except farming, fishing, and forestry households, of which statistics are separately collected. The 2009 HSD has information on 10,881 households.

Besides specific income and expenditure data on each household, the Survey also collects very comprehensive demographic information on family members – including the head of household, spouse, children, and seniors – such as gender, age, level of education, occupation, number of family members, etc. It also collects information on their housing status: renting or owning, price of the house, housing types, and area of houses; and also records if the household owns a car and if the household is in an urban or rural area.

Table 4.2 summarizes the classification of the income and expenditure of the HSD by providing information on household expenses for 394 goods and services. Using this database, this study will explore changes in average monthly consumption patterns by different groups due to the implementation of a carbon pricing mechanism. In order to compare the distributional impacts of a carbon pricing policy among different groups, this study will reorganize expenditure for 394 goods and services into 26 goods and services. The classification of expenditure items is based on 12 aggregated expenditure categories of the original HSD except for "housing, light, water and heating" and "transportation." These two categories are further desegregated according to fuel type. The “Housing, light, water and heating” item is divided into “Housing and Related Service,” “Electricity,” “City Gas,” “LPG-Heating,” “Kerosene,” “Diesel-Heating,” “Briquettes,” “Multi-housing heating” and “Other fuels.” “Transportation” is disaggregated into “Cars and related service,” “Gasoline,” “Diesel-Car,” “LPG-Car,” “Other fuels-Car,” “Logistics,” and “Mass Transportation.”

Table 4.2 Item Classifications of the HSD

Income	Ordinary income	Earned income (6)	Compensation for supplying labor
		Business income (5)	Income earned from running business including rental income
		Property income (4)	Revenue generated from running property including interest, dividend, and other property income
		Transfer income (8)	Income transferred from other households or the government including subsidy and pension
	Irregular income (3)		Income irregularly generated including severance package and gifts for celebration or sorrow
Other income	Income resulted from change in assets (7)		Income generated from decrease in assets through deposit withdrawal or sale of real estate
	Income resulted from increase in debt (2)		Debt increase due to purchase of real estate
	Property transfer (1)		Property inherited from other households.
Expenditure	Consumption (394)		Expenditure to purchase goods and service It is aggregated to 12 aggregated categories: Foods and nonalcoholic beverage (129), Alcohol and tobacco (8), Clothing and shoes (29), Housing, light, water and heating (22), Appliances and services (53), Health service (13), Transportation (23), Leisure (44), Education (24), Foods at restaurant and travel (8), Other goods and services (32) Each category is disaggregated more.
	Current transfer paid (24)		Expenditure to pay taxes and social insurance or transfer between households
Other expenditure (10)			Expenditure for decrease in debt including saving, purchase of real estates, and etc.

* The number between parentheses refers to a specific classification for each category.

Source: (Kang et al., 2011)

4.2.2.1 Expenditure Pattern of Different Income Groups

Based on the total income, this study categorizes households into ten different income groups (deciles) as follows. Each household is listed in ascending order according to the total income (not dispensable income). Then, the sample is divided into ten groups. The first 10% is the poorest income decile. The last 10% is the wealthiest income group.

The lowest income households earned about 390,338 South Korean Won (KRW), which is only about 5% of the average monthly income of the wealthiest income decile (7,662,857 KRW). The household head is generally elderly in the poorer household. The head of the first decile is on average 63.8 years old, while the head of the wealthiest group is about 46.3 years old. The head of the 7^{th} decile is the youngest (44.7 years old) overall. The average age of the head appears to decline as the income increases up to the seventh decile, but then it slightly increases afterwards. This occurs because the income declines due to retirement or lay-off, as the head gets older.

In contrast, family size increases according to the income level. The number of persons per household is 1.6 persons/household in the first decile and 3.6 persons /household in the wealthiest decile respectively. In addition to income levels, the family size also declines due to the separation of children from the parents and the death of the spouse, as the head gets elder. As a result, the low-income households have a small number of family members and the head is relatively older in the low-income households.

Table 4.3 Monthly Household Expenditures on 26 Goods and Services in 10 Income Deciles

(Unit: thousand KRW)

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
Average Income	390.3	939.9	1,465.2	1,959.0	2,426.7	2,900.9	3,421.9	4,065.2	4,983.1	7,662.9
Average number of Persons/Households	1.6	2.0	2.4	2.8	3.1	3.3	3.3	3.4	3.5	3.6
Average age of the head of household	63.8	56.9	51.9	47.2	45.9	45.1	44.7	44.8	45.4	46.3
Average Household Expenditures on 26 Consumer Goods and Services										
Food and non-alcohol beverage	138.3	178.4	209.7	233.9	252.9	280.3	291.4	318.9	341.7	384.6
Alcohol and tobacco	13.3	16.1	22.0	25.6	27.7	28.5	29.1	31.8	29.9	28.7
Clothing and shoes	23.0	40.4	60.1	81.6	95.3	119.1	139.7	166.6	190.7	272.9
Housing and Related Service	67.1	110.1	115.2	115.2	111.6	109.8	116.6	124.0	126.6	163.9
Electricity	25.2	30.1	36.1	37.4	40.5	41.2	43.9	48.4	49.0	55.6
City Gas	13.0	19.1	26.6	32.3	34.1	36.6	41.5	38.7	39.0	42.4
LPG-Heating	3.3	3.7	4.6	4.3	5.0	5.1	5.0	5.3	5.4	4.8
Kerosene	7.8	8.6	7.3	7.1	6.9	7.7	5.9	7.4	6.5	5.9
Diesel-Heating	0.3	0.2	0.2	0.5	0.3	0.2	0.3	0.3	0.2	0.8
Briquettes	1.1	1.3	1.1	0.7	0.5	0.8	0.5	0.9	0.4	0.2
Multi-housing heating	2.0	2.8	2.4	3.7	4.1	5.1	5.1	5.7	8.8	14.8
Other fuels	0.3	0.3	0.2	0.3	0.2	0.3	0.4	0.3	0.3	0.3
Housing supplies and service	22.3	27.4	39.3	47.5	52.7	63.0	78.6	87.5	108.7	165.2
Public health	71.6	85.4	98.7	111.1	112.9	125.1	132.3	148.3	167.6	202.1
Cars and related service	7.2	26.6	30.6	49.9	58.8	56.2	97.6	129.7	181.3	279.3
Gasoline	7.4	15.4	29.4	41.7	53.9	66.0	78.6	84.2	95.4	128.4
Diesel-Car	4.9	8.1	13.2	20.6	28.5	33.8	35.3	44.1	44.1	53.6
LPG-Car	2.5	3.4	7.9	10.4	14.6	13.7	14.7	15.7	22.7	22.0
Other fuels-Car	0.0	0.1	0.1	0.2	0.1	0.0	0.2	0.2	0.0	0.2
Mass Transportation	22.6	31.9	39.4	40.4	41.1	42.0	44.3	52.8	49.6	68.3
Logistics	2.1	1.3	3.1	3.3	2.6	4.7	5.8	2.9	4.0	6.4
Communication	37.0	59.0	86.8	110.5	125.8	131.8	143.3	152.5	157.7	165.8
Leisure and cultural activities	24.8	36.3	47.2	65.2	80.2	92.2	105.4	127.8	158.7	211.3
Education	31.1	44.0	81.5	137.2	182.1	227.7	260.0	311.5	402.7	501.2
Restaurant and lodging	42.7	86.4	135.6	189.8	234.8	255.4	292.7	333.3	374.8	461.0
Other commodities & Services	36.8	55.4	81.9	119.4	155.2	180.6	197.8	225.4	246.5	370.7

Source: (Statistics Korea, 2010)

In terms of expenditure, the poorer households spent relatively more to meet their consumption level than the wealthier did and the poorest group spent more than their income (see Figure 4.2).

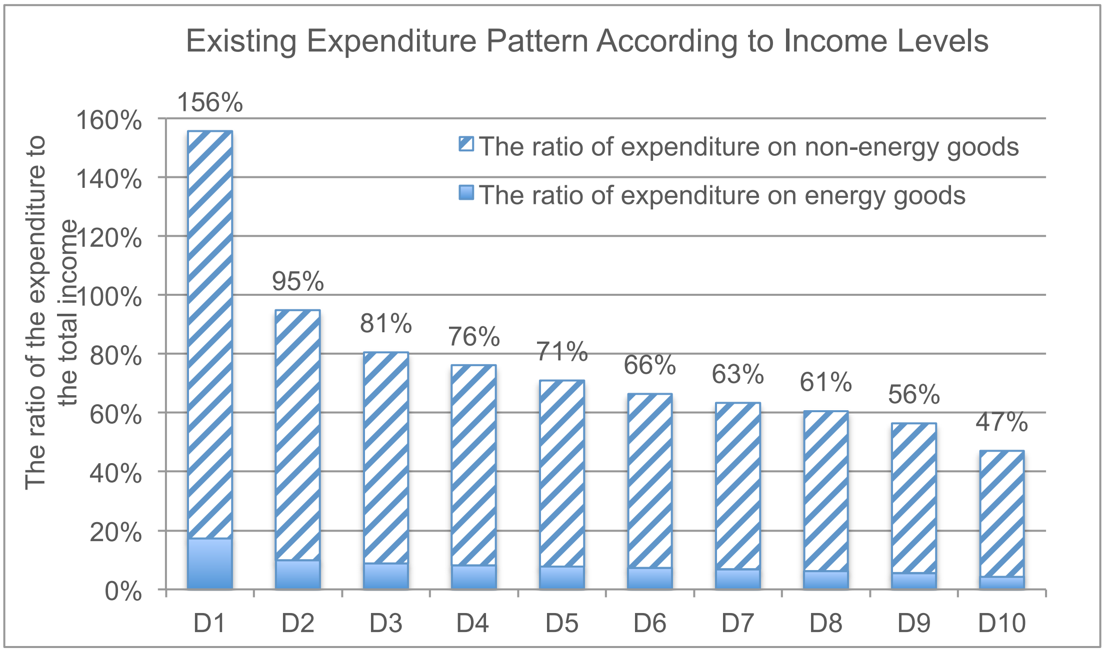

Figure 4.2 Existing Expenditure Pattern according to Income Levels

The lowest income group spent 17.3% of total income on energy (including heating & cooling fuels and transportation fuels), while the wealthiest income decile spent only 4.3% of their income on energy. Regarding the expenditure on only heating & cooling energy, the difference was bigger. The poorest group spent 13.5% of the total income on heating fuels while the wealthiest group spent 1.6% of the income. The difference in spending on transportation fuels between the groups is smaller. The first decile spent 3.8% of the total income on transportation fuels while the tenth decile spent 2.7%.

The poorest group ironically depended more on expensive fuels to meet heating & cooling demands. City gas and electricity accounts for 79% and 72% of the heating & cooling fuels in the wealthiest households and the poorest households respectively. The poorest households depended more on LPG, kerosene and briquettes than the wealthiest households did. Kerosene accounted for 14.7% of the spending on heating & cooling fuels of the first decile but it accounted for only 4.8% of that of the tenth decile. In addition, briquettes contributed 2.0% and 0.1% of the heating & cooling fuels of the poorest households and the wealthiest households respectively. The consumer energy prices in 2009 were as follows: according to prices per net heat value, kerosene, diesel, propane and briquettes were more expensive than city gas (see Table 4.4 below). It implies that the poorest group spent more due to their expenditure profile.

Specifically, the poorer group used relatively more LPG and diesel than the wealthier did. LPG and diesel contributed 50% and 39% to the transportation fuels of the poorest households and the wealthiest households respectively. In South Korea, only the disabled and the national honorees could purchase LPG passenger cars[30]. Although the HSD did not include information for family members with disabilities, it is likely that the income of the disabled person is smaller.

[30] Since the end of 2011general citizens are allowed to buy used LPG cars.

Table 4.4 Energy Prices in 2009

	Price	Net heating value	Price per heat
City Gas	48.6 KRW/m3	9440-13800 kcal/nm3	0.004 KRW/kcal
Electricity	76.9 USD/kWh	860 kcal/kwh	100.176 KRW/kcal
Kerosene	976.2 KRW/l	8,350 kcal/l	0.117 KRW/kcal
Diesel	1,397.5 KRW/l	8,450 kcal/l	0.165 KRW/kcal
Propane	1,577.2 KRW/kg	11,050 kcal/kg	0.143 KRW/kcal
Briquettes	489.5 KRW/unit (3.6kg)*	4,400-4,599 kcal/kg	0.030 KRW/kcal

* Without the government subsidy, the price for briquettes is 722.91 KRW/unit.

Source: (IEA, 2012; Korea Energy Economics Institute [KEEI], 2012)

Besides expenditure pattern on energy goods, the poorest group spent 138.3% of their total income on non-energy goods[31] while the wealthiest group spent 42.8%. The current expenditure pattern implies that the incidence will be regressive (see Figure 4.2). In sum, the incidence of a carbon pricing policy is likely to be regressive due to the existing expenditure pattern – the poorer spent relatively more on non-energy goods as well as energy goods than the wealthier did.

4.2.2.2 Expenditure Pattern according to the Age of the Head

The raw data of the HSD is grouped based on the age of the household's head. Table 4.5 shows expenditure profile by age groups. The average number of family members declines according to the age of household's head: 3.3 family members live

[31] According to the raw data of the HSD, 56.2% of the poorest decile spent more than their total income. This larger expenditure than their income level is dependent on debt.

in a household with a head younger than 49 and only 1.6 persons live in a household with a head older than 75. The average income decreases according to the head's age. The average income of the "under 49" group is highest (3,431.1 thousand KRW) – about four times as great as that of the "75 +" group (885.5 thousand KRW). Also, the average expenditure of the "under 49" group (2,789.9 thousand KRW) is about three times as great as that of the "75+"group (800.3 thousand KRW).

The expenditure profile shows that the households with the most elderly head spent relatively more on energy goods. The eldest group spent 8.2% of their income on energy goods including heating fuels and transportation fuels, while the "50-64" group spent 6.3%. In addition, the youngest group spent 6.3% of their income on energy goods.

Specifically, a household with an elder head spent relatively more on heating & cooling energy - 2.8% of the income in the "under 49" group; 3.0% of the income in the "50-65" group; 5.1% of the income in the "65-74" group; 6.9% of the income in the "75 +" group. In contrast, when it comes to expenditure on transportation fuels, the younger households spent more on transportation fuels. While the " under 49" group spent 3.5% of their income on transportation fuels including gasoline, diesel, LPG, and other fuels, the "75 +" group spent 1.3% of their income on these fuels.

The elder households depended more on expensive fuels. While city gas contributed to 39% of the expenditure on cooling & heating energy in the "under 49" group, it accounted for 22% in the "75+" group. The elder group depended relatively more on kerosene and briquettes. Kerosene contributed to 6% and 16% of the home energy expenditure in the “under 49” group and in the “+75” group respectively. In addition, while the youngest group used very few briquettes (nearly zero), they account for 3% of heating & cooling energy spending for the eldest group. As noted earlier, kerosene and briquettes are more expensive fuels than city gas in terms of the price per net heat value. In addition, the use of briquettes carries a risk of carbon monoxide poisoning, which can cause death in severe cases.

Regarding the expenditure pattern of transportation fuels, the younger households used diesel more and LPG less. Diesel accounted for 29% of the expenditure on transportation fuels in the “under 49 group” while it contributed to 17% in the “75+” group. In contrast, LPG contributed to 12% and 26% of the transportation fuels in the households with the youngest head and households with the elderly head respectively.

Table 4.5 Monthly Household Expenditures on 26 Goods and Services according to the Age of the Head in Households

(Unit: thousand KRW)

	under49	50-64	65-74	75+
Average Income	3,431.1	3,169.0	1,510.3	885.5
Average number of Persons/Households	3.3	2.7	2.0	1.6
Average age of the head of household	39.2	55.9	69.3	78.8
Average Household Expenditures on 26 Consumer Goods and Services				
Food and non-alcohol beverage	273.0	274.5	232.9	152.4
Alcohol and tobacco	27.8	26.8	16.2	7.9
Clothing and shoes	143.7	115.9	44.4	21.4
Housing and Related Service	127.9	109.0	85.5	88.5
Electricity	40.1	45.5	37.0	29.3
City Gas	37.4	29.8	21.2	13.7
LPG-Heating	5.0	4.3	4.3	3.0
Kerosene	6.1	8.2	8.3	9.9
Diesel-Heating	0.3	0.4	0.3	0.3
Briquettes	0.3	1.0	1.6	1.6
Multi-housing heating	5.9	5.6	3.5	3.3
Other fuels	0.3	0.4	0.3	0.4
Housing supplies and service	79.8	65.0	40.5	37.1
Public health	120.0	131.9	142.3	114.9
Cars and related service	107.4	99.8	30.2	5.0
Gasoline	70.9	61.5	25.2	6.4
Diesel-Car	34.9	28.0	10.0	1.9
LPG-Car	14.9	12.8	5.9	3.0
Other fuels-Car	0.1	0.1	0.1	0.0
Mass Transportation	41.8	54.6	31.7	20.8
Logistics	4.6	2.8	2.2	0.9
Communication	135.3	121.9	51.6	26.6
Leisure and cultural activities	116.8	85.3	40.0	23.7
Education	306.1	152.5	28.0	13.1
Restaurant and lodging	286.8	241.6	92.3	41.6
Other commodities and Services	198.9	158.9	86.0	31.5

The pattern of expenditure on non-energy goods is similar. The "50-64" group spent 51.8% of their total income on non-energy goods and the eldest group spent 66.1% of their income on energy goods. Together with expenditure on energy goods, this implies that the burden induced by the implementation of a carbon pricing policy would be heavier on the eldest group (See Figure 4.3).

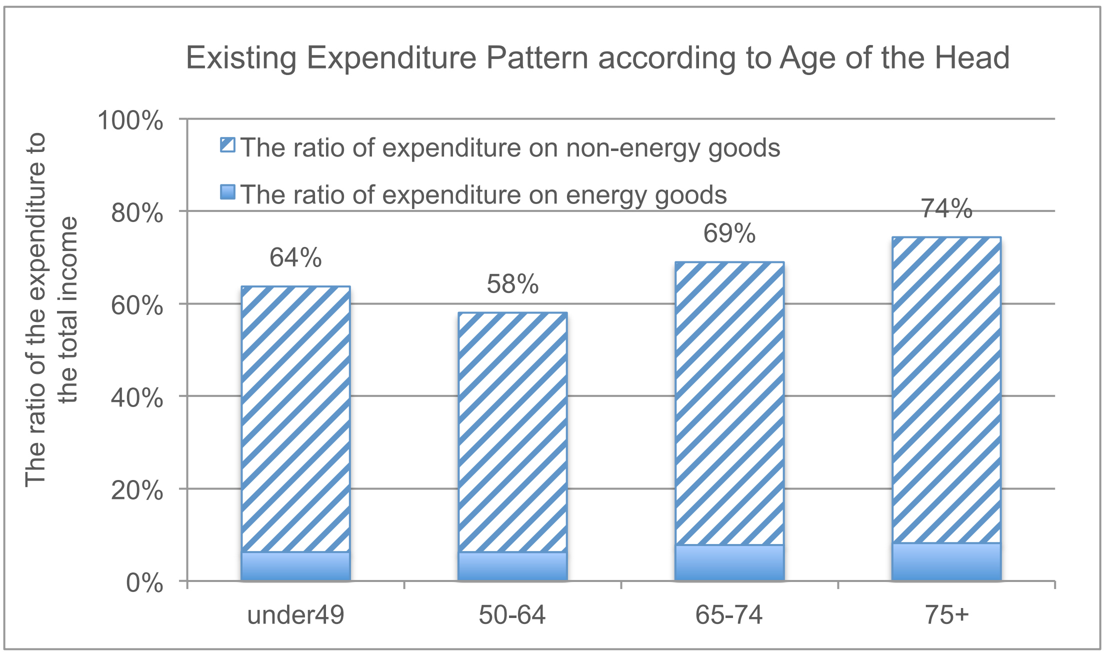

Figure 4.3 Existing Expenditure Pattern according to Age of the Head

4.2.2.3 Expenditure Pattern of Urban and Rural Households

The HSD is divided into two different groups: urban households and rural households depending upon the classification of administrative divisions[32]. Towns (*eup*), townships (*myeon*), and villages (*ri*) are classified as a rural area. Table 4.6 shows expenditure patterns on 26 goods and services of urban households and rural households, respectively.

The average age of the heads in rural households is older (51.9 years old) than in urban households (48.5 years old). In contrast, the average income is higher in urban households (3,122 thousand KRW) than in rural households (2,627.9 thousand KRW).

Rural households spent slightly more on energy than urban households did. Rural households spent 7.3% of their total income on energy including heating & cooling fuels and transportation fuels and urban households spent 6.2%. Overall, rural households spent slightly more on heating & cooling fuels. Urban households spent 3.0% of their monthly income on heating fuels while rural households spent 3.4%. In addition, rural households spent slightly more on transportation fuels (3.9%) than urban households did (3.2%).

In addition, the expenditure profile shows that rural households depend on more expensive fuels. While city gas account for about 40% (in monetary value) of the

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[32] In South Korea, the administrative divisions are as follows: cities (*si*), counties (*gun*), districts (*gu*), towns (*eup*), townships (*myeon*), neighborhoods (*dong*) and villages (*ri*). The administrative divisions are classifieds based on the population. For example, eup should have a population larger than 20,000 but less than 500,000.

heating & cooling energy expenditure in urban households, it account for only 16% in rural households. Rural households depended relatively more on kerosene, diesel, and briquettes. LPG and kerosene accounted for 13% and 18% of the home energy spending of rural households while they contributed to only 3% and 5% in urban households. With regard to transportation fuels, urban and rural households similarly depended on gasoline (41% in urban households and 42% in rural households), but the rural households depended more on diesel. Diesel contributed to 28% of the transportation fuel spending of the rural households while it contributed to 18% in urban households.

Table 4.6 Monthly Household Expenditures on 26 Goods and Services in the Rural and Urban Households

(Unit: thousand KRW)

	Urban	Rural
Average Income	3,122.0	2,627.9
Average number of Persons/Households	2.9	2.7
Average age of the head of household	48.5	51.9
Average Household Expenditures on 26 Consumer Goods and Services		
Food and non-alcohol beverage	271.1	231.4
Alcohol and tobacco	24.9	26.5
Clothing and shoes	126.0	91.2
Housing and Related Service	122.1	92.3
Electricity	40.3	42.4
City Gas	36.9	14.7
LPG-Heating	2.9	11.6
Kerosene	4.7	16.4
Diesel-Heating	0.3	0.5
Briquettes	0.4	2.2
Multi-housing heating	6.6	0.8
Other fuels	0.3	0.4
Housing supplies and service	71.6	59.8
Public health	128.1	115.5
Cars and related service	92.5	88.5
Gasoline	61.4	54.5
Diesel-Car	26.7	35.9
LPG-Car	12.8	12.5
Other fuels-Car	0.1	0.1
Mass Transportation	47.4	27.1
Communication	3.7	3.3
Leisure and cultural activities	120.2	104.4
Education	99.2	78.1
Restaurant and lodging	235.7	148.4
Other commodities and Services	252.8	193.0

In sum, the relative expenditure of urban households is larger than that of rural households. As mentioned earlier, although the expenditure on energy goods of rural households is larger, the expenditure on non-energy goods and services of urban households is vice versa. The urban households spent 56.6% of their income on non-energy goods while the rural households spent 53.5%. As a result, the total burden induced by the implementation of carbon pricing policy is expected to be heavier on urban households.

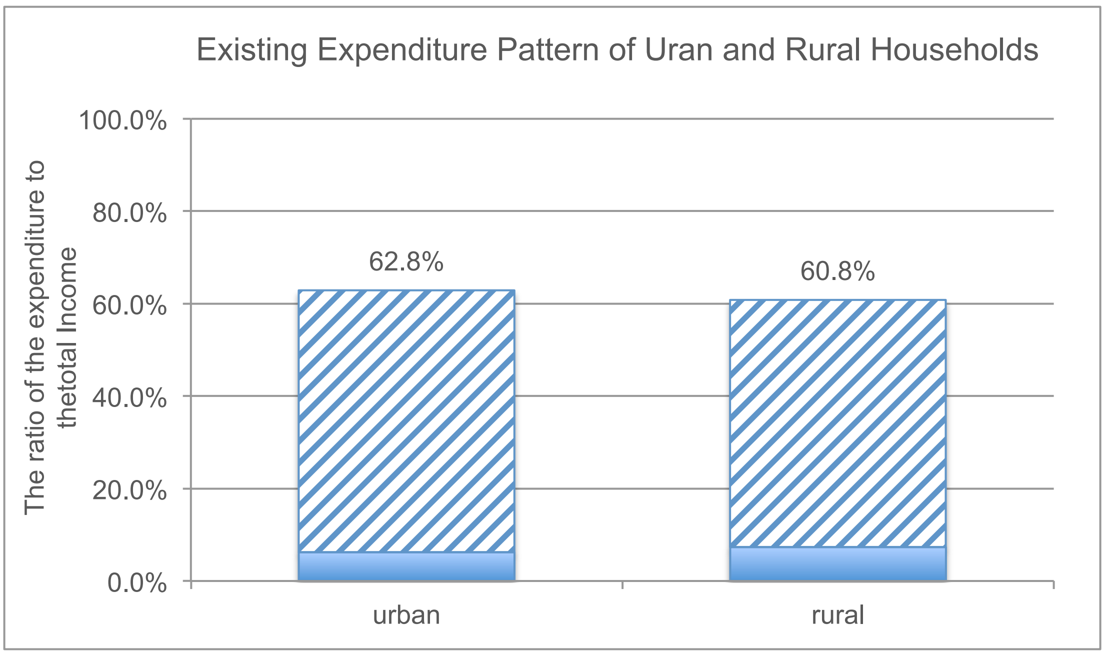

Figure 4.4 Existing Expenditure Pattern of the Urban and Rural Households

4.2.3 Sectoral Energy Consumption and CO_2 Emissions

Although the Yearbook of Energy Statistics (2012) annually provides information on final energy consumption by industry sectors, the sector classification of the Yearbook is not consistent with that of the I-O table constructed in this study. While final energy consumption is estimated by 21 sectors[33] in the energy balance table of the Yearbook, the sector classification of the I-O table is more disaggregated into 35 industry sectors. Therefore, this study needs to estimate sectoral energy consumption. I construct a hybrid I-O table in order to estimate sectoral total primary energy consumption (TPEC) and sectoral CO_2 emissions.

4.2.3.1 Sectoral Energy Consumption

Every element of a typical I-O table is in monetary value such as KRW or USD. However, in a hybrid I-O table, elements of energy sectors are expressed in a unit of physical quantity such as ton, barrel or toe, while elements of non-energy sectors remain expressed in monetary unit (see Table 4.7).

[33] The sectors of the energy balance table include [1] Agriculture & Fishery, [2] Mining, [3] Food & Tobacco, [4] Textile & Apparel, [5] Wood & Wood Product, [6] Pulp & Publications, [7] Petroleum Chemical, [8] Non-metallic product, [9] Iron & Steel, [10] Non-ferrous metal, [11] Fabricated Metal, [12] Other Manufacturing, [13] Other energy, [14] Construction, [15] Rail transportation, [16] Land transportation, [17] Water transportation, [18] Air transportation, [19] Residential sector, [20] Commercial sector, and [21] Public sector.

Table 4.7 The Structure of an Energy Input-Output Table

		Industries (Intermediate Demand)		Final Demand	Total Demand	Import	Total Output
		Energy	Non-Energy				
Industries (Intermediate Input)	Energy	Physical Quantity	Physical Quantity	Physical Quantity	Physical Quantity	Physical Quantity	Physical Quantity
	Non-energy	Monetary Unit	Monetary Unit	Monetary Unit	Monetary Unit	Monetary Unit	Monetary Unit
Value Added		Monetary Unit	Monetary Unit	Monetary Unit			
Total Input		Monetary Unit	Monetary Unit	Monetary Unit			

Source: (Park & Lee, 2011)

The flow chart below illustrates how to construct an energy I-O table and a CO_2 I-O table starting from an I-O table. First, an energy input I-O table can be obtained by converting the measurement unit of elements of energy sectors to physical units such as ton or barrel. The elements of energy sectors can be expressed in the form of physical quantity by dividing elements in monetary units by the energy price per each physical unit. Here, the amount of total demand of energy sectors except exports (the cell colored in grey in Table 4.7) should correspond with the total TPEC of the Yearbook.

After the first step, sectoral TPEC can be estimated. In order to compute CO_2 emissions by sector, it needs to exclude the amount of energy used as raw materials such as naphtha, lubricant, asphalt, etc. The carbon contents of these materials will not be discharged to the atmosphere through their combustion but remain in the goods. Subtracting the amount of energy used as raw materials (the amount of non-energy use in the energy balance table) from the amount of total energy input, an energy consumption I-O table is obtained. For the sake of convenience, I coordinated different measurement units of elements in energy sectors into caloric value – from 1,000 barrels for petroleum products, 1,000 tons for anthracite, etc. to kTOE. Finally, a CO_2 I-O table is estimated multiplying sectoral energy consumption (in kTOE) by emissions factors.

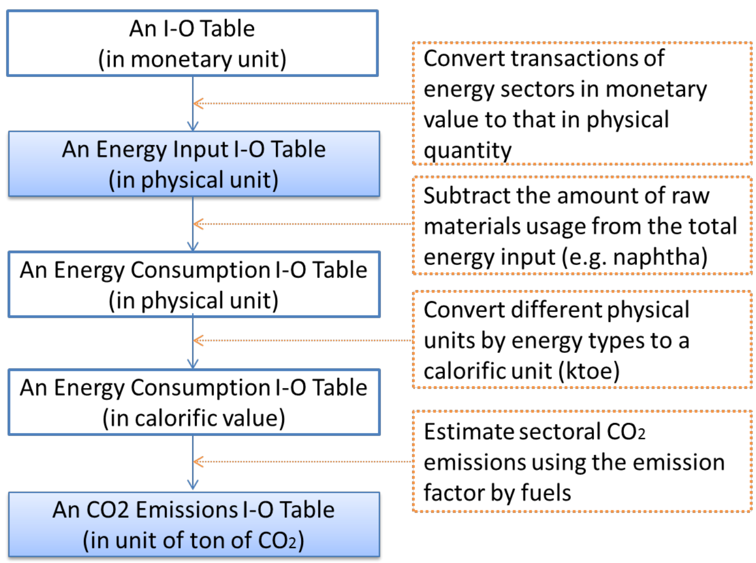

Figure 4.5 Procedures to Construct an Environmental I-O table

Source: (Kim, 2006a)

An I-O table records all transactions within an economy; as a result, primary energy (crude oil, LNG, coal, hydro power, nuclear power, and renewable energy) as well as final energy (electricity, gasoline, diesel, briquettes, etc.) is included in an I-O table. Therefore, an energy I-O table needs to be constructed based on either final energy or primary energy in order to avoid a duplicate estimation of the amount of energy consumption by sectors.

In general, an energy I-O table is constructed using primary energy because it is relatively easier to construct the table than using final energy (Park & Lee, 2011). (Choi & Lee, 2006) constructed an energy I-O table, which consists of 28 industry sectors and five energy sectors including anthracite, bituminous coal, crude oil, natural gas, and hydro and nuclear power. Since there were only five primary energy sources used to construct an energy I-O table, the energy amount of petroleum products was neglected and the amount of imported petroleum products was assumed to be equivalent to that of exported energy in their study. However, the difference between the amounts of imported petroleum products and exported petroleum products is not a negligible amount. In 2009, the amount of exported petroleum product (caloric value)[34] exceeded imported petroleum by 13,463 kTOE, which accounts for about 13.2% of the TPEC of the petroleum products (See cells colored in grey of Table 4.8).

Therefore, more detailed energy sector classification is needed in order to consider the supply situation of primary energy – a significant proportion of TPEC is supplied in the form of imported final energy. This study constructs an energy I-O table, which consists of 35 non-energy sectors and 13 energy sectors. In detail, energy sectors are [1] anthracite, [2] bituminous coal, [3] LNG, [4] gasoline, [5] kerosene, [6]

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[34] Interestingly, although South Korea imports every barrel of crude oil, petroleum products domestically produced through refinery are exported to various countries including Taiwan, Japan, China, Russia, etc. The largest amount was exported to Singapore followed by China and the Netherlands in 2009 (Petronet, n.d.).

diesel, [7] heavy oil, [8] jet oil, [9] LPG, [10] naphtha, [11] other petroleum products, which include solvent, asphalt, lubricant, paraffin-wax, petroleum coke, and other products, [12] hydro power, and [13] nuclear power. As a contrast to Choi and Lee (2006), crude oil is not included in this study because it is used as an input to produce gasoline, diesel, and other petroleum products. If crude oil consumption is included together with petroleum products consumption, the total primary energy consumption (TPEC) will be overstated.

Table 4.8 Total Primary Energy Supply by Energy Sources in 2009

(Unit:kTOE)

	Production	Import	Export	Intl' bunkering	Increase in stock	Statistical Difference	TPEC
Anthracite	1,171	4,236	-	-	261	144	5,812
Bituminous	-	59,194	-	-	-	3,597	62,791
LNG	498	33,568	-	-	1,144	-1,303	33,907
Gasoline	13,823	-	-5,111	-	-70	-263	8,379
Kerosene	4,549	9	-759	-	14	-177	3,636
Diesel	37,655	120	-18,053	-483	160	-363	19,036
Heavy oil	19,578	3,125	-3,997	-5,564	68	-2,307	10,903
Jet oil	14,279		-9,712	-938	28	-4	3,653
LPG	3,656	6,834	-12	-	37	564	11,079
Naphtha	20,357	23,144	-3,400	-	186	1,002	41,289
Other petro.	12,953	61	-5,713	-	-77	-2,863	4,361
Hydro	1,213	-	-	-	-	-	1,213
Nuclear	31,771	-	-	-	-	-	31,771

Source: (KEEI, 2012)

In order to construct an energy input I-O table, it is necessary to convert the transaction values between energy sectors to physical amounts. It is recommended to use an I-O table at basic price, which is obtained by subtracting production tax excluding subsidies from an I-O table at producer price (Park & Lee, 2011). However, this study uses an I-O table at producer price due to the limited availability of data.

As prices of imported energy sources are clearly different from those of domestic energy prices, this study constructed a domestic energy input I-O table and an import energy input I-O table respectively; and then integrated these two energy input I-O tables into the total energy input I-O table. In order to convert the unit of the elements of energy sectors to physical quantities, domestic energy prices and import energy prices by energy sources must be estimated. I estimated those prices using the Yearbook, the domestic I-O table at producer price, and import I-O table at producer price. The estimated domestic energy prices and imported energy prices are in Table 4.9. These prices do not exactly equal the actual prices of each energy product. It is noted that the estimated prices are used as a means to convert the measurement unit of elements into physical quantities and to allocate sectoral energy inputs.

Using the prices of both domestic and imported energy, I converted the measurement units of row elements of energy sectors into physical quantity units (1,000 barrels for petroleum products, 1,000 tons for anthracite, and GWh for nuclear power). Those elements are converted again to numbers in a caloric unit (kTOE).

Table 4.9 Energy Supply and Energy Prices by Energy Sources

	Domestic			Import		
	Quantity supplied	**Value supplied (MKRW)**	**Price (KRW/ton ;KRW/bbl ;KRW/kWh)**	**Quantity supplied**	**Value supplied (MKRW)**	**Price (KRW/ton ;KRW/bbl ;KRW/kWh)**
anthracite (K ton)	2,519	300,114	119,140	6,468	874,379	135,185
bituminous (K ton)	-	-	NA	92,952	11,786,008	126,797
LNG (K ton)	383	170,928	446,287	25,822	19,557,316	757,390
Naphtha (K bbl)	159,064	14,315,711	90,000	180,840	12,760,688	70,563
Gasoline (K bbl)	108,680	17,145,248	157,759	-	-	NA
Jet oil (K bbl)	102,649	9,381,182	91,391	-	-	NA
Kerosene (K bbl)	32,514	3,613,070	111,124	68	25,939	381,456
Diesel (K bbl)	261,714	33,650,614	128,578	836	549,124	656,847
Heavy oil (K bbl)	124,579	11,371,259	91,277	19,858	3,543,300	178,432
LPG (K bbl)	35,113	3,450,904	98,280	66,191	5,596,923	84,557
Other petroleum products (K bbl)	55,579	8,971,317	161,416	420	1,356,167	3,228,969
Hydro (GWh)	5,641	434,361	77	-	-	NA
Nuclear (GWh)	147,771	11,812,584	80	-	-	NA

Source: (Bank of Korea, n.d.; KEEI, 2012)

Figure 4.6 shows the TPEC by sectors. The energy consumption is largest in the chemical industry followed by electricity sector, city gas sector, and transportation sector. Naphtha consists of the largest proportion of TPEC in the chemical industry while bituminous coal contributes the most TPEC in the electricity sector and natural gas contributes the most TPEC in the city gas industry.

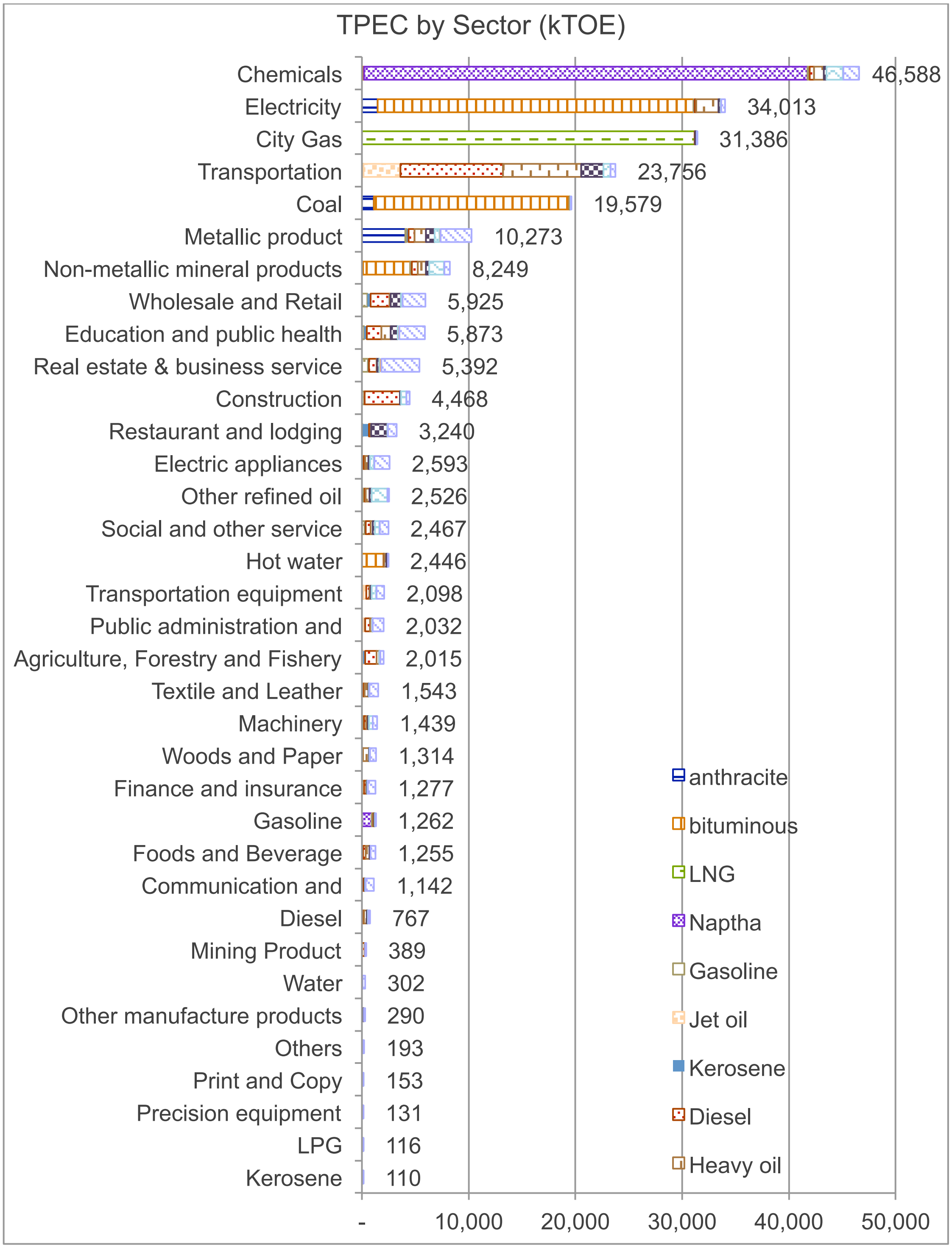

Figure 4.6 Sectoral TPEC in 2009 (kTOE)

One of limitations of this methodology is that it cannot take account of a small portion of the data of the Yearbook. This methodology cannot take account of international bunkering, stock change and statistical differences of the Yearbook. As a result, there is a difference between the total amount of TPEC of this study and that of the Yearbook, which is around 3% (negative) of the total TPEC. In other words, this method is overstating the total TPEC by 3%.

In addition, the sectoral energy consumption is estimated not in the final energy consumption but in the primary energy consumption. As a result, the energy consumption of an energy producer, such as the electricity or city gas sector can be overestimated.

4.2.3.2 Sectoral CO_2 Emissions

As explained earlier, the amount of energy used as raw materials including naphtha or asphalt needs to be excluded from the amount of energy input estimated above in order to calculate sectoral CO_2 emissions. This is because the carbon content will not be discharged into the atmosphere through combustion. Some literature examines process flow of each industry to identify how much energy is used as raw materials (Park, 2009; Park & Lee, 2011). Y. Kim (2006b) estimated the energy consumption I-O table using information of the ratio of energy combusted and information of carbon content in products. However, they employed Japanese data since that information has rarely been studied in South Korea.

This study simply excludes the amount of naphtha and other petroleum product consumption from sectoral energy input. The Yearbook categorizes consumption of naphtha, solvent, asphalt, lubricant, paraffin-wax, petroleum coke, and other products into non-energy use, which means these petroleum products are not combusted but used as goods themself or used as raw materials to produce other goods. The non-energy-use petroleum products of the Yearbook are compatible with naphtha and other petroleum products of this study. After subtracting the amount consumed as non-energy use, the energy-consumption IO table is ready to estimate sectoral CO_2 emissions.

Using the estimated energy consumption I-O table and CO_2 emissions factor by fuels (Korea Energy Management Corporation, n.d), sectoral emissions can be estimated. In addition to the consumption of naphtha and other petroleum products, it is assumed that hydropower and nuclear power consumption does not emit CO_2. The sectoral CO_2 emissions are as follows.

In 2009, the total CO_2 emissions from fossil fuel combustion were 485.2 Mt, of which emissions from the industrial sector were estimated to be 435.5 Mt. The rest of the emissions came from final demand excluding exports. Top CO_2 emitters are the electricity sector (128 MTOE), the city gas sector (73.3MTOE) and the transportation sector (69.2MTOE). The emissions from the top six emitters account for about 70% of the national CO_2 emissions in 2009 (about 78.4% of the total industries emissions) (See Figure 4.7). Different from the sectoral TPEC, CO_2 emissions of the chemical industry (6.3 Mt) is not high compared to its TPEC because the naphtha is the largest part of the energy input in the chemical industry and it is excluded in the estimation of the emissions.

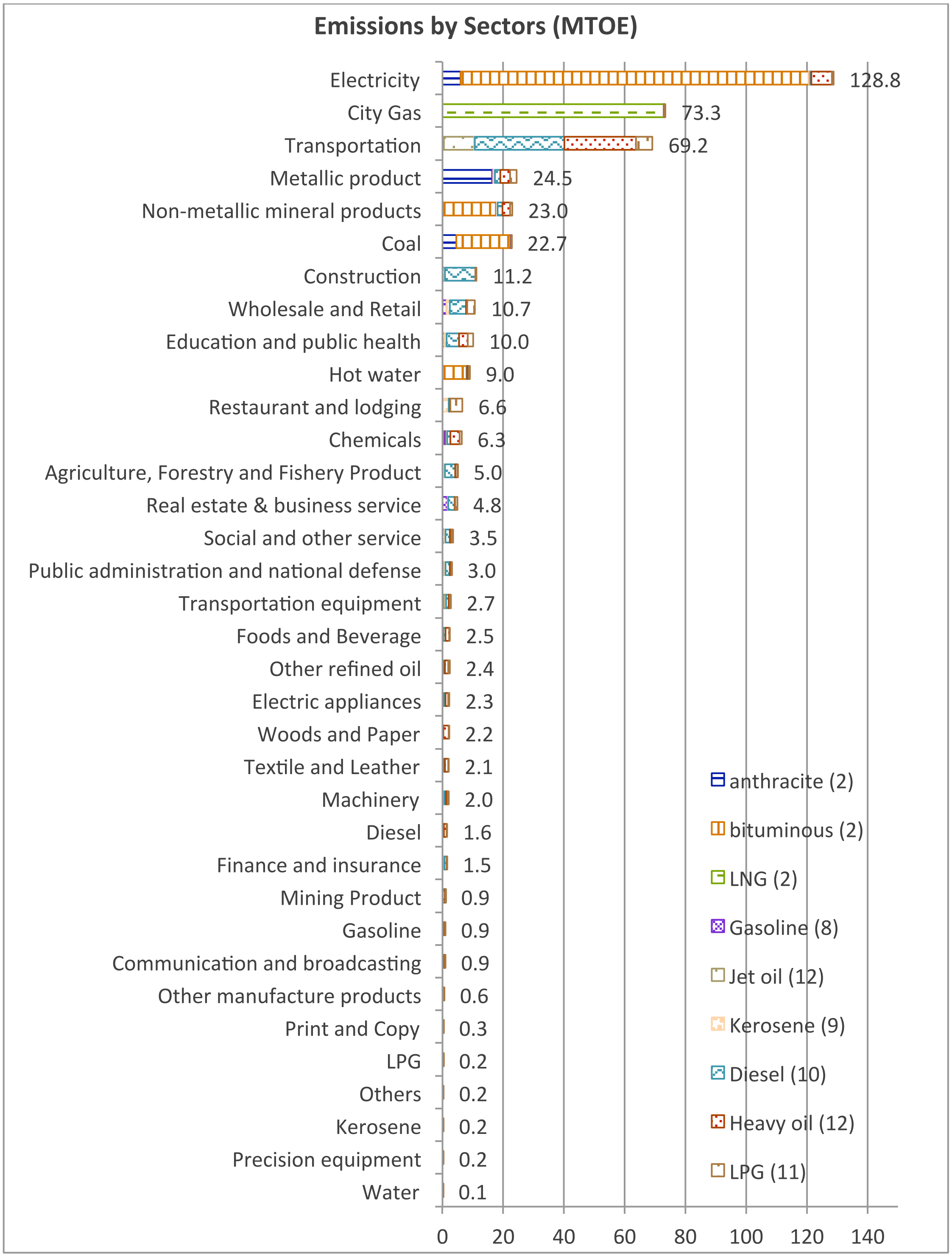

Figure 4.7 Sectoral CO_2 Emissions in 2009 (million tons of CO_2)

4.3 Methodology: Model Specifications

In the previous section, the data sets required for this study are explained in detail. This section explains how to assess the impacts of a carbon pricing policy on economy, energy, environment (CO_2 emissions) and equity dimensions.

In order to evaluate the equity implications of the policy, this study primarily follows the methodologies of Hassett, Mathur, and Metcalf (2009) and Grainger and Kolstad (2010). First, carbon permit price / carbon tax level is externally determined through the review of relevant literature. Second, the impact of carbon pricing on producer price is estimated using the I-O table. Third, using increased producer prices and the households' expenditure data I will derive the impact on consumer prices. It is assumed that the cost of the implementation will be passed on to customers. As noted in chapter 2, the concept of forward-shifting – a policy increases production cost and raises output price, which then affects consumers – contributes to a large part of the incidence of the policy (Fullerton, 2009). Based on these procedures, this study will estimate the incidence of a carbon pricing policy at the household level. Using extensive databases on households' expenditures in 2009, this study evaluates more comprehensive distributional impacts: [1] the incidence according to household income level, [2] distributional impacts according to head's age, and [3] comparison of the distributional impacts between rural areas and urban areas.

Besides equity implications, this study aims to assess the impacts of cap-and-trade on economy, environment and energy dimensions. With the assumption that the final demands will be changed depending on the changes in producer prices, I will assess how changes in final demands will drive changes in sectoral production levels, energy consumption, CO_2 emissions, etc.

One of the objectives of this research is to recommend a better policy design, which can relieve the regressivity that might be induced by the implementation of the policy. Therefore, in addition to the reference scenario – imposition of a specific carbon permit price without revenue recycling – this study will assess additional policy scenarios with revenue recycling in order to determine how revenue recycling helps to relieve the regressivity that resulted from the implementation.

This section consists of the following sections. Section 4.3.1 explains how to evaluate equity implications of the imposition of a carbon permit price. Section 4.3.2 illustrates the method employed to evaluate the economy-wide impacts of the policy. Finally, section 4.3.3 explains how to assess the impacts on energy consumption and CO_2 emissions.

4.3.1 How to Evaluate Equity Implications of Carbon Charges

The I-O model is constructed based on several assumptions: [1] once a good is produced, it is sold in a perfectly-competitive market. Here, all price increases will be passed on to consumers; [2] according to the Armington assumption, domestic goods and foreign goods are differentiated by the country of origin; and [3] input substitution is not allowed according to changes in factor prices. This means that every industry produces goods and services based on a fixed proportion of production technology.

Therefore, it will produce outputs using inputs at fixed rates even after the prices are increased.

The I-O table illustrates the interdependence among a number of sectors in the form of a matrix, which can be expressed as a set of linear equations. Two sets of equations can be derived from the I-O table. The first set is derived from the row sum of the table, which explains how goods and services produced from a sector are allocated/distributed to final demands and intermediate demands in a specific year.

$$\begin{aligned} x_{11}p_1 + x_{12}p_1 + \cdots + x_{1n}p_1 + d_1p_1 &= x_1p_1 \\ x_{21}p_2 + x_{22}p_2 + \cdots + x_{2n}p_2 + d_2p_2 &= x_2p_2 \\ &\vdots \\ x_{n1}p_n + x_{n2}p_n + \cdots + x_{nn}p_n + d_np_n &= x_np_n \end{aligned} \qquad (4.1)$$

x_{ij} is the quantity of the product of sector i used as input for sector j, p_i refers to the price of product i, d_i is the final demand for output i, and x_i is the total output of sector i. In other words, this set of equations illustrates that the output (x_ip_i) is distributed to intermediate demands ($\sum_{j=1}^{n} x_{ij} \times p_i$) and final demands ($d_ip_i$). Here, units of every product are normalized to make the producer price equal to one. In this case, the total number of industry sectors, n, is 35.

The second set of equations describes how a sector utilizes/purchases intermediates and value added to produce the output.

$$x_{11}p_1 + x_{21}p_2 + \cdots + x_{n1}p_n + v_1 = x_1p_1$$
$$x_{12}p_1 + x_{22}p_2 + \cdots + x_{n2}p_n + v_2 = x_2p_2 \tag{4.2}$$
$$\vdots$$
$$x_{1n}p_1 + x_{2n}p_2 + \cdots + x_{nn}p_n + v_n = x_np_n$$

v_i is value added, such as labor and capital, absorbed to the sector *i* to produce output. Using this set of equations, the prices of products can be calculated. By dividing the set with the output of the sector *i*, technical coefficients or input coefficients $a_{ij} = x_{ij}/x_j$ can be estimated. The coefficients illustrate how much unit of x_i is required to produce 1 unit of x_j.

The second set can be expressed differently using input coefficients.

$$(1 - a_{11})p_1 - a_{21}p_1 - \cdots - a_{n1}p_1 = v_1 / x_1$$
$$-a_{12}p_1 + (1 - a_{22})p_2 - \cdots - a_{n2}p_2 = v_2 / x_2 \tag{4.3}$$
$$\vdots$$
$$-a_{1n}p_1 - a_{2n}p_n - \cdots + (1 - a_{nn})p_n = v_n / x_n$$

The set of linear equations can be expressed in matrix form:

$$(I - A')P_I = A^V \tag{4.4}$$

I is a 35x35 identity matrix. A is a 35x35 input coefficient matrix or technical coefficient matrix. The elements of matrix A, $a_{ij} = x_{ij}/x_j$, can be interpreted as the monetary value amount of inputs from sector *i* required to produce a unit of output from sector j. In addition, in an I-O model, the technical coefficients are unchanging. As the output quadruples, the inputs will quadruple. This means that economies of scale do not hold in the Leontief system (Miller & Blair, 2009). This model is based on the constant return to scale.

P_I is a 35x1 vector of producer prices. A^V is a 35x1 vector of ratio of value added to the total output (v_i / x_i). If (I-A) matrix is nonsingular or has a matrix inverse, price vector can be obtained as follows.

$$P_I = (I - A')^{-1} A^V \tag{4.5}$$

The unitary carbon permit price per ton of CO_2 cannot be estimated by the I-O model. Therefore, the permit price should be exogenously chosen through literature review as done by M. Kang et al. (2011) and Grainger and Kolstad (2010). Here, the permit price is supposed to be equivalent to \$15/tCO_2, as done by Grainger and Kolstad (2010) and Hassett et al. (2009).

In this model, cap-and-trade implementation is treated like a carbon tax; if an industry is required to purchase emission permits, the impact is as if different unit taxes are imposed in proportion to the consumption of fossil fuel intermediates in each industry sector.

$$CO_2Rev_i = \sum_{ff} CO_2\ Emissions_{ff} \times Cpermit \tag{4.6}$$

$$t_i = CO_2Rev^{i} / \sum_{j=1}^{n} x_{ij} \qquad (4.7)$$

CO_2Rev_i is the revenue of cap-and-trade collected from sector i, which is in proportion to sectoral CO_2 emissions from fossil fuel combustion. The revenue is calculated multiplying CO_2 emissions from fossil fuel combustion ($CO_2\ Emissions_{ff}$) in sector i by permit price ($Cpermit$). CO_2 emissions consist of the emissions from combustion of nine different fossil fuels (ff): [1] anthracite, [2] bituminous, [3] LNG, [4] Gasoline, [5] Jet oil, [6] Kerosene, [7] Diesel, [8] Heavy oil, and [9] LPG. Sectoral primary energy consumptions are further disaggregated into thirteen energy sources. However, naphtha, other petroleum products, hydro, and nuclear are excluded in the estimation of CO_2 emissions because hydropower and nuclear power are treated as zero-emission sources and naphtha and other petroleum products, such as asphalt or lubricant, are not combusted but are used as products themselves or as raw materials to produce other goods.

t_i refers to the unit tax rate imposed on each sector, as a result of carbon charges. The tax rates (t_i) are different by sector depending on the sectoral CO_2 emissions patterns. The tax rate for a sector is computed as the ratio of the revenue collected from the sector to the output of the sector.

Implementation of a carbon pricing mechanism will impact producer prices, which can be expressed by adding taxes to the system.

$$x_{11}p_1(1+t_1) + \cdots + x_{n1}p_n(1+t_1) + v_1 = x_1p_1$$
$$x_{12}p_1(1+t_2) + \cdots + x_{n2}p_n(1+t_2) + v_2 = x_2p_2 \qquad (4.8)$$
$$\vdots$$
$$x_{1n}p_1(1+t_n) + \cdots + x_{nn}p_n(1+t_n) + v_n = x_np_n$$

In a similar fashion to the above solution (divide the set of equation with the output of sector *i*), this set of equations can be expressed in the form of a matrix as follows:

$$(I - B')P_I = A^V \qquad (4.9)$$

B is a 35x35 matrix, and its elements are $(1 + t_j)a_{ij}$. The set of changed prices after the implementation of cap-and-trade can be solved as follows:

$$P_I = (I - B')^{-1}A^V \qquad (4.10)$$

Once new producer prices are obtained, it is possible to estimate how increased producer prices impact consumer prices. As noted earlier, this model assumes 100% forward-shifting of the implementation cost – the burden will be totally passed on to customers. The flowchart below in Figure 4.8 illustrates that this model simulates how the compliance cost is passed on to households. Once a cap-and-trade program is implemented, the producer prices are affected. Changes in producer prices impact consumer prices. The distributional implications vary with the existing consumption profiles of each household group.

Here, it is required to construct a Z transition matrix, which links producer prices with consumer prices. Through the Z matrix, changes in producer prices are conveyed to consumer prices.

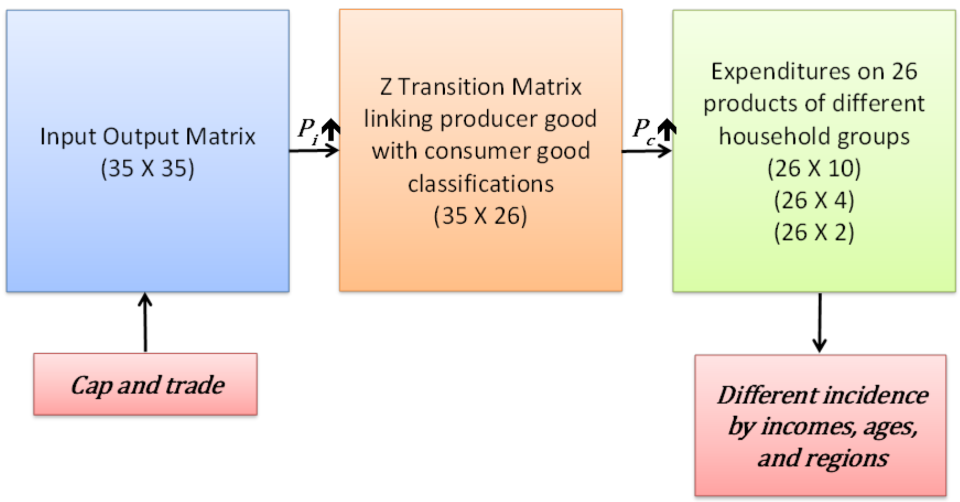

Figure 4.8 The Schematic Diagram of the Methodology

Once the Z matrix (a 35x26 fixed coefficient matrix) is constructed, the vector of consumer prices (P_C) can be calculated according to the equation 4.11.

$$P_C = Z'P_I \tag{4.11}$$

The classification of industries in the I-O table is different from that of the HSD. In order to solve this inconsistency between two databases, it is necessary to construct a transition matrix, which links producer goods to consumer goods. The elements of transition matrix / Z matrix (Z_{ij}) are coefficients that illustrate how much each industry's output is used in producing each consumer good or how each consumer good consists of different outputs in industry sectors such as the input structure of the I-O table. It is assumed that producer goods are converted to consumer goods at a fixed proportion (Ballard, Fullerton, Shoven, & Whalley, 1985).

The Z matrix is constructed as follows. First, the original I-O table with 403 industries needs to be aggregated to a 35x26 matrix. For the rows, 403 industry sectors are aggregated into 35 sectors like the I-O table constructed in this study (refer to Table 4.2). For the columns, 403 industry sectors are distributed to 26 categories of consumer goods and services (see Table 4.3). However, every industry sector is not included into consumer goods since consumers do not purchase goods or services directly from specific industries (e.g., mining). It is because a consumer seldom purchases a product directly from industries (e.g., products from the crude oil industry, the natural gas industry, and/or the mining industry).

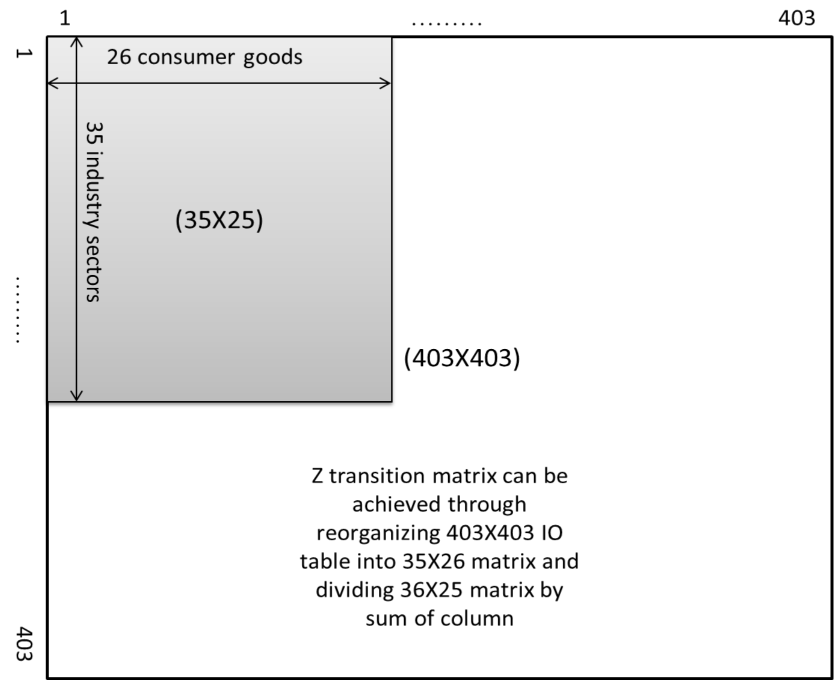

Figure 4.9 The Construction of Z matrix

Once the original I-O table is reorganized into a 36X26 matrix, the elements of the matrix need to be divided by the sum of the column (Kim, Ahn, & Lee, 2002). The Z matrix and the classification are provided in the Appendix.

After the Z matrix is estimated, the incidence of carbon price can be estimated. The burden on each household will be provided in the form of the proportion of the increased expenditure to income.

4.3.2 Impacts of a Carbon Pricing Mechanism on the Economy

The previous section clarified how to evaluate the income-based equity implications of cap and trade in South Korea. As mentioned previously in Chapter 2, in addition to its effects on the status of equity in a nation, cap and trade will impact economy, environment, and energy dimensions as well. This section will explain how to assess the impacts on other dimensions. Based on the assumption that final demand by sector will change depending on the change in producer prices it is possible to estimate economic impacts on: [1] sectoral output, [2] value added, [3] imports, and [4] employment (Kang et al., 2011). Subsequently, changes in sectoral output and final demands allow this study to compute both changes in TPEC and in CO_2 emissions by sector.

4.3.2.1 Impact on Final Demand

Final demand will change depending on changes in producer prices. As the price increases, the final demand will decline and the reduction will vary according to the price elasticity of demand. Once the price elasticity and percentage change in price are given, the percentage change in final demand can be estimated. In addition, the changes in final demands are obtained with existing values of final demands (see the equation below).

$$e_I = \frac{\%\ change\ in\ demand}{\%\ change\ in\ price} = \frac{\Delta Y_I / Y_I}{\Delta P_I / P_I} \qquad (4.12)$$

$$\Delta Y_I = e_I Y_I \Delta P_I / P_I \qquad (4.13)$$

The price elasticity varies according to the region, age of the purchaser, etc. For example, the price elasticity for rice ranges from -0.8 in China to -0.25 in Japan and the price elasticity for cigarette of the youth is -0.6 to -0.7 while the general price elasticity ranges from -0.3 to -0.6. This paper will use the numbers in the table "Reduction in Final Demands After Imposition of Carbon Tax by Scenarios" from M. Kang et al. (2011). Based on these numbers, the reductions in final demands are estimated (See Table 4.10 below).

Table 4.10 Final Demand Elasticities by Sector

	Price Elasticity of Final Demand	Initial Final Demand (million KRW)
Agriculture, Forestry and Fishery Product	-0.500	16,170,917
Mining Product	-1.000	(2,182,833)
Foods and Beverage	-1.000	55,997,692
Textile and Leather	-1.000	40,390,282
Woods and Paper	-1.000	2,684,810
Print and Copy	-1.000	564,928
Coal	-0.500	(1,210,737)
Gasoline	-0.820	12,635,242
Kerosene	-0.820	1,535,424
Diesel	-0.820	13,494,600
LPG	-0.820	1,356,025
Other refined oil	-0.820	14,682,736
Chemicals	-0.820	57,798,821
Non-metallic mineral products	-1.000	1,637,834
Metallic product	-0.996	33,313,982
Machinery	-1.000	70,685,388
Electric appliances	-1.000	191,281,461
Precision equipment	-1.000	13,841,777
Transportation equipment	-1.200	135,381,303
Other manufacture products	-1.000	11,053,066
Electricity	-0.820	7,613,213
Natural gas	-0.820	6,142,085
Hot water	-0.820	926,946
Water	-0.820	1,367,274
Construction	-1.200	177,879,793
Wholesale and Retail	-1.000	67,455,585
Restaurant and lodging	-2.000	55,319,950
Transportation	-1.200	57,558,854
Communication and broadcasting	-1.200	24,106,814
Finance and insurance	-1.000	49,771,363
Real estate & business service	-1.000	130,114,836
Public administration and national defense	-1.000	92,320,008
Education and public health	-1.000	159,903,117
Social and other service	-0.500	57,798,493
Others	-1.000	262,859

Source: (Kang et al., 2011)

In turn, changes in final demands will impact economy in terms of output, value added, import, and employment.

4.3.2.2 Impacts on Output

The equation set (1) is revisited and it can be expressed as follows using the matrix notation.

$$X = D_i + Y$$

$$X = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}, \qquad D = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nn} \end{bmatrix}, and\ Y = \begin{bmatrix} d_1 \\ \vdots \\ d_n \end{bmatrix} \qquad (4.14)$$

$$Here\ n = 35$$

As mentioned above, the I-O table assumes the fixed production technology throughout industries. With consideration to a set of fixed technical coefficients (A), the equation above can be rewritten as follows.

$$X = AX + Y$$

$$Here, A = D\hat{X}^{-1} \qquad (4.15)$$

$\hat{X}^{-1}$ is a diagonal matrix of which its elements, industries' outputs, are located along the main diagonal.

This equation can be rewritten as follows.

$$X = (I - A)^{-1}Y \qquad (4.16)$$

Based on this equation, once an exogenous shock, such as an increase in foreign demand for one or multiple goods or an increase in government demand due to its economic stimulus policy, occurs, we can estimate the changes in sectoral outputs. However, I am interested in how a policy impacts on domestic industries' output. In order to extract impacts of a change in final demand on only domestic industries, it is necessary to remove competitive imports from the I-O table. In contrast with uncompetitive imports, which are separately located in a column of "imports" in an I-O table, competitive imports comprise of intermediates inputs. Competitive imports have the same counterpart, which is domestically produced and is used as intermediate inputs together with products produced by domestic industries (Miller & Blair, 2009). Fortunately, the Bank of Korea provides the I-O table including only domestically produced inputs. Using the I-O table, the domestic technical coefficient matrix (A^D) can be derived (See the table of A^D in the appendix).

Using the equation below, we can estimate the impact of cap-and-trade policy on industry outputs.

$$\Delta X = (I - A^D)^{-1} \Delta Y \quad (4.17)$$

4.3.2.3 Impacts on Value-added

Once the output is changed depending on the changes in final demand, the value-added, such as depreciation of capital, indirect business taxes, labor, etc.—

which depends on the production level—will be also affected. Therefore, the change in final demand will consequently impact the value added.

Similar to the procedure employed to derive the impact of the implementation on outputs, the impacts on value added can be estimated as follows. V is a 35X1 vector of value added (v_i). $\hat{A}^V$ is a diagonal matrix with elements of the ratio of value added to the output (v_i / x_i) along the main diagonal of the matrix. As seen in the equations below, the vector of value added is equivalent to the product of the value-added coefficient diagonal matrix and the output vector. Then, if ΔX is replaced with $(I - A^D)^{-1}\Delta Y$, it is possible to estimate the changes in value added induced by the changes in final demands: $\Delta V = \hat{A}^V (I - A^D)^{-1} \Delta Y$.

$$
\begin{gathered}
\hat{A}^V = VX^{-1} \\
V = \hat{A}^V X \\
\Delta V = \hat{A}^V \Delta X \\
\Delta V = \hat{A}^V (I - A^D)^{-1} \Delta Y
\end{gathered}
\tag{4.18}
$$

4.3.2.4 Impacts on Import

The IO table of imports records the transactions of imports between industries and final demands for imports. The sum of the intermediate demands and final demands for imports is equivalent to the total amount of imports. Here, D^M, the matrix of transactions of imported intermediates between industries, can be expressed in the form of the product of A^M(technical coefficient of imports) and X. Once X is replaced with $(I - A^D)^{-1}Y$, we can get the matrix of import inducement coefficients ($A^M(I - A^D)^{-1}$), which illustrates how imports are indirectly and directly induced by a unit of change in final demand.

$$
\begin{gathered}
D^M + Y^M = M \\
A^M X + Y^M = M \\
A^M(I - A^D)^{-1}Y + Y^M = M \\
A^M(I - A^D)^{-1}\Delta Y
\end{gathered}
\qquad (4.19)
$$

4.3.2.5 Impacts on Employment

Unfortunately, since the Bank of Korea provides information on employees by 168 sectors instead of 403 sectors, it is impossible to analyze the impact of the scheme on employment of 35 sectors. Five industries including Gasoline (8), kerosene (9), diesel (10), LPG (11), and other refined oil (12) need to be integrated into the "Petroleum" sector because of the limitation of the data. Other sectors will remain as they are classified by 35 sectors. Therefore, this study will analyze the impacts on employment by 31 sectors.

The Bank of Korea records sectoral employment as follows: [1] workers (L_w) and [2] employees (L_w). Workers are a more extensive concept than employees. While employees refer to people hired by someone or a company in return for payment, workers consist of employees, self-employees, and unpaid family workers.

The impact on employment can be analyzed as follows. The vector of changes in employment is equivalent to the product of the diagonal matrix of employment coefficients, Leontief Inverse and the vector of changes in final demand. Here, $\widehat{l_w}$ and $\widehat{l_e}$ refer to diagonal matrixes with elements of the ratio of employment to the output (L_w/x_i and L_e/x_i respectively). ΔL_w and ΔL_e illustrates how a large number of workers and employees are induced according to the change in final demand.

$$\Delta L_w = \widehat{l_w} \times (I - A^D)^{-1} \Delta Y \quad (4.20)$$

$$\Delta L_e = \widehat{l_e} \times (I - A^D)^{-1} \Delta Y \quad (4.21)$$

4.3.3 Impacts on Energy and Environment of a Carbon Pricing Mechanism

I have reviewed how a cap-and-trade policy will impact South Korean economy based on the change in output, value added, and imports. The impacts on energy and environments can be estimated in a similar way using a Leontief inverse matrix.

4.3.3.1 Impacts on Energy Demand

Once an energy-IO table is constructed, we can estimate primary energy intensity by sector and by energy source. This energy intensity means how much primary energy is required to produce 1 KRW's worth of output in a sector. It is referred to as the direct energy requirement, which only accounts for the emissions from a sector when a commodity or service is produced in this sector.

$$\varepsilon = EX^{-1}$$

$$\varepsilon: a\ matrix\ of\ sectoral\ energy\ intensities\ or\ direct\ energy$$

$$-coefficients \qquad (4.22)$$

$$E: a\ matrix\ of\ sectoral\ energy\ consumption\ by\ energy\ sources$$

As a change in final demand comprehensively impacts an economy by inducing changes in outputs of sectors which are used as intermediates, it will impact the energy inputs in sectors. Using the Leontief inverse matrix, the total energy requirement matrix—including direct and indirect energy requirement to meet the final demands—can be derived as follows:

$$\tau = \varepsilon(I - A)^{-1} \qquad (4.23)$$

$$\tau: a\ matrix\ of\ sectoral\ total\ energy\ coefficients$$

Unique from the methodology used to analyze the economic impacts, I use the matrix A rather than A^d. Park and Lee (2011) stated that studies regarding energy demand aim to estimate the total energy demand to meet the changed final demand. While we focus on the impacts of a change in final demand on domestic industries, it is appropriate to utilize the technical coefficients matrix rather than the domestic technical coefficients matrix. The total sectoral TPEC change due to the change in final demand is a product of τ and ΔY, which includes indirect and direct energy consumption by sector.

$$\tau \times \Delta Y = \varepsilon(I - A)^{-1}\Delta Y \quad (4.24)$$

In addition, the indirect energy requirement by sector can be obtained by subtracting ε from τ, which refers to the energy demands/consumption due to the production of intermediates.

$$i\varepsilon = \tau - \varepsilon \quad (4.25)$$

4.3.3.2 Impacts on Environment

The impacts on the environment can be estimated in the same manner. Based on the CO_2 emissions- IO table, I can calculate sectoral CO_2 emission intensities. The intensities refer to how much CO_2 emissions result from producing the output of 1KRW in sector *i*. These CO_2 emission intensities are also called direct emissions. In addition to the direct emissions, a change in final demand of sector *i* indirectly induces the changes in emissions from the sectors of which products contribute as intermediates to the production of outputs of sector *i*. The total amount of the emissions changed is the product of sectoral emission intensities, the Leontief inverse matrix, and change in final demand.

$$p = GX^{-1}$$
$$p \times \Delta Y = G(I - A)^{-1}\Delta$$

$$p: a\ matrix\ of\ sectoral\ emission\ intensities\ or\ direct\ -emission\ coefficients \quad (4.26)$$

$$G: a\ matrix\ of\ sectoral\ emissions\ by\ energy\ sources$$

Chapter 5

EMPIRICAL ANALYSIS RESULTS

This study tested three different scenarios: [1] comprehensive participation scenario (S1), [2] partial participation scenario with a higher carbon tax (S2) and [3] comprehensive participation scenario with a higher carbon tax (S3). The S1 assumes that every industry sector is required to purchase CO_2 permits at \$15/ton of CO_2 in order to comply with the policy, while S2 assumes that only large emitters are required to purchase CO_2 permits at about \$18.9/ton of CO_2 in order to achieve the same amount of reduction with the S1 case (1.41% of the total emissions). The participating industries are determined based on the amount of emissions and as such the coal, non-metallic, metal, electric, natural gas and transportation sectors are all required to join the scheme. These six industries contribute to 78.4% of the total emissions from industries in South Korea. Similar to the S1, the S3 supposes the participation of every sector in the imposition of a CO_2 tax of \$18.9/ton of CO_2 permit.

In addition, this study analyzes the equity implications of revenue recycling for S1, S2 and S3 respectively: [1] equal per-capita dividend (R1) and [2] equal per-household dividend (R2). By recycling a certain proportion of proceeds of permit sales, the regressivity induced by the implementation is expected to be relieved. The R1 assumes that 25% of the revenue is distributed to households on an equal per capita basis, which means larger families will receive a higher dividend. The R2 assumes that a quarter of the revenue is distributed to households through an equal per household dividend, which means each household will receive the same amount of lump-sum transfer regardless of family size.

Table 5.1 Policy Scenarios

Basic Scenarios	**Revenue Recycling Cases**
S1: Comprehensive participation of 35 sectors, CO_2 permit price of $15/ton of CO_2	R1: Distribute 25% of the proceeds to households on the basis of equal per capita dividend
	R2: Distribute 25% of the proceeds to households on the basis of equal per household dividend
S2: Partial participation of six large emitting industries (coal, non-metallic, metal, electric, natural gas and transportation sectors), CO_2 permit price of about $18.9/ton of CO_2)	R1: (same as above)
	R2: (same as above)
S3: Comprehensive participation, CO_2 permit price of $18.9/ton of CO_2)	R1: (same as above)
	R2: (same as above)

The results will be discussed in following sections.

5.1 Economic Implications

5.1.1 Impacts on Prices

In the comprehensive participation scenario (S1), the producer prices increase, on average[35] by 0.74%. Specifically, the price of hot water increases the most (2.25%)

[35] It is a weighted average of change rates in producer prices according to outputs by sector.

followed by the electricity sector (2.16%), while the producer price for the finance and insurance sector increases the least (0.23%). In the partial participation scenario (S2), the weighted average of increase rates in producer prices is 0.73%, which is slightly less than that under S1. However, the producer price of electricity sector increases more (2.32%) than the result under S1. In the comprehensive participation scenario with a higher permit price (S3), the producer prices increase on average by 0.93%. While the increases in producer prices are different between sectors, the pattern is equal to that of the S1 case.

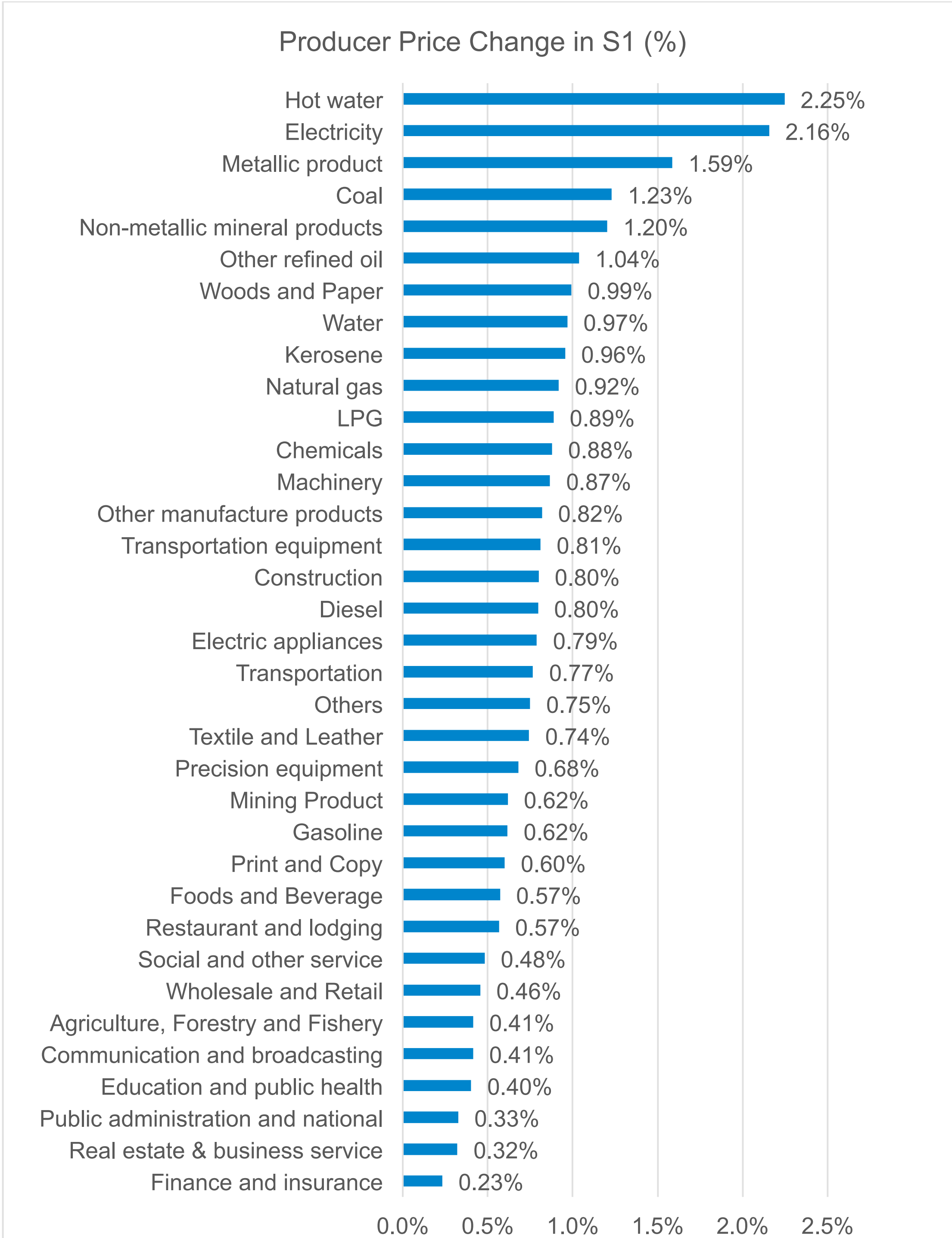

Figure 5.1 Producer Price Changes in the S1 Scenario

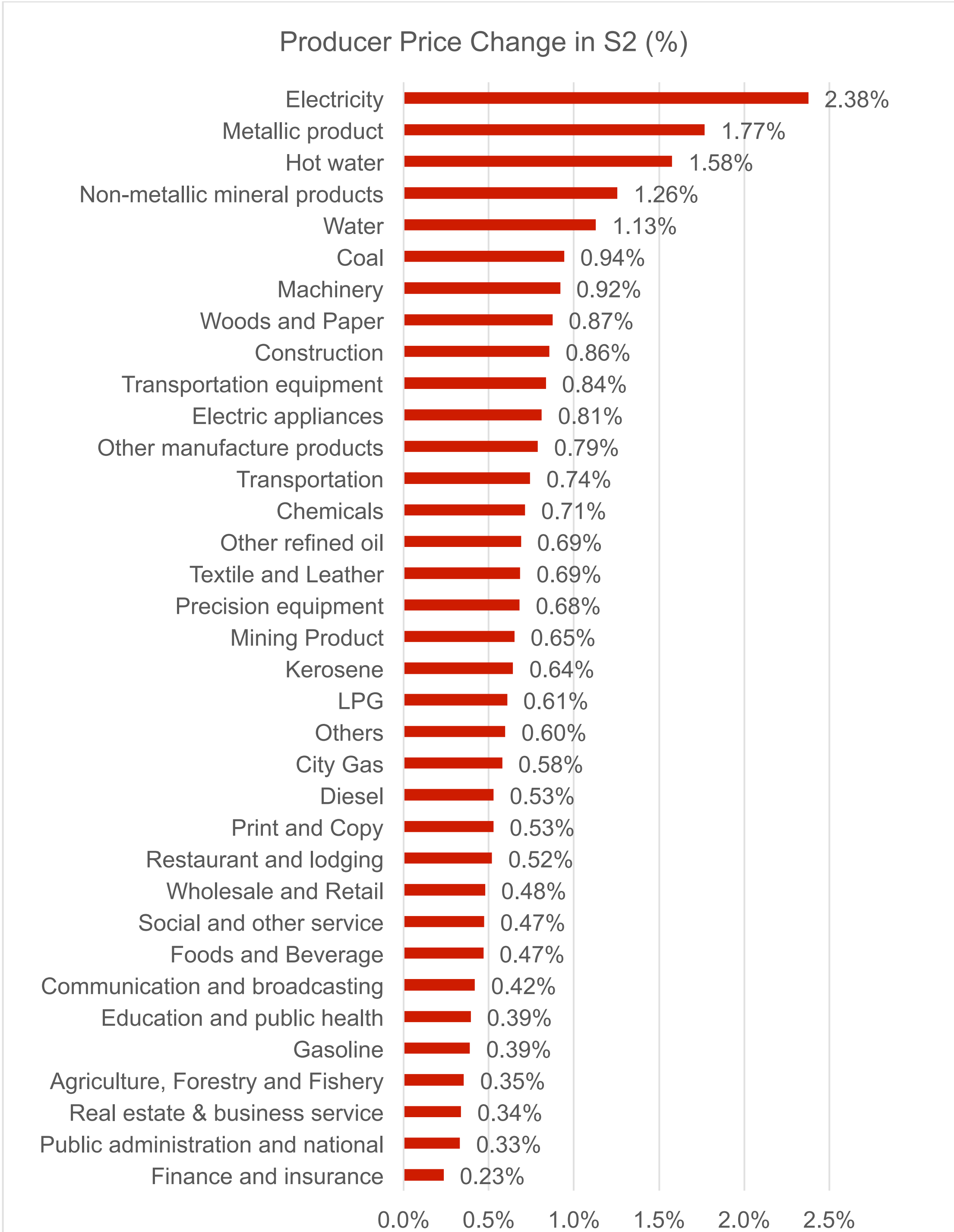

Figure 5.2 Producer Price Changes in the S2 Scenario

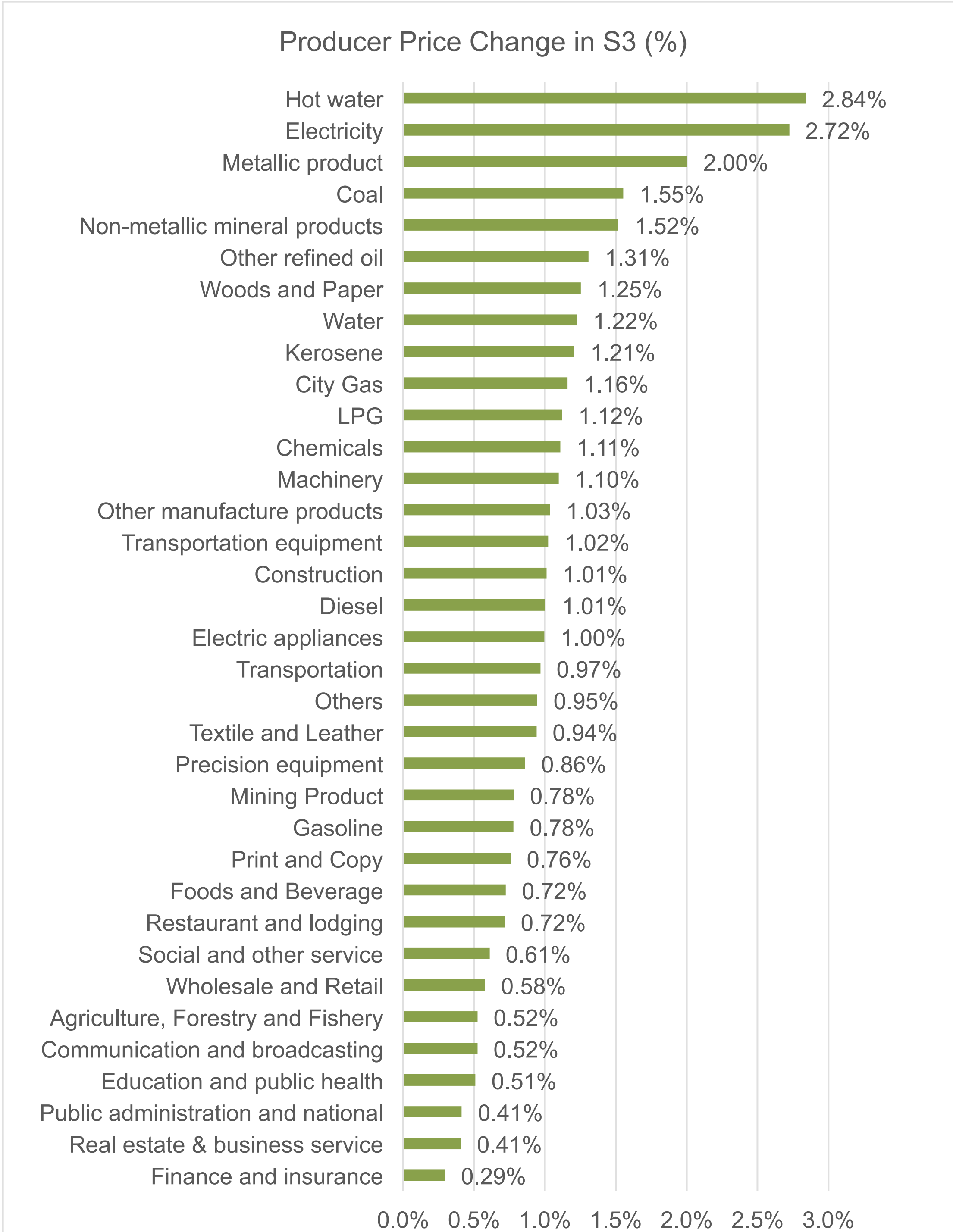

Figure 5.3 Producer Price Changes in the S3 Scenario

Due to the increases in producer prices, the consumer prices, in turn, increase. In the S1, the consumer prices increase on average by 0.70%[36]. The consumer price of other heating fuels increases the most (1.19%) in the S1, while the price of other commodities and services increases the least (0.53%).

The higher increase in the consumer price of a good or service is dependent on the structure of the Z matrix. In detail, the changed consumer price of other fuels is a product of the vector of producer prices and the column corresponding to the other fuels of the Z matrix.

In the S2, the weighted average increase of consumer prices is slightly less (0.66%) than that of S1. In S2, the highest increase in consumer price is observed for housing and related services (1.02%) while the consumer price of other commodities and services increases the least (0.51%).

The weighted average of increases in consumer prices is highest in S3 (0.88%) due to the higher carbon price on every sector.

[36] It is a weighted average of increase rates in consumer prices according to the average household expenditure pattern.

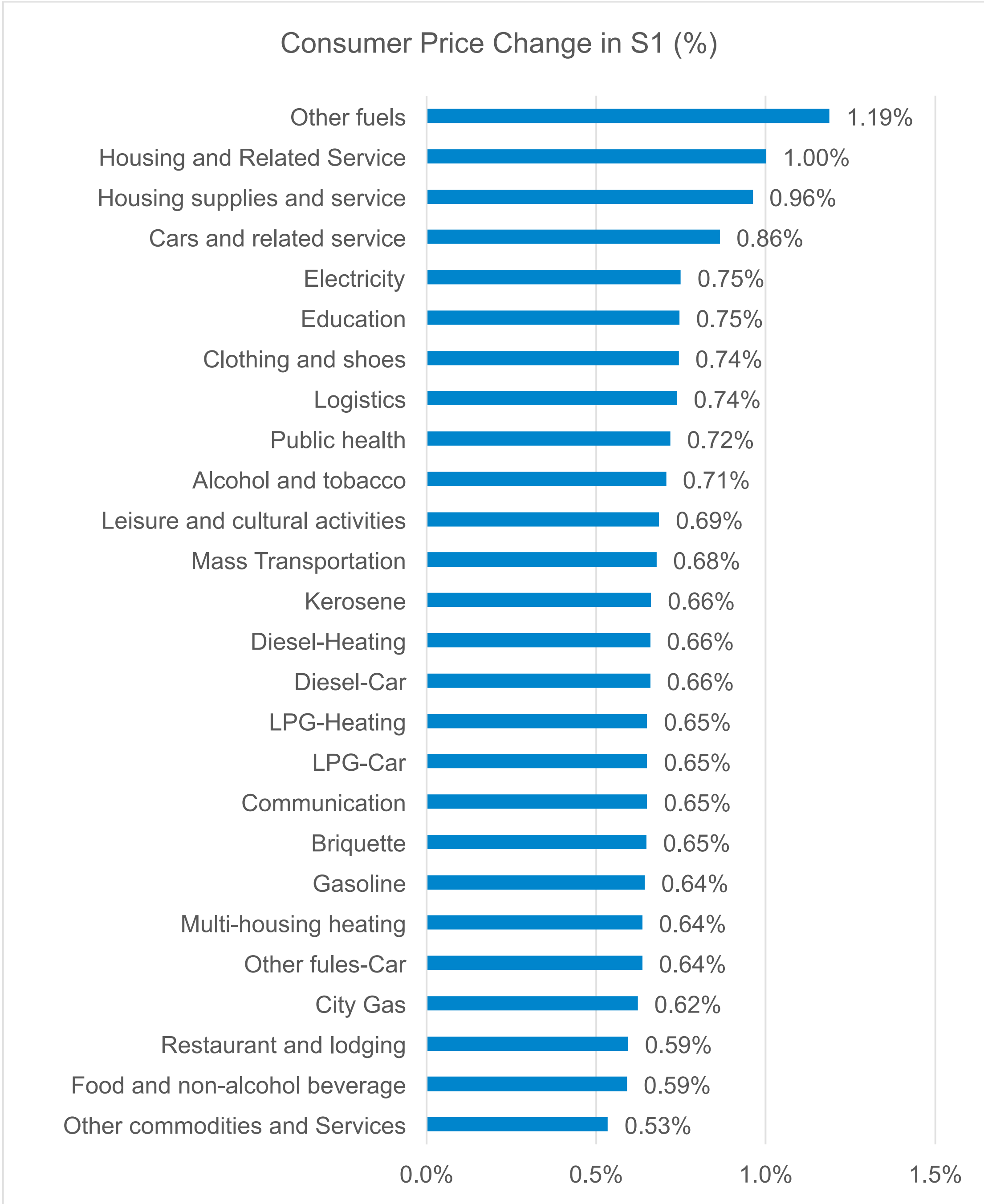

Figure 5.4 Consumer Price Changes in the S1 Scenario

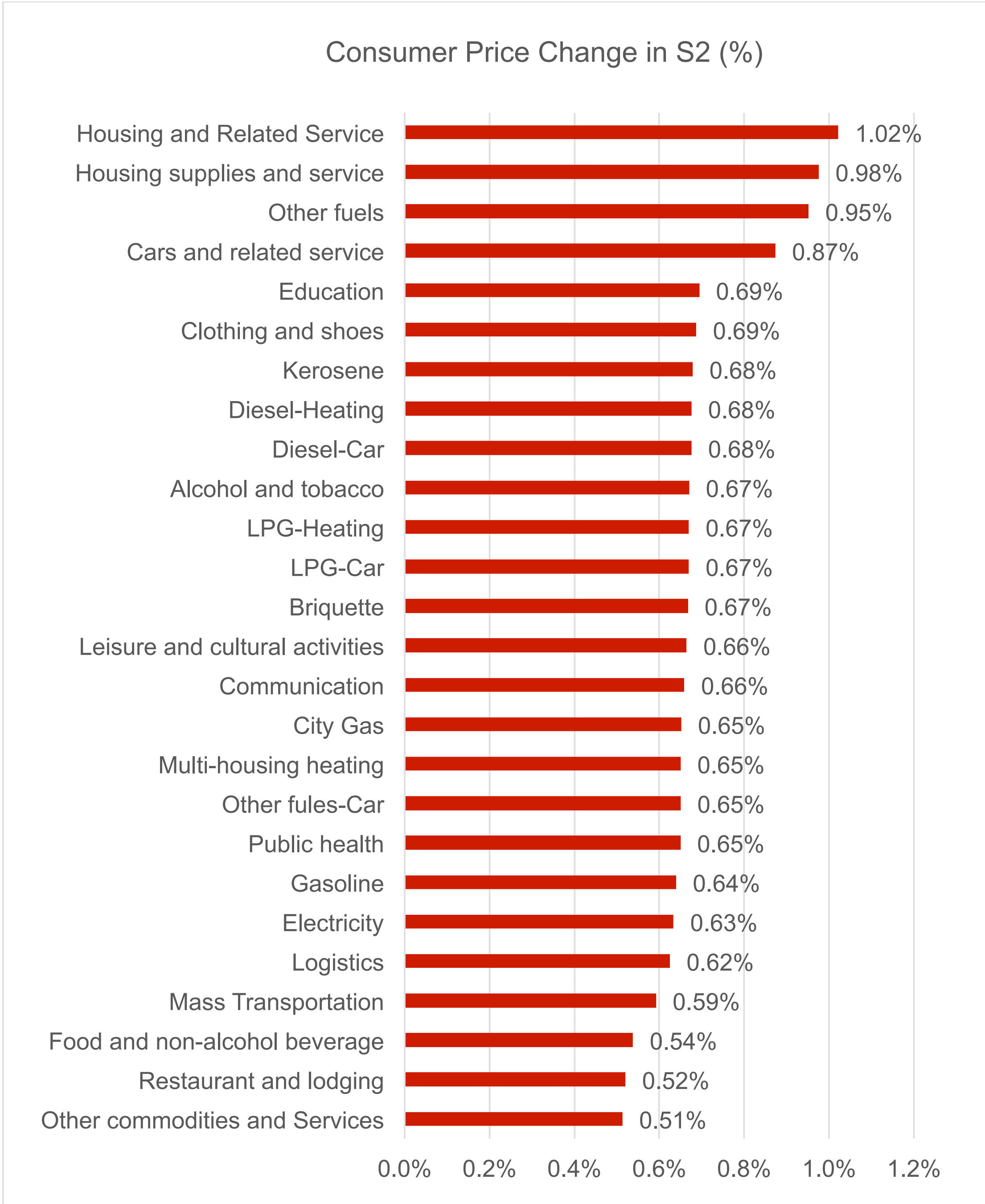

Figure 5.5 Consumer Price Changes in the S2 Scenario

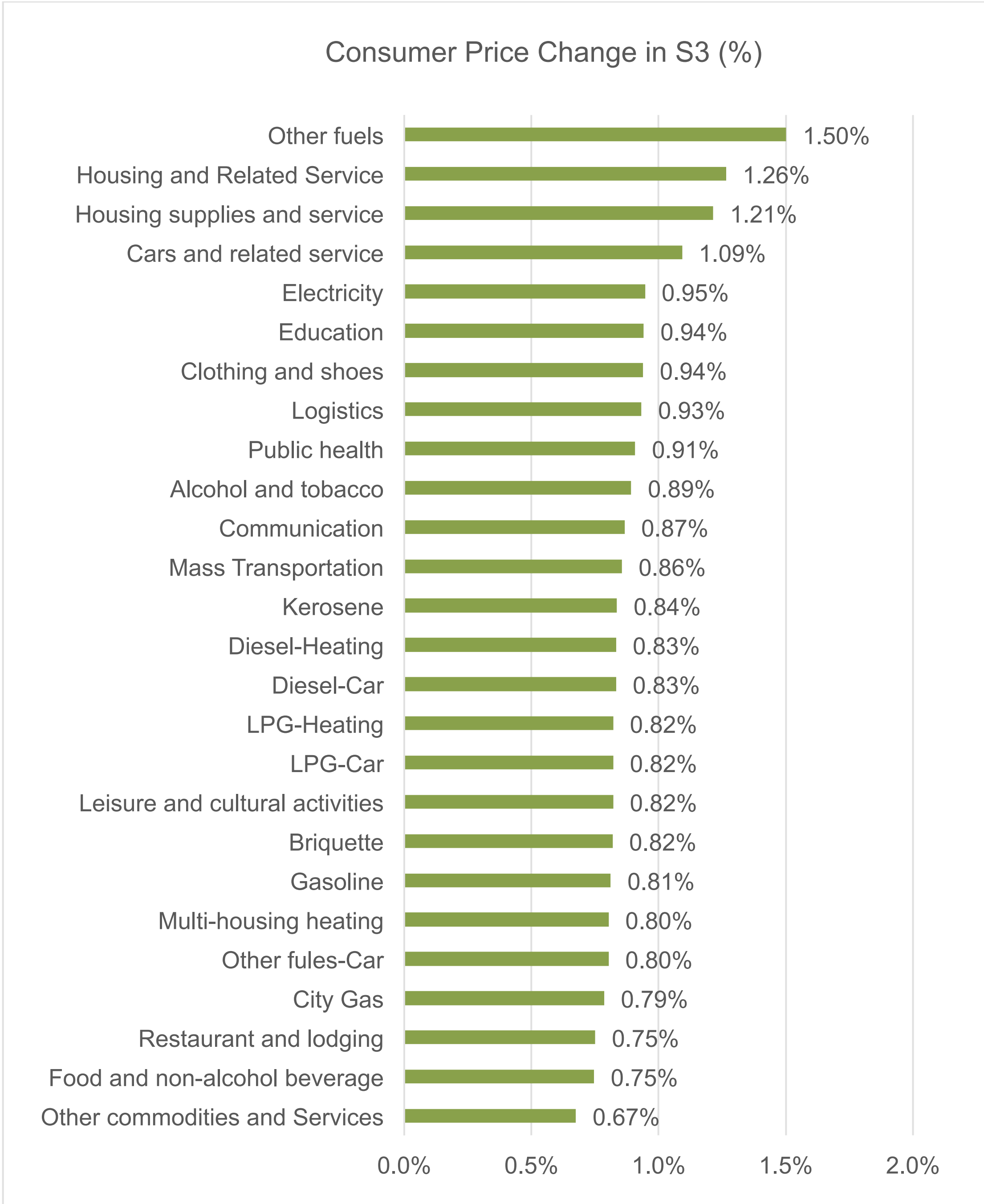

Figure 5.6 Consumer Price Changes in the S3 Scenario

In sum, the comprehensive participation scenario (S1) has a slightly higher impact on producer and consumer prices than the partial participation scenario with a higher carbon permit price (S2). In addition, with its higher carbon permit price, the comprehensive participation scenario (S3) impacts producer and consumer prices the most.

Based on these price changes, it is possible to analyze the implementation of a carbon pricing policy further. Changes in consumer prices induced by the implementation are used to estimate the additional burden on different household groups. Changes in producer prices are used to estimate impacts on final demands, output, value-added, employment, import, energy consumption and CO_2 emissions.

5.1.2 Impacts on Final Demands

The changes in producer prices will impact final demands. Based on changes in final demands, it is possible to analyze the likely economic implications of the policy. The changes in final demands are dependent upon the price elasticities of final demands and the percentage changes in producer prices. As mentioned above, the sectoral elasticities of M. Kang et al.'s study (2011) is utilized in order to consider the situation of the South Korean economy.

The sectoral final demands generally decrease due to the implementation of the scheme. In the S1, final demands for hot water decrease the most (-1.84%) followed by those for the electricity sector (-1.77%). The actual amount of final demand declines the most in the construction sector followed by the electric appliances manufacturing sector. This result is attributed to the combined effects of the existing final demands, percentage changes of producer prices and elasticities.

The results of S2 are somewhat different from those of S1 and the impacts on final demands for particular segments of the industrial sector are higher. In S2, the carbon charge affects the demand for the electricity sector the most (-1.95%) followed by demand for metallic products (-1.76%) and then that for hot water (-1.29%).

The pattern of changes in sectoral final demands is repeated under the S3. Final demands for hot water decreases the most followed by that for electricity. Although the pattern is identical, decreases in sectoral final demands are larger under S3 than S1. As mentioned earlier, these larger decreases in sectoral final demands are dependent on larger increases in producer prices under S3 than other scenarios.

Interestingly, the amount of final demand for the mining product sector and coal sector increases in all of the scenarios. It is because the reference values of final demand for these sectors are negative. In detail, the final demands of the I-O table consist of private consumption, government consumption, private capital stock formulation, government capital stock formulation, increased stock and exports. In 2009, the increased stock, which refers to a change in stocks between two points within a year, was negative for the mining product and coal sectors.

In sum, the change in the total final demand is slightly larger in the S1 case (-0.6839%) than in the S2 case (-0.6827%) because producer prices increase slightly more under the S1 case. The total final demand decreases most by 0.8640% under S3. As mentioned earlier, changes in final demands depend not only on elasticities, but also on changes in producer prices. The largest decrease in the total final demand in S3 is induced by the largest increases in producer prices.

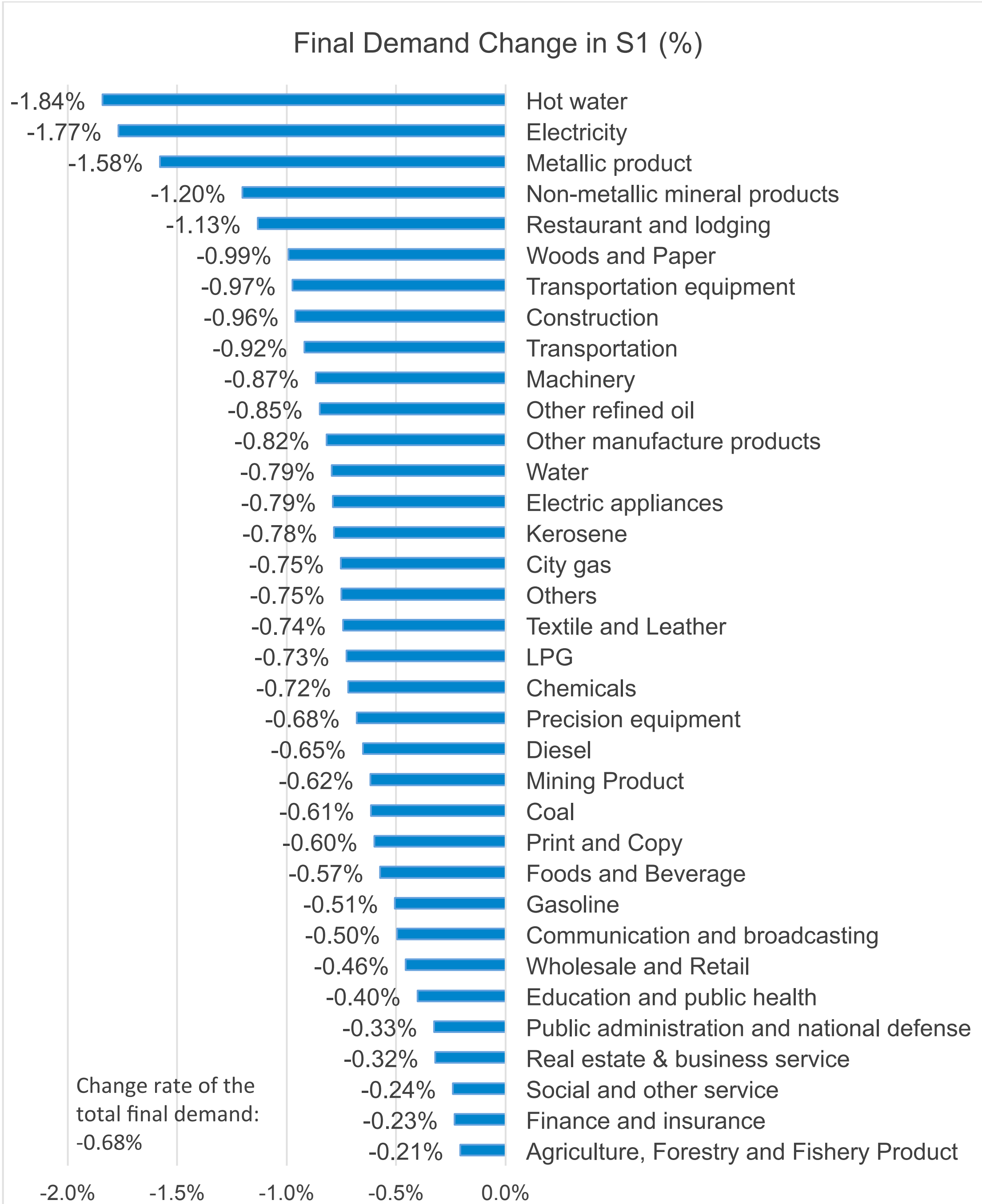

Figure 5.7 Final Demand Changes in the S1 Scenario

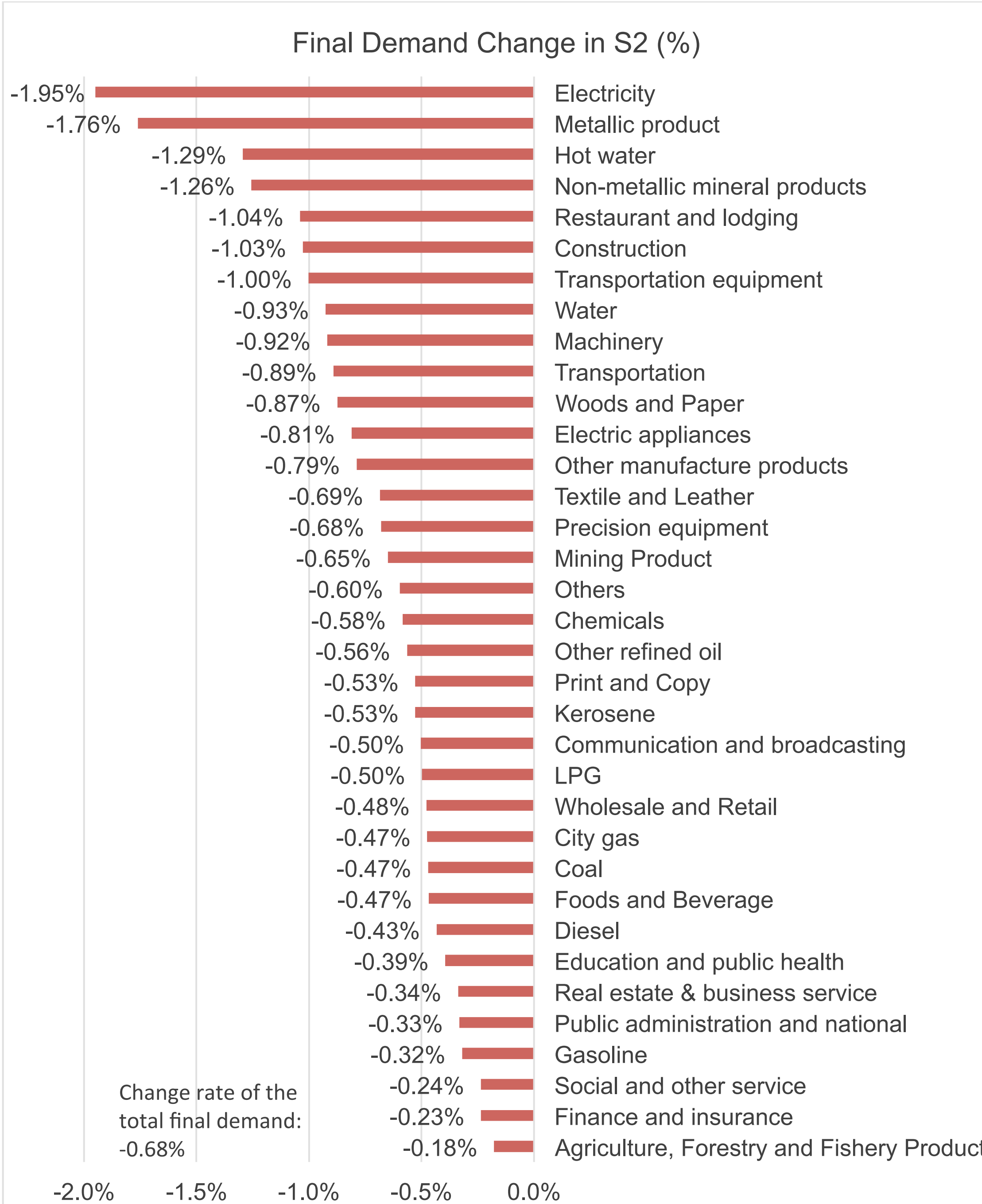

Figure 5.8 Final Demand Changes in the S2 Scenario

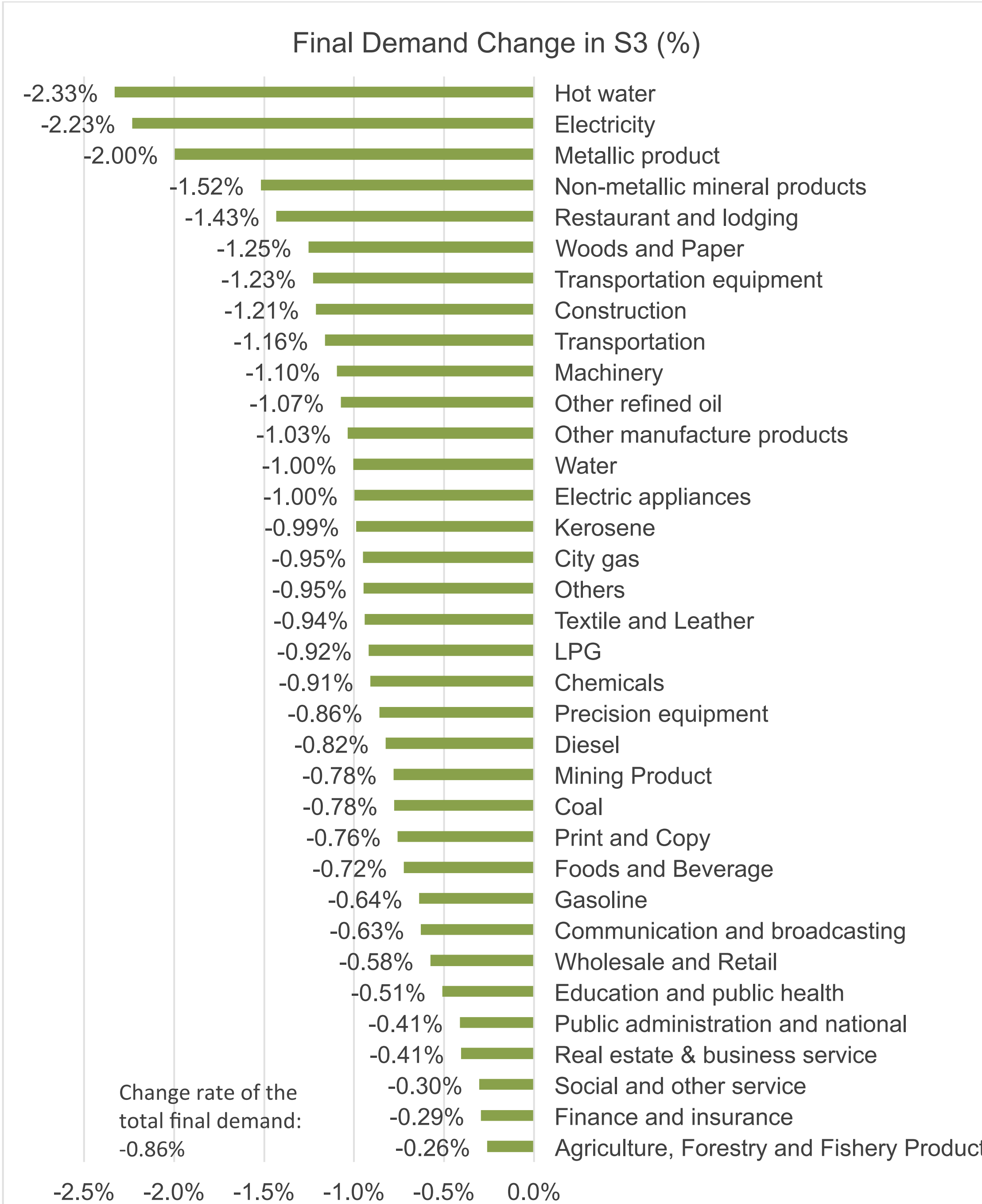

Figure 5.9 Final Demand Changes in the S3 Scenario

5.1.3 Impacts on Sectoral Outputs

Changes in final demands impact sectoral outputs. The induced impacts on outputs are as follows. In S1, the output decreases the most in the coal sector (-1.17%) followed by the hot water (-1.14%), the metallic products (-1.09%) and machinery sectors (-1.08%). In S2, the output of coal also declines the most (-1.29%) followed by those of the hot water (-1.17%) and metallic products (-1.14%) sectors. In the S2 case, the hot water sector is impacted less than in the S1 because only five large-emitting sectors are included in S2 while the hot water sector is not required to join the program in the S2. In contrast with the results of impacts on prices and final demands, the total output declines slightly more in the S2 scenario: -0.7609 % of total output in S1 and -0.7646% of total output in S2. In S3, sectoral outputs decrease more than in S1. The output also decreases the most in the coal sector (-1.48%) followed by hot water (-1.44%).

Based on the impacts on the outputs by sector, it is possible to speculate the impacts on the regional economy. According to the Regional Account in 2009 (Statistics Korea, 2009) (See Figure 5.10), the total output by region was largest in Seoul, which accounts for 24% of the national output in 2009, followed by Geonggi-do (20%), Geongsangnam-do (7%) and Geongsangbuk-do (6%). The ratio of the share of value-added of the manufacturing sector to the total value-added is highest in Ulsan (69.1%) followed by Chungchungnam-do (50.7%) and Geongsangbuk-do (49.3%). Specifically, the primary material manufacturing sector and processed &

assembly manufacturing sector[37], such as the transportation equipment manufacturing industry, chemical industry and petroleum refinery, significantly contributes to the value-added of the manufacturing sector in Ulsan. The share of value-added from agriculture, forestry & fishery to the total regional value-added is highest in Jeju-do (19.0%) followed by Jeollabuk-do (9.8%) and Jeollanam-do (8.4%). In addition, the value-added of the mining sector is highest in Gangwon-do (3.1%). Based on this regional profile of value-added by sector, it is possible to speculate that the regional economies of Ulsan, Chungchungnam-do and Geosangbuk-do can be more adversely impacted than other regions due to a relatively higher dependence on industries, such as the petroleum refinery and transportation equipment manufacturing industries. The output of the coal sector is impacted the most regardless of scenarios. Since the dependence of the regional economy on the mining industry is 3.1% and the dependence on manufacturing industries is much lower in Gangwon-do, Gangwon-do is not likely to be impacted as much as Ulsan. However, specific impacts on regional economies needs to be analyzed by constructing regional I-O tables of which sectors

[37] Korean Statistical Information Service annually provides information on regional economic activities by 19 sectors. The manufacturing sector consists of the primary material manufacturing sector, the processed & assembly manufacturing sector and other manufacturing sectors. The primary material-manufacturing sector includes primary metal manufacturing industry, non-metallic mineral product manufacturing industry, petroleum refinery, chemical industries etc. The processed & assembly manufacturing sector includes the transportation equipment manufacture industry, the electric appliance manufacture industry, precision machinery manufacture industries etc. Other manufacturing sector refers to the sector that produces processed foods, beverages, tobacco, clothing, shoes, furniture, etc.

are compatible with the classification (35 industry sectors) of the I-O table in this study.

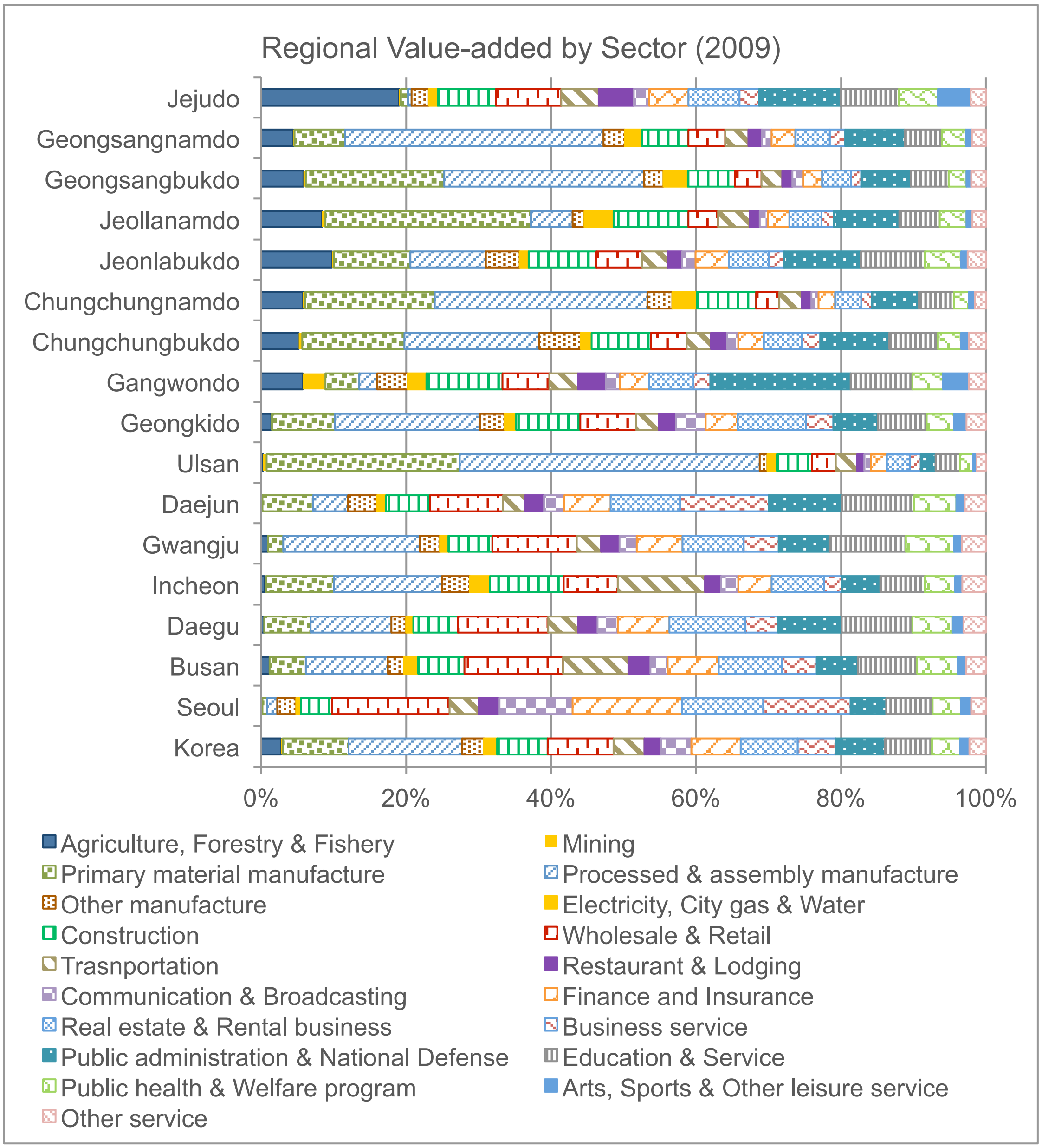

Figure 5.10 Regional Value-added by Sector in 2009

Figure 5.11 Changes in Sectoral Outputs in the S1 Scenario

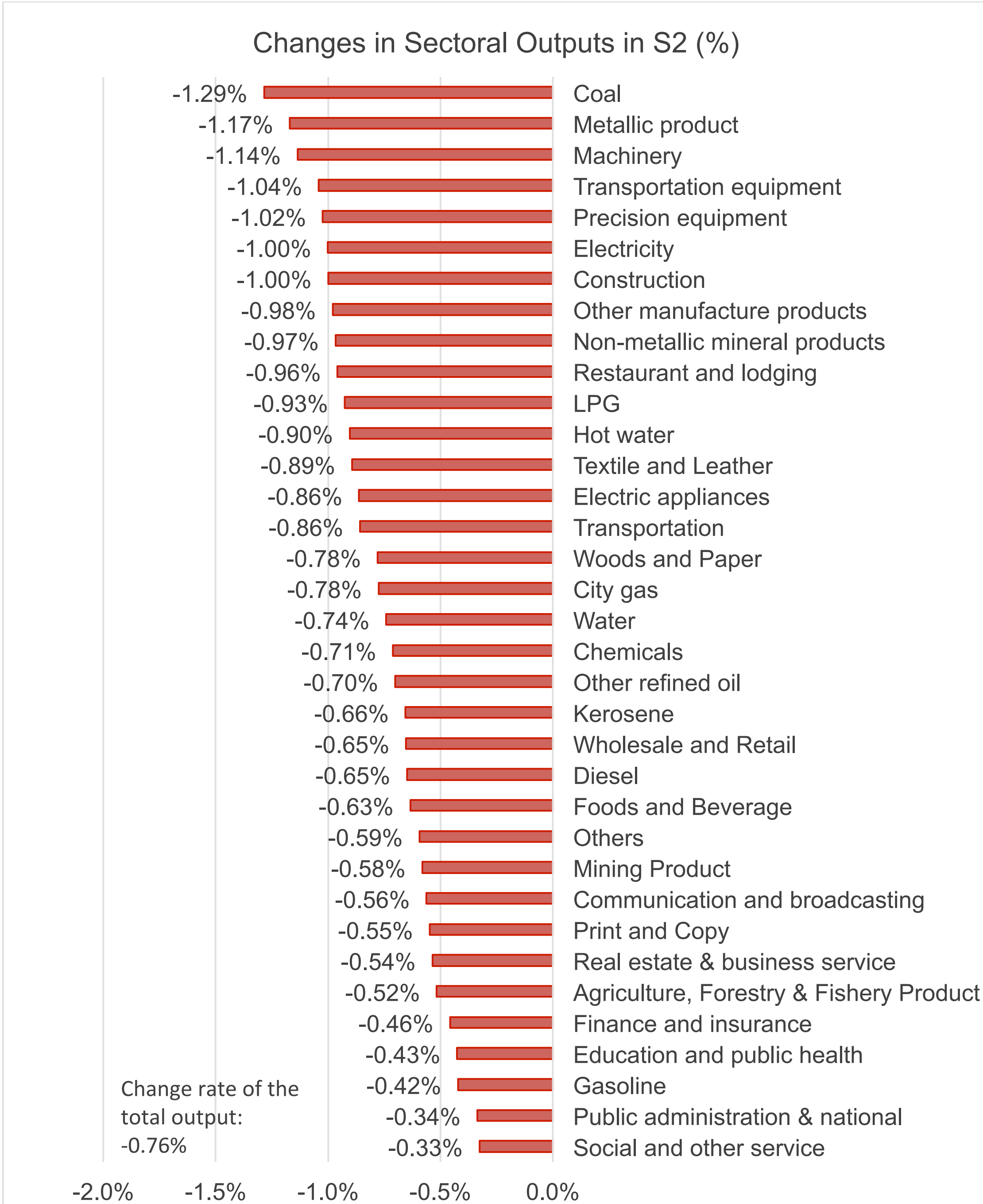

Figure 5.12 Changes in Sectoral Outputs in the S2 Scenario

Figure 5.13 Changes in Sectoral Outputs in the S3 Scenario

5.1.4 Impacts on Value-added

Value-added refers to the value that economic agents create through economic activities and consists of factors used to produce goods and services, such as labor, profit, capital stock and production tax. As a result, a change in final demands induces not only changes in output production, but also changes in value-added.

Similar to the results of impacts on outputs, value-added declines slightly more in S2: the S1 reduces the total amount of value-added by 0.67% and the S2 reduces it by 0.68%. The reduction in value-added is largest (0.85%) in S3.

Percentage changes in value-added by sector are exactly the same as the percentage changes in outputs. These results are originated from the formula used to estimate changes in the value-added induced by the changes in final demands. The diagonal matrix with elements of the ratio of value-added to the output or value-added input coefficients, $\hat{A}^V$, is multiplied to estimate the induced impacts on value-added. The percentage changes in value-added is described as follows ($\Delta V V^{-1}$). Here, if the diagonal matrix is replaced with VX^{-1}; the percentage changes become the same to the percentage changes in outputs.

$$
\begin{aligned}
&\Delta V V^{-1} \\
&= \hat{A}^V (I - A^D)^{-1} \Delta Y V^{-1} \\
&= VX^{-1} (I - A^D)^{-1} \Delta Y V^{-1} \\
&= X^{-1} (I - A^D)^{-1} \Delta Y
\end{aligned} \tag{5.1}
$$

As a result, the value-added declines the most in the coal sector (-1.17%) followed by the hot water (-1.14%), metallic product (-1.09%) and machinery sectors (-1.08%) in the S1. In the S2, value-added of coal also declines the most (-1.29%) followed by those of the metallic product (-1.17%) and machinery (-1.14%) sectors. The pattern of reduction in value-added by sector in S3 is identical to that in S1. In S3, the value-added also declines the most in the coal sector (-1.48%) followed by the hot water (-1.44%) and metallic product (-1.38%) sectors. Since the others sector initially does not use value-added, therefore, there will be no change in this sector. As a result, the percentage change in the total amount of value-added is different from those of outputs.

Figure 5.14 Changes in Sectoral Value-added in the S1 Scenario

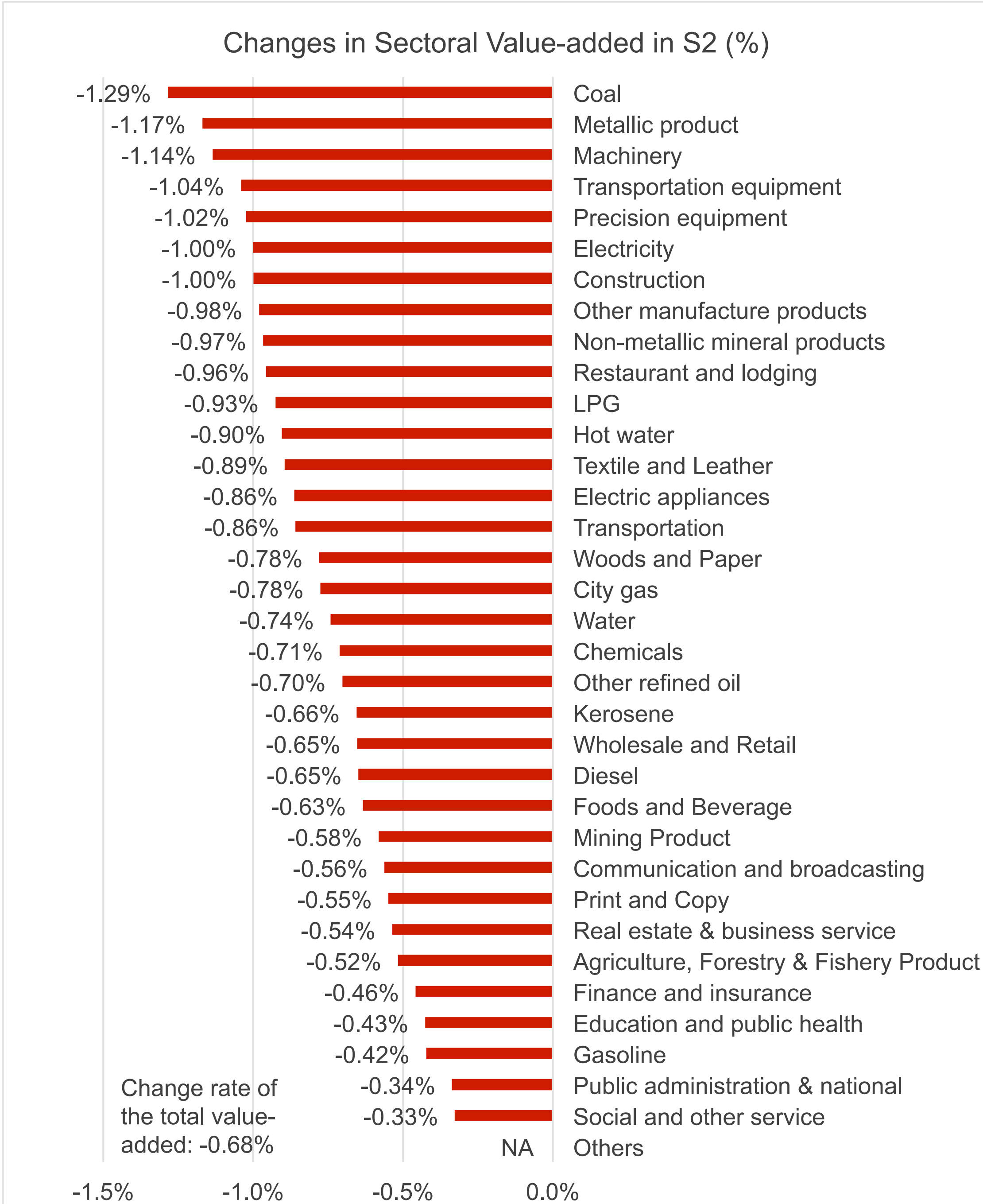

Figure 5.15 Changes in Sectoral Value-added in the S2 Scenario

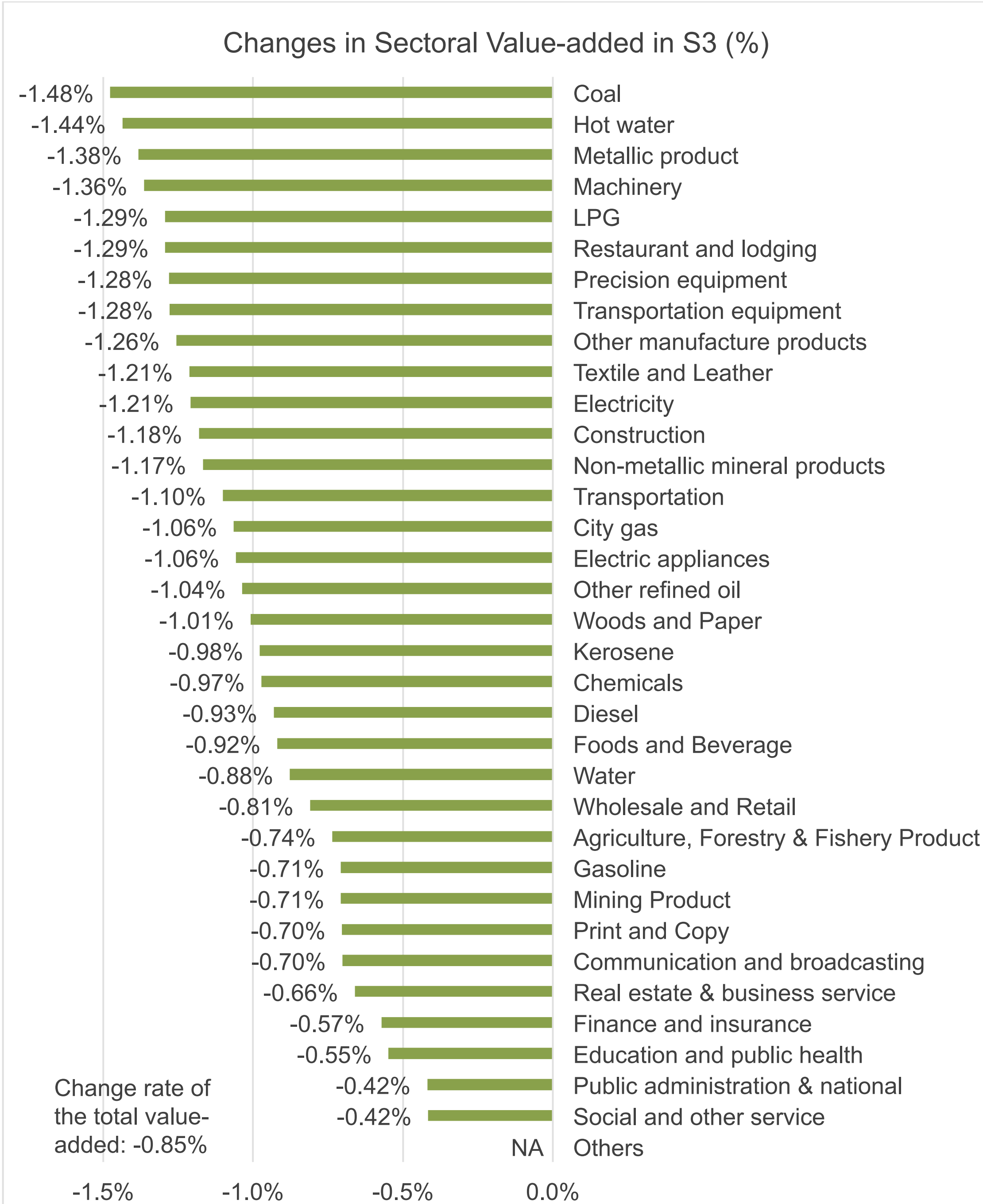

Figure 5.16 Changes in Sectoral Value-added in the S3 Scenario

5.1.5 Impacts on Imports

As outputs and value-added are impacted, imports are also affected. Among the 35 industry sectors, imports for the metallic product sector decreases the most (-1.07%) in the S1, (-1.13%) in the S2 and (-1.35%) in the S3. As a result, a steel industry such as Posco will be significantly affected. There will be no change in imports for the hot water sector because hot water is not imported for the intermediate inputs - the row elements of the hot water sector in Imports I-O table are zero. In addition, the total amount of imports is declining slightly more in the S1 (-0.71%) than in the S2 (-0.70%). The total amount of imports declines the most in the S3.

Figure 5.17 Changes in Imports by Sector in the S1 Scenario

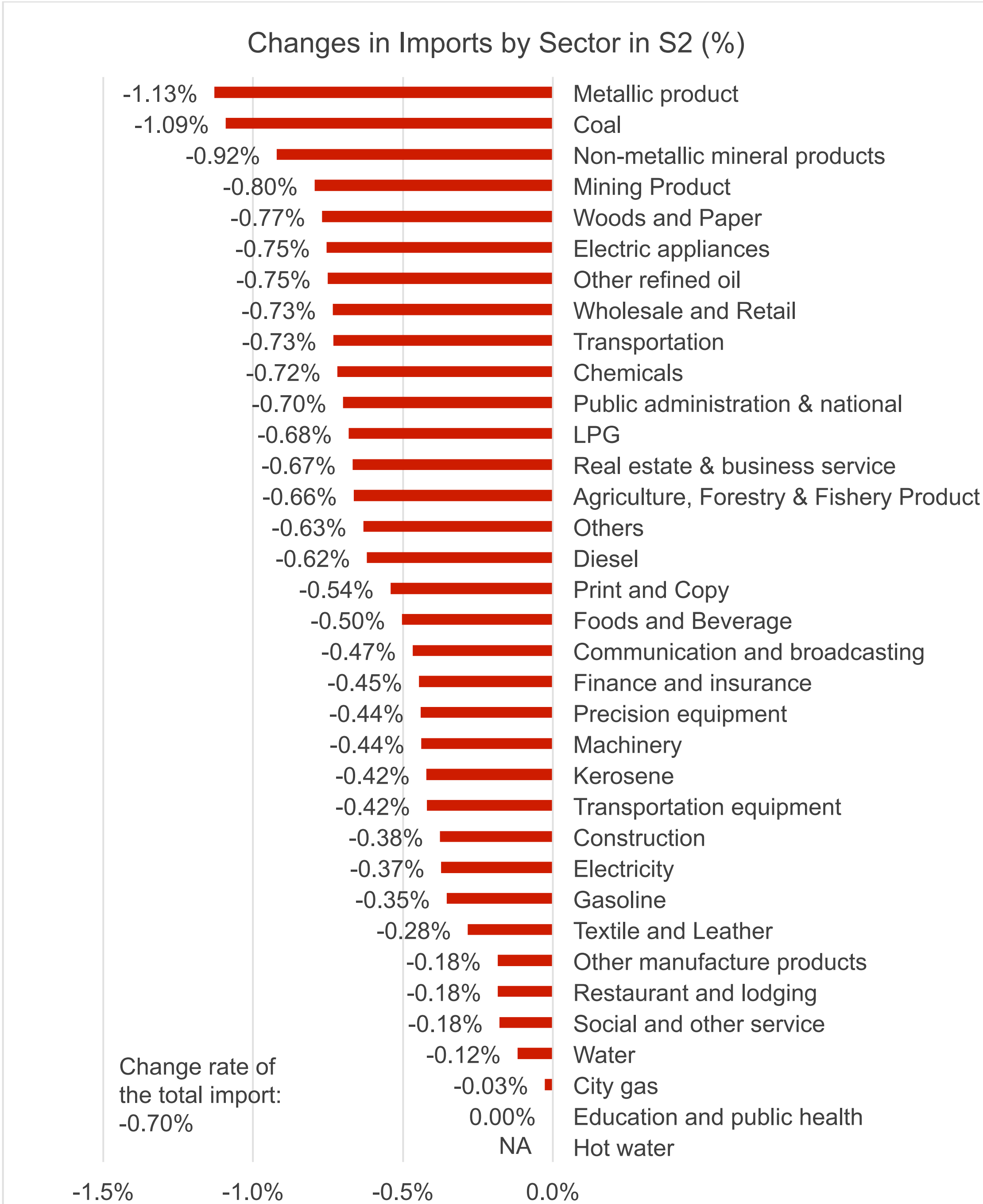

Figure 5.18 Changes in Imports by Sector in the S2 Scenario

Figure 5.19 Changes in Imports by Sector in the S3 Scenario

5.1.6 Impacts on Employment

A change in final demands also induces changes in employment. Due to the comprehensive imposition (S1 and S3) or the partial imposition (S2) of a carbon charge, employment will be reduced. The S3 impacts employment and workers the most – the number of workers and employees is reduced by 167,060 and 120,477 persons respectively. In addition, employment is slightly more adversely impacted in the S1 case than in the S2. The number of workers and employees is reduced by 132,234 and 95,360 persons respectively in the S1 case. Lastly, the number of workers and employees is reduced by 132,005 and 96,412 persons respectively in the S2 case.

Among the 31 sectors (as explained in Chapter 4, 35 sectors are aggregated into 31 sectors due to the limit of information on sectoral employment.), employment for the coal sector is impacted the most regardless of scenarios. Employment for the coal sector is reduced by 1.16% in the S1 case, by 1.28% in the S2 case and by 1.47% in the S3 cases respectively. Besides the coal sector, employment in the metallic product, the machinery, the transportation equipment, and precision equipment manufacturing sectors is reduced more than that in other sectors.

Furthermore, this analysis result implies that the regional economy where the employment is adversely impacted will be affected as well. For example, the reduced employment is likely to induce the reduction in consumption/private final demand. Ulsan is likely to be more adversely impacted due to a larger reduction in employees of heavy industries. According to the regional value-added profile by sector reviewed earlier, the primary material manufacturing sector and processed & assembly manufacturing sector are contributing to 26.7% and 41.4% of the total value-added of Ulsan city in 2009 (See Figure 5.10). Since the results show that employment in the primary material manufacturing sector and processed & assembly manufacturing sector (the metallic product, the machinery, the precision equipment, and the transportation equipment) are impacted more than other sectors, a region such as Ulsan in which the economy is heavily reliant on these sectors will be more adversely impacted than other regions. The reduction in private consumption induced by job loss can be expected in Ulsan area. In addition, Gangwon province is affected due to job loss in the coal sector. While the value-added of the coal sector contributes to on average less than 0.5% of the total regional value-added, it contributes to 3.1% of the total value-added of Gangwon province.

From an economic perspective, the economy is most adversely impacted under the S3 scenario since the higher carbon price of \$18.9/ton of CO_2 is imposed on every industry sector. However, the other two scenarios did not show that significant of a difference as they are designed to reduce the same amount of CO_2 emissions. Although the difference is small, the economy-wide impact of the S1 scenario is less adverse. While the producer prices increase more and final demands, in turn, decrease more under S1, outputs, employment and value-added are interestingly less impacted under S1 than under S2. Therefore, comprehensive participation can be said to be better for the economy when both policy scenarios aim to reduce a same amount of emissions.

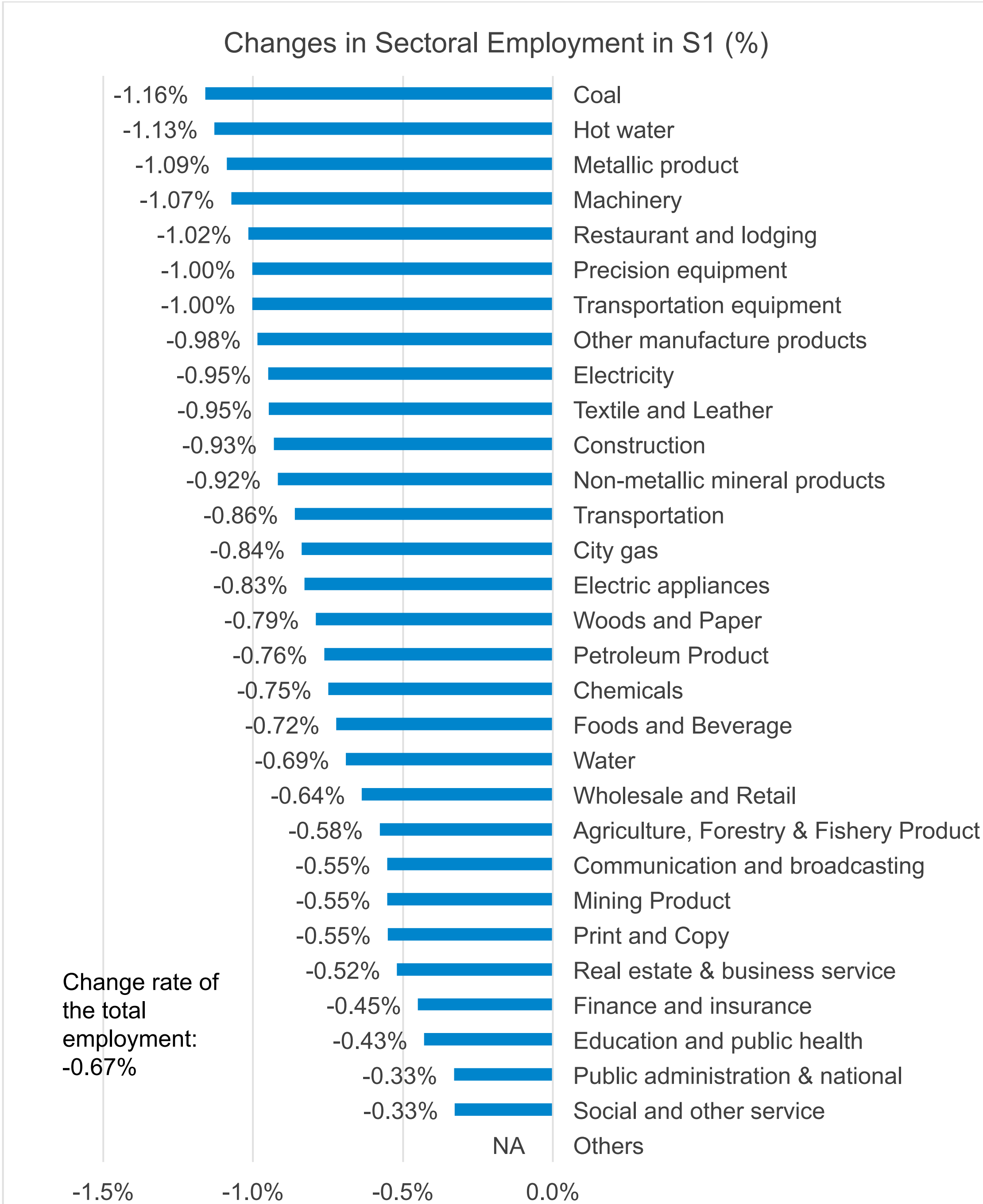

Figure 5.20 Changes in Employment by Sector in the S1 Scenario

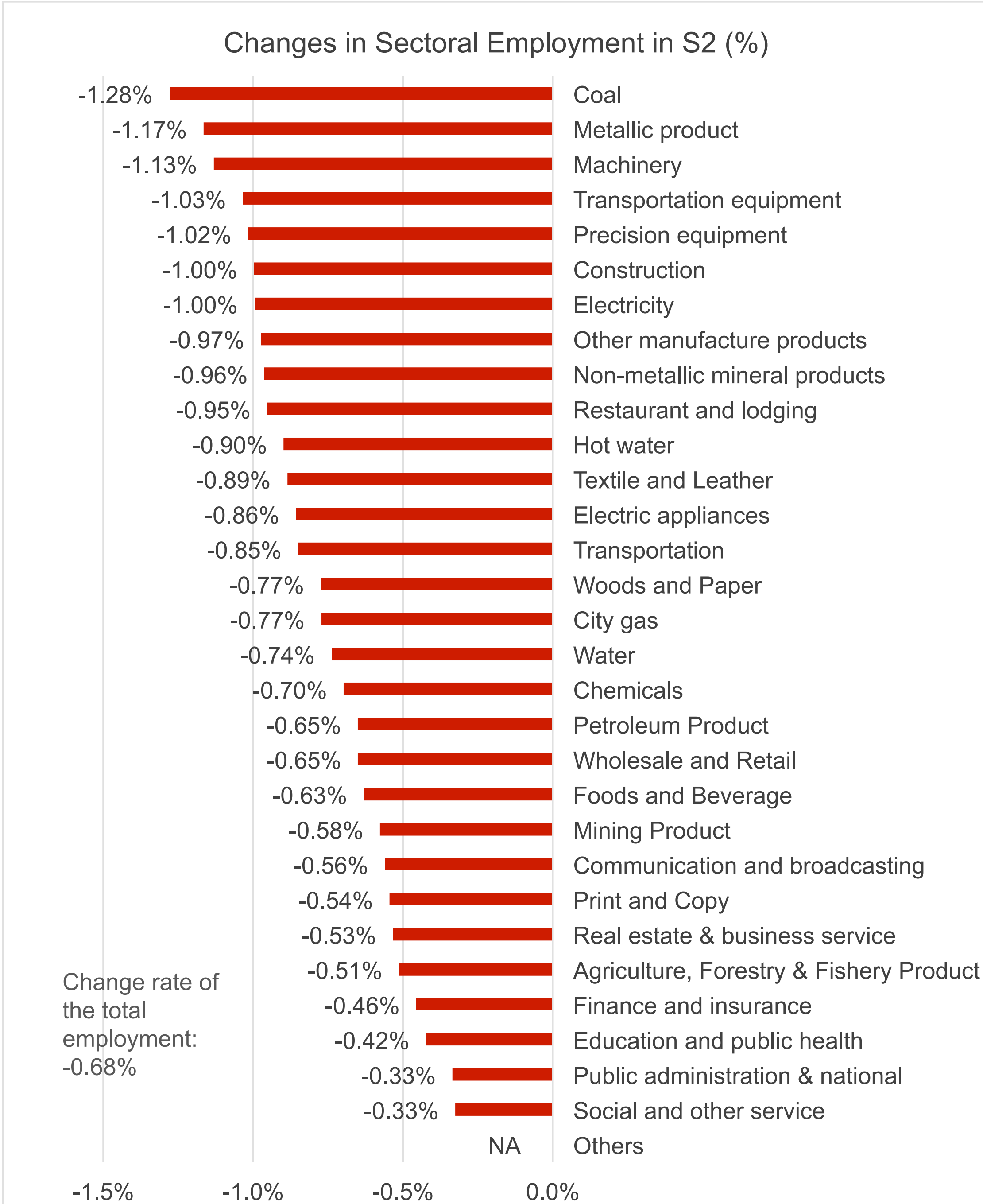

Figure 5.21 Changes in Employment by Sector in the S2 Scenario

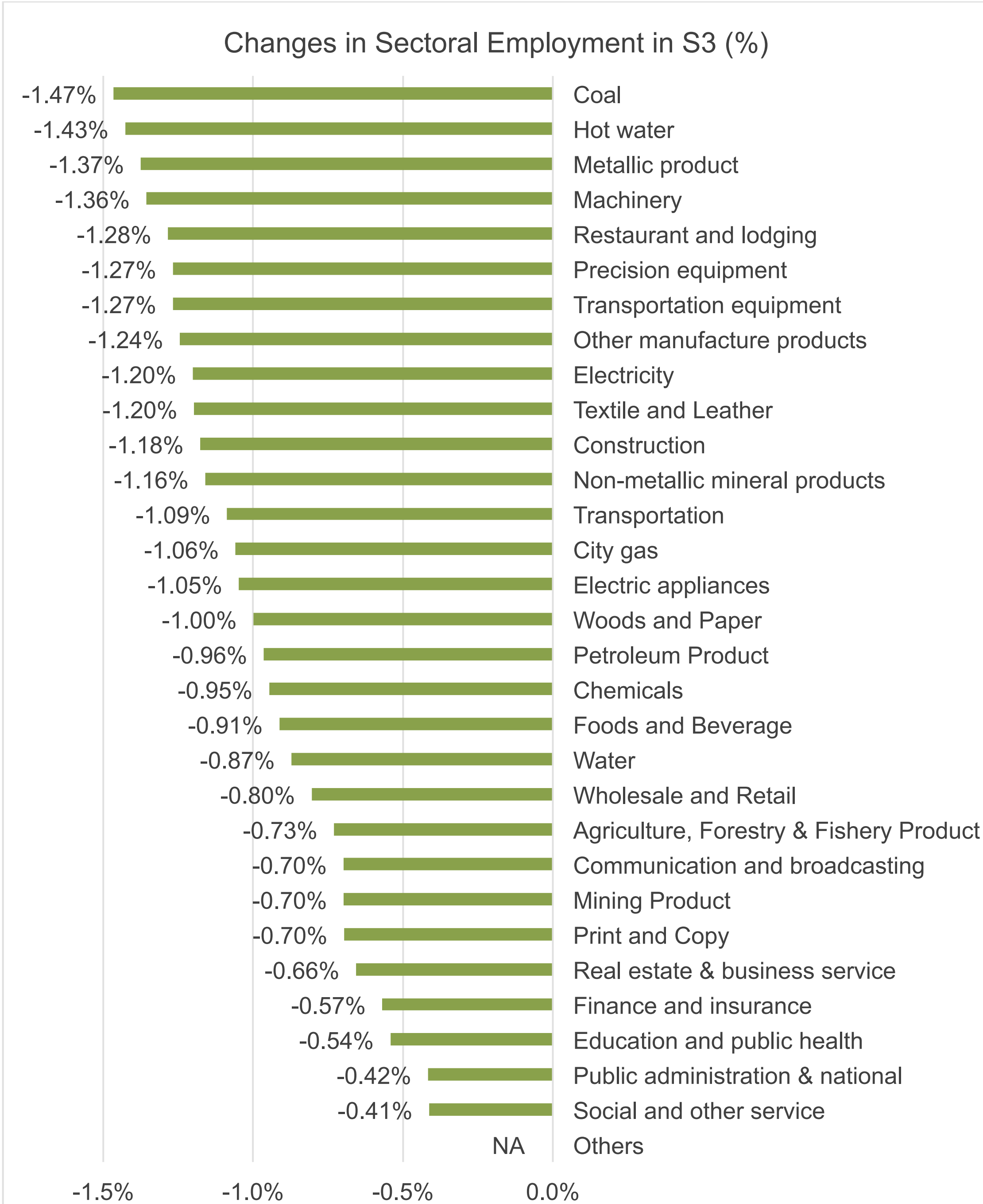

Figure 5.22 Changes in Employment by Sector in the S3 Scenario

5.2 Equity Implications

This study explores the equity implications of carbon charges (\$15/ton of CO_2 and \$18.9/ton of CO_2) and of revenue recycling. The impacts will be examined based upon how additional burdens induced by the implementation are distributed between households with different income levels, according to age of heads in households and between locations of households (urban or rural).

5.2.1 Impacts on Different Income Households

According to the changes in consumer prices (see Figure 5.4, Figure 5.5 and Figure 5.6), the expenditure of households will be affected. The additional burden induced by the implementation depends upon the existing expenditure pattern of a household. This section will explore how households will be impacted according to their income levels.

This study analyzes the relative burden using disposable income, which refers to the ratio of additional expenditure induced by a carbon pricing policy to disposable income. As shown in Figure 5.23, the relative burdens on different income groups show clear regressivity regardless of the scenarios. In addition, the S2 scenario impacts the poorest households the least and the relative burden on the 1st decile is largest under the S3. Specifically, the poorest household group needs to pay an additional 1.31% of their disposable income, while the wealthiest group needs to pay only 0.40% due to the implementation in the S1. Under the S2, the poorest group needs to pay 1.24% more, but the wealthiest household needs to pay only 0.38% more.

Due to larger increases in customer prices, the burdens on households increase most in S3. In S3, the poorest needs to pay an additional 1.66% of their disposable income while the wealthiest only needs to pay 0.50% more.

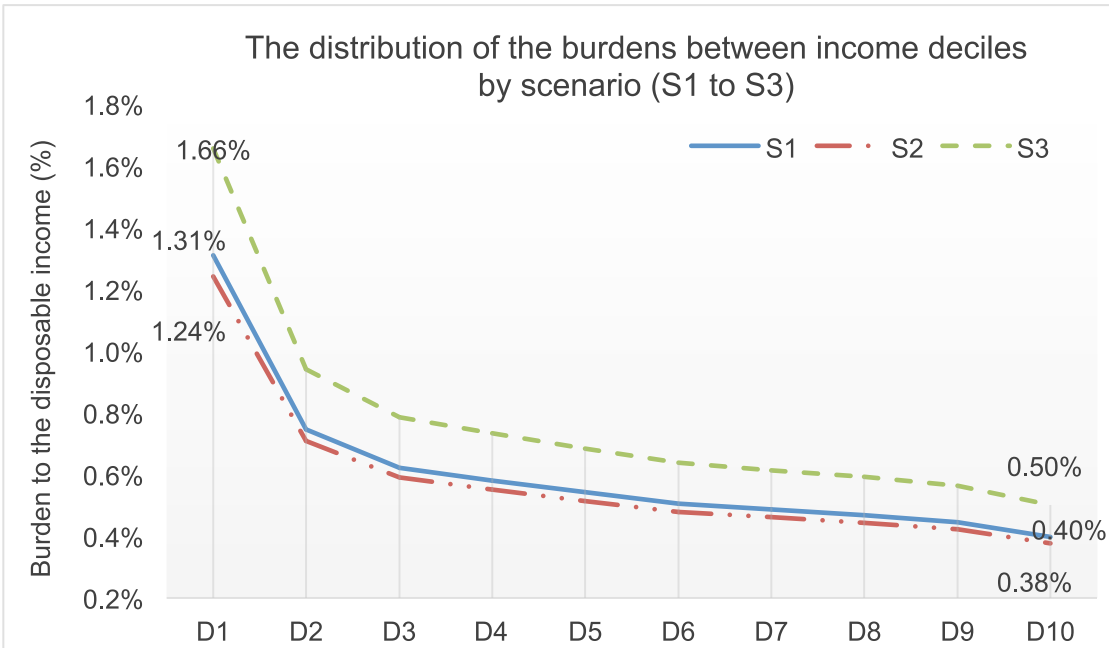

Figure 5.23 The Distribution of the Relative Burdens between Income Deciles

In addition, this study tests two revenue-recycling cases (R1 and R2) for each scenario, which distributes 25% of the total proceeds to households on the basis of equal per capita dividend or on the basis of equal per household dividend to relieve the regressivity induced by the implementation. As a result of this revenue recycling, the incidence of the carbon charge becomes progressive regardless of the scenarios. In other words, the wealthier will pay more while the poorer will pay less.

The R1 scenario assumes that a quarter of the proceeds are recycled to households through the equal per capita lump-sum transfer (See Table 5.1). When the proceeds are recycled through equal per capita dividend, the first decile will receive a benefit of 0.17% (S1) to 0.22% (S2) of their disposable income. In addition, the burden on the 10th decile will be also reduced from 0.38% (S2) ~ 0.50% (S3) to 0.21% (S2) ~ 0.28% (S3). This result shows that recycling a small proportion of the proceeds can protect the poor and reduce the burdens on every group as well.

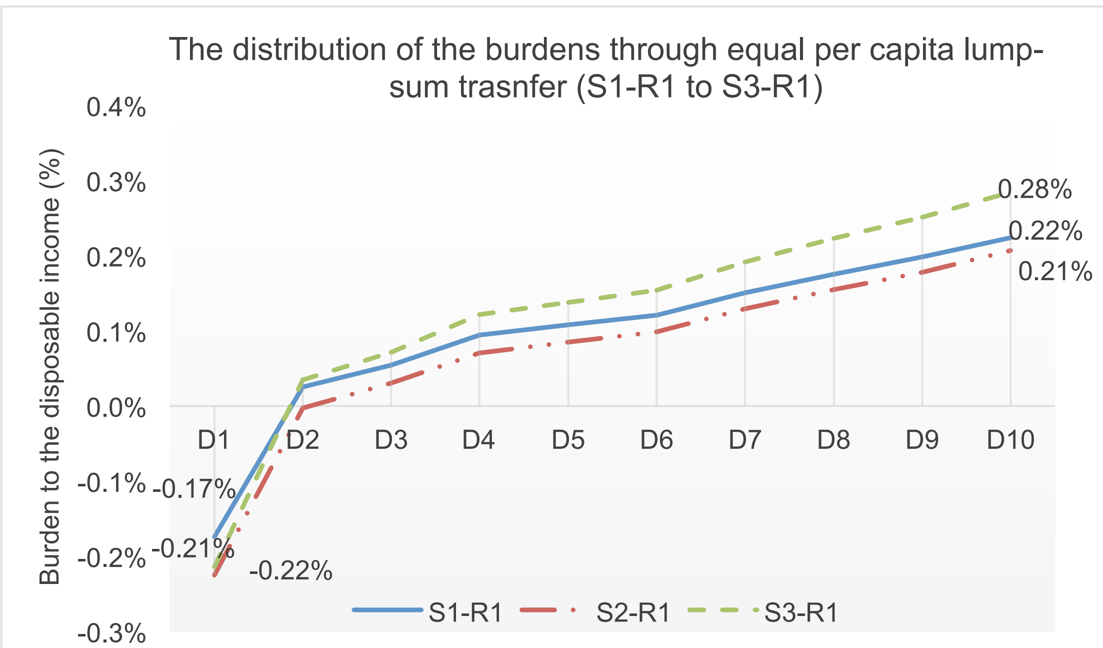

Figure 5.24 The Distribution of the Relative Burdens Relieved through the Equal per capita Lump-sum Transfer between Income Deciles

The S1-R2 scenario shows stronger progressivity than the S1-R1 scenario. In this scenario (S1-R2), three poor groups (the 1st decile, the 2nd decile and the 3rd decile) become beneficiaries from the revenue recycling. The poorest household will earn 1.46% (S1) to 1.83% (S3) of their income. The second decile will also receive the benefit of 0.32% (S1) to 0.40% (S3) of their income. The third decile, rather, will earn an additional 0.06% (S1) to 0.07% (S3) of their income rather than pay more. The burden on the wealthiest group is reduced from 0.38% (S2) ~ 0.50% (S3) to 0.32% (S2) ~ 0.24% (S3). However, this group needs to pay slightly more than they do in the R1 cases.

The stronger progressivity of R2 cases originated from the pattern of the average number of family members depending on income levels. The average number of family members increases as the income level increases: the average number of family members in the poorest household is 1.56 persons per a household, while it is 3.55 persons in the wealthiest household. As a result, when the proceeds are distributed to households based on the equal per household dividend method, the poorer household receives relatively higher dividends compared to their family size.

Figure 5.26 summarizes the results. The higher carbon permit price aggravates the regressivity – as the permit price increases from $15 to $18.9 per ton of CO_2, the difference between the relative burdens on the poorest group and the wealthiest group increases from 0.91% in S1 to 1.16% in S3. This implies that the first decile needs to pay 0.91% more than the tenth decile does. In addition, when the proceeds are distributed to the public on the equal per household basis, the incidence shows stronger progressivity. The relative burden on the poorest group is 1.72% in S1-R2 to 2.15% in S3-R2 less than that on the wealthiest group.

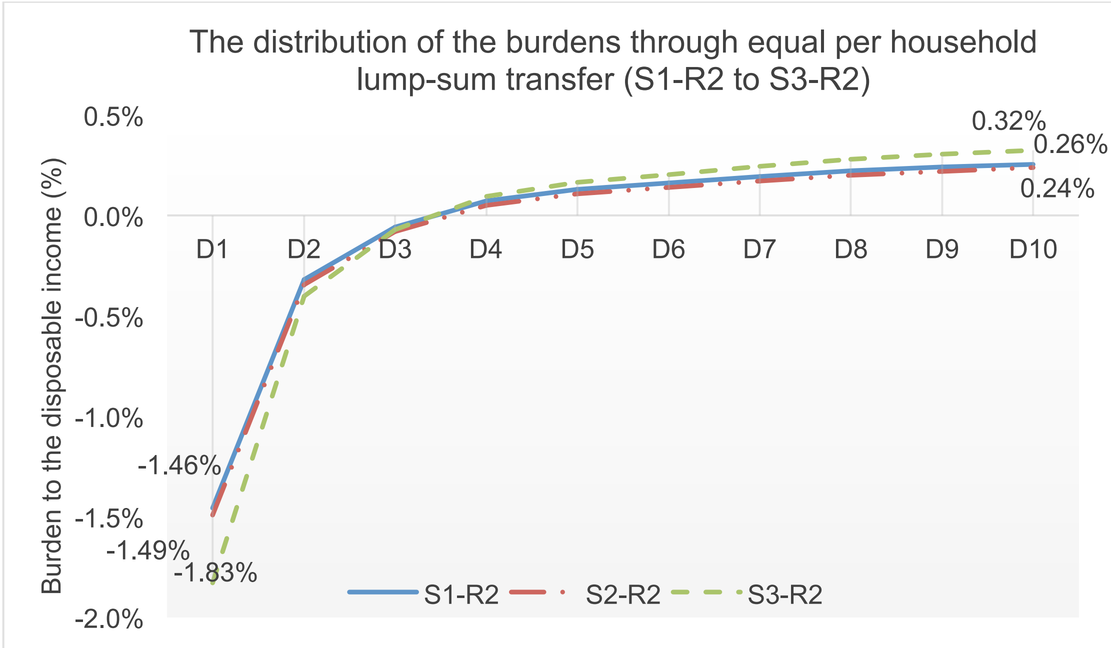

Figure 5.25 The Distribution of the Relative Burdens Relieved through the Equal per households Lump-sum Transfer between Income Deciles

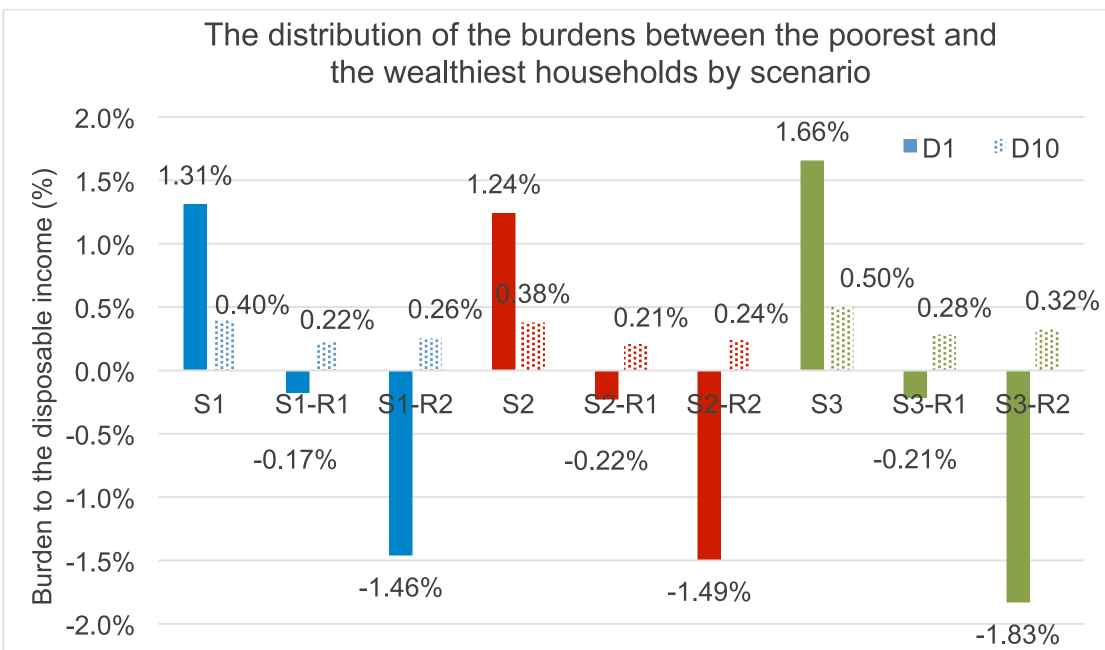

Figure 5.26 The Summary of the Distribution of the Burdens between the 1st and 10th Deciles by Scenario

5.2.2 Impacts on Different Age Households

This study disaggregates the data set into four groups according to age of the heads: [1] under 49; [2] 50-64; [3] 65-74; and [4] 75+. Regardless of the scenarios, the eldest group will be the most affected. The burden on households with heads over 75 years old ranges from 0.57% (S2) to 0.76% (S3) of their disposable incomes. In contrast, the households with heads who are 50 to 64 years old are impacted the least (0.44% in the S2 to 0.59% in the S3).

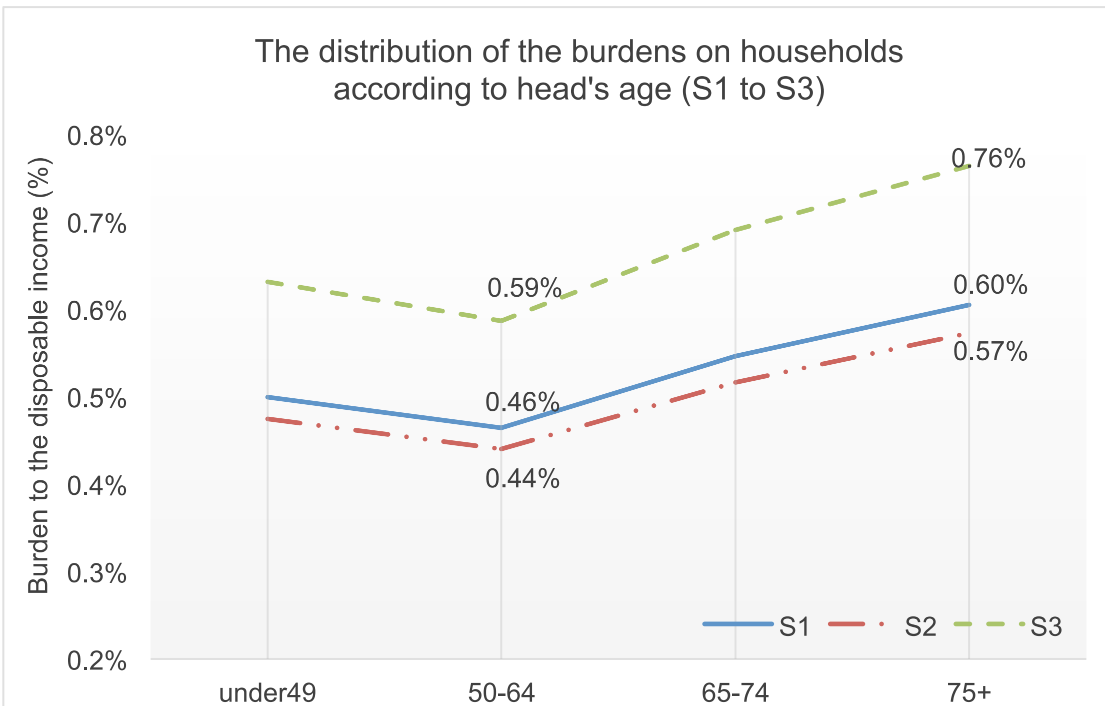

Figure 5.27 The Distribution of the Relative Burdens on Households according to Head’s Ages

When recycling a quarter of the revenue on the basis of equal per capita dividend, the oldest group will be protected. The oldest group can earn 0.04% (S1) to 0.07% (S2) of their income. In addition, the burdens on the rest of the groups are also relieved. The relative burden on the 50-64 group reduces from 0.44% (S2) ~ 0.59% (S3) to 0.14% (S2) ~ 0.21% (S3) when 25% of proceeds is transferred to households on the equal per capita dividend basis.

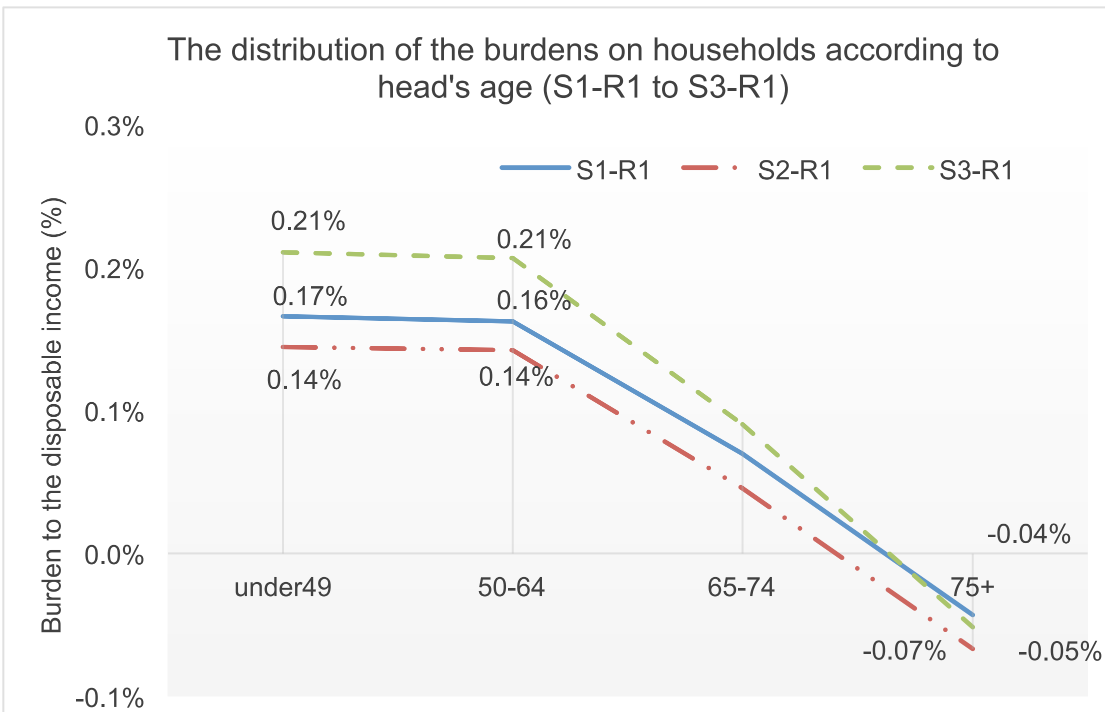

Figure 5.28 The Distribution of the Relative Burdens Relieved through the Equal per capita Lump-sum Transfer according to Head's Ages

Similar to the results of the previous analysis on different income groups, equal per household dividend protects the older group more effectively. The 65-74 group and the 75+ group become beneficiaries in the R2 case while the 75+ group can only earn additional income under the R1 case. The 65-75 group will earn 0.14 (S1)% to 0.17% (S3) of their income and the 75+ group will earn 0.55% (S1) to 0.65% (S3) of their income. This is because the family size decreases according to the head's age. Specifically, 3.3 family members live in a household with a head younger than 49, while only 1.6 persons live in a household with a head older than 75. When the proceeds are distributed on the equal per household basis, the households with less family members, such as the 75+ group, are favored more than other groups.

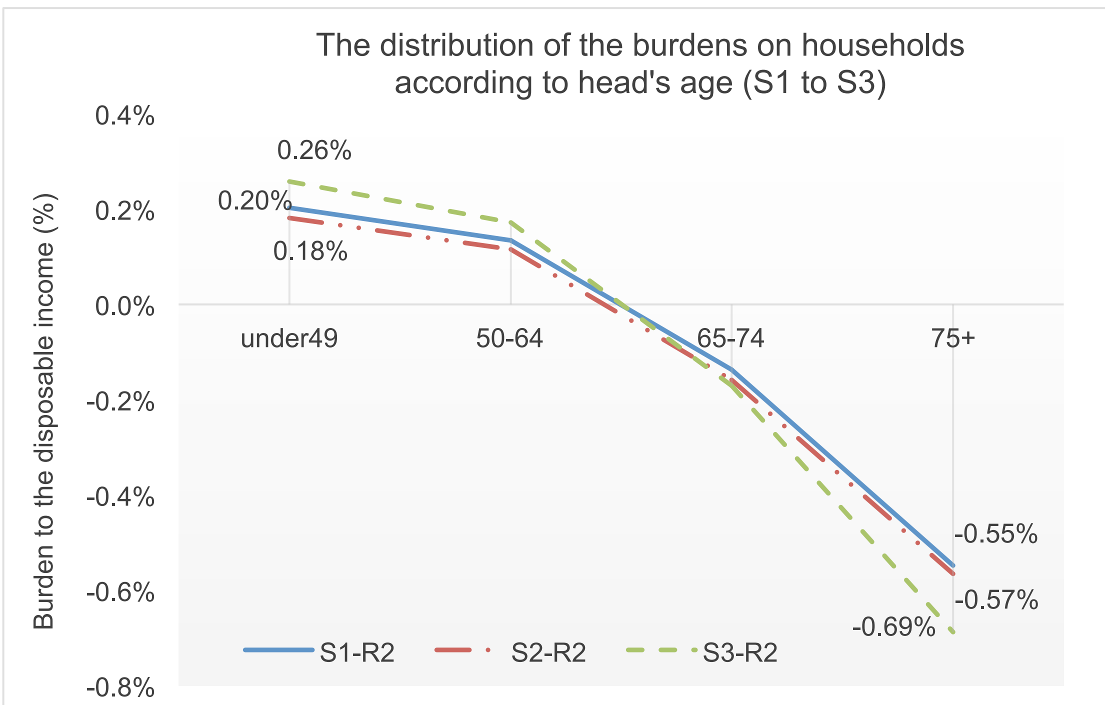

Figure 5.29 The Distribution of the Relative Burdens Relieved through the Equal per household Lump-sum Transfer according to Head's Ages

In sum, the S3 scenario most adversely impacts the 75+ group followed by the S1 and the S2. The difference between the relative burdens on four age groups was also largest in the S3 followed by the S1 and the S2 (see Figure 5.30). The revenue-recycling scenarios effectively resolve this issue. As a result of revenue-recycling, the 75+ group spends 0.21% to 0.26% less than the under 49 group in R1. In addition, the 75+ group spends 0.75% to 0.95% less in R2. Without revenue-recycling, the S3 scenario adversely affects the households with elderly heads; however, it rather helps those households more than the rest of the scenarios. This is because the higher carbon price results in higher proceeds, which can be distributed to the public.

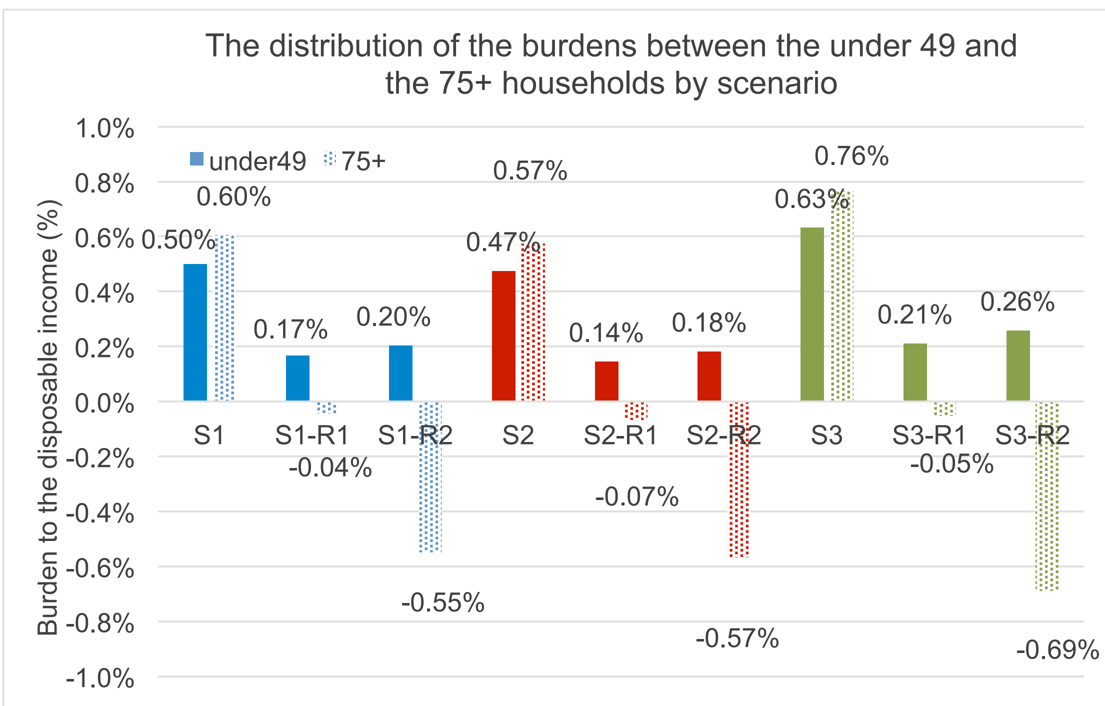

Figure 5.30 Difference between the Relative Burdens on the Under 49 Group and the 75+ Group

5.2.3 Impacts on Urban and Rural Households

This study additionally tests the equity implication of the location of the households: urban area or rural area[38]. The burden on the urban households is slightly larger than that on rural households in terms of the relative burden as well as the amount of burden. The burden on urban households ranges from 0.47% in S2 to 0.63% in S3 while the burden on rural households ranges from 0.46% in S2 to 0.61% in S3.

This result is not consistent with the findings of Feng et al. (2010), which found that the burden of carbon pricing policies was heavier on the rural households than on the urban households. It is partly because the average energy consumption in the rural households is less than that in the urban households in South Korea. According to the Energy Consumption Survey (KEEI, 2009), the average energy consumption in urban and rural households is 12,130.1 Mcal and 9,600.4 Mcal, respectively in 2008. While the average income of the urban households is 18.8% higher than that of the rural households (see Table 4.6), the energy consumption of the urban households is 26.3% larger than that of the rural households.

In addition, different energy consumption patterns in urban and rural households may also contribute to this result, As shown in Figure 5.31, rural households depend more on fuel with higher carbon content, such as briquettes (3%) and petroleum (58%), while electricity and city gas account for 52% and 25% of the

[38] As mentioned in Chapter 4, the HSD provides very simple information on locations: rural area and urban area. For more complete analysis on equity implications of a carbon pricing policy, is necessary to construct several regional IO tables.

average energy consumption of the urban households. However, since the sample of the HSD excludes farming, fishing and fishery households in rural areas[39], the difference between the burdens on the urban and rural households may be relatively small.

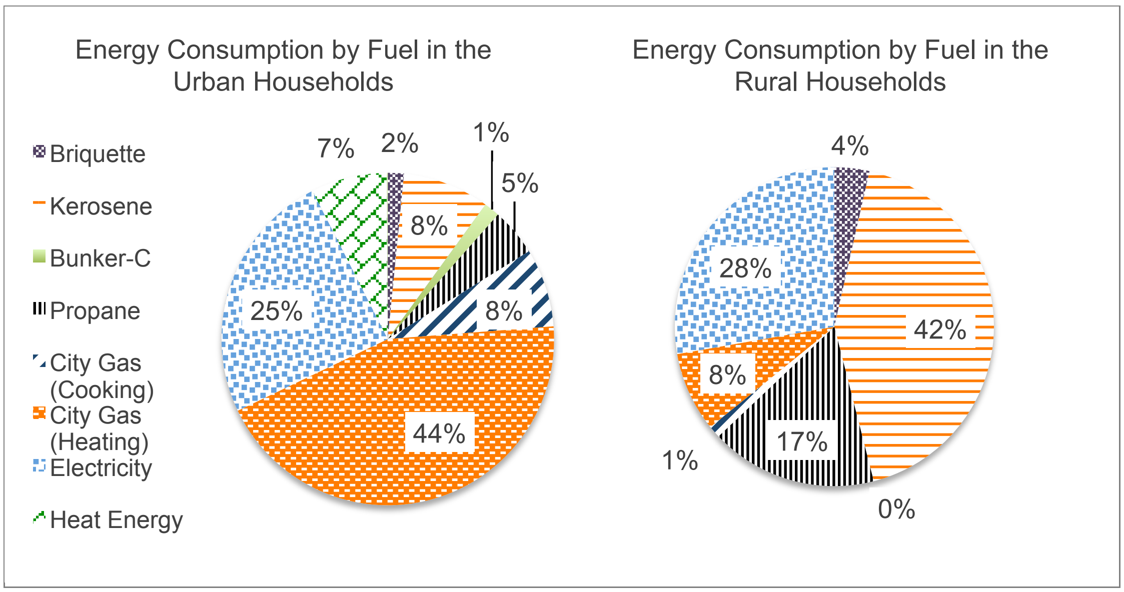

Figure 5.31 Energy Consumption by Fuel in Urban and Rural Households

Source: Constructed using KEEI, 2009

Regardless of the basis for revenue-recycling, the recycling more effectively relieves the burden on rural households. Specifically, the relative burden on rural households is reduced by 0.36% (S1 & S2) to 0.45% (S3) in R1, while the burden on urban households is reduced by 0.33% (S1 & S2) to 0.42% (S3). In R2, the burden on

[39] The expenditure and incomes of these households are separately collected by Statistics Korea.

rural households decreases by 0.39% (S1 & S2) to 0.50% (S3) while it decreases by 0.32% (S2) to 0.41% in urban households. Therefore, the equal per household dividend case relieves the burden on rural households more. This occurs because the average number of family numbers of rural households (2.68 persons per a household) is smaller than that of urban households (2.95 persons per a household).

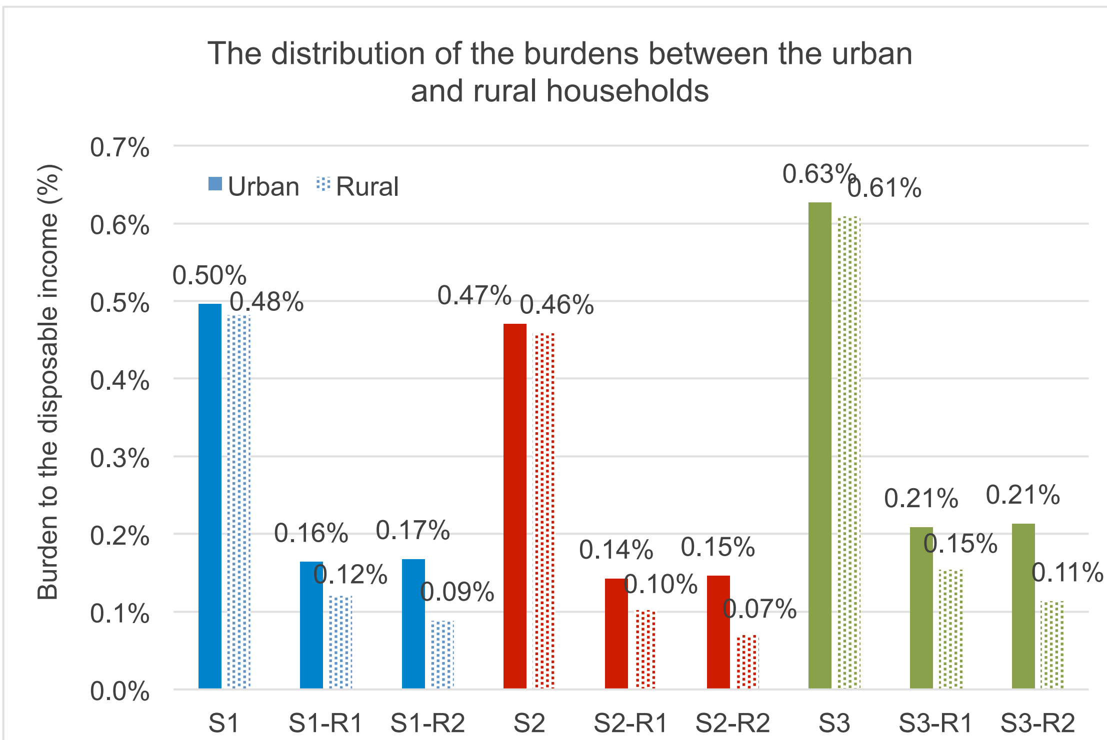

Figure 5.32 Distribution of the Relative Burdens on the Urban Households and the Rural Households

In sum, on the basis of the additional expenditure increased to the disposable income, the burden is clearly regressive. Without revenue-recycling, the difference between the burdens on the poorest household and the wealthiest household is largest in the S3. In addition, the S1 slightly more adversely impacts income distribution than the S2 case because the S1 case increases consumer prices more than the S2 does.

The poorest decile becomes the beneficiary when a quarter of the revenue is recycled. In addition, the R2 is more effective protecting poorer groups than the R1 scenario. This is because the equal per household dividend favors households with smaller family sizes, which is usually the case with poorer households.

The implementation of a carbon pricing policy more adversely impacts the oldest group. The burden on the oldest group is the largest while the burden on the 50-64 groups is the smallest. The equal per household dividend (R2) is more effective to protect the oldest group than the equal per capita dividend (R1), as the family size gets smaller according to the head's age.

The analysis results show that the difference between the burdens on the urban and rural households is very small. This result originates from the feature of the original dataset that excludes fishery, farming, and forestry households. Urban households need to pay slightly more than the rural households due to the implementation. The R2 scenario favors the rural households than the R1 does.

Without revenue-recycling, the S3 scenario is the worst in terms of distribution of burdens between different income groups, different age groups and households in different locations. However, with revenue-recycling, the S3 scenario is the best. Although the higher carbon price is imposed on every industry, the more proceeds collected can be distributed to the households to relieve the burden induced by the implementation. In addition, since poorer households or households with older heads or households in rural areas generally have a smaller number of family members, these households can be more favored if the proceeds are distributed on the equal per households dividend basis.

5.3 Energy and CO_2 Emissions Implications

5.3.1 Impacts on Sectoral Energy Requirements

The sectoral primary energy consumption generally declines except for the mining and coal sectors. In particular, the total energy consumption, including both direct and indirect energy requirements, increases by 3.6 kTOE in the mining sector and 34.0 kTOE in the coal sector in the S1[40]. As explained earlier, the increase in these sectors is because the initial final demands are negative.

The highest reduction in total energy consumption is observed in the construction sector followed by the electric appliances sector, transportation equipment sector and metallic product sector in all of the scenarios. In the construction sector, the direct energy consumption does not decrease much, but the indirect energy consumption significantly decreases. In other words, the legal incidence of a carbon price on the construction sector results in decreases in energy consumption in sectors that produce and supply the intermediate inputs used in the construction sector. In the electric appliances, the transportation equipment and metallic product sectors, the reduction in indirect energy consumption significantly accounts for the total energy reduction amount. After the first four sectors that show the largest reduction in the total energy consumption, the profile of the sectoral reductions in the S2 is different from that in the S1 and the S3. Following the metallic

[40] The total energy consumptions in the mining and coal sectors increase 3.7 kTOE and 26.1 kTOE in the S2 and 4.5 kTOE and 42.9 kTOE in the S3.

product sector, reductions in the electricity sector are the largest in the S2, while it is largest in the chemicals sector in the S1 and the S3.

Since the S1 and S2 scenarios are designed to reduce the same amount of CO_2 emissions, the reduced amount of energy consumption in S1 is similar to that in the S2. It decreases by 3,231 kTOE in the S1 and 3,206 kTOE in the S2 respectively. In the S3, the total energy consumption is reduced by 4,081 kTOE.

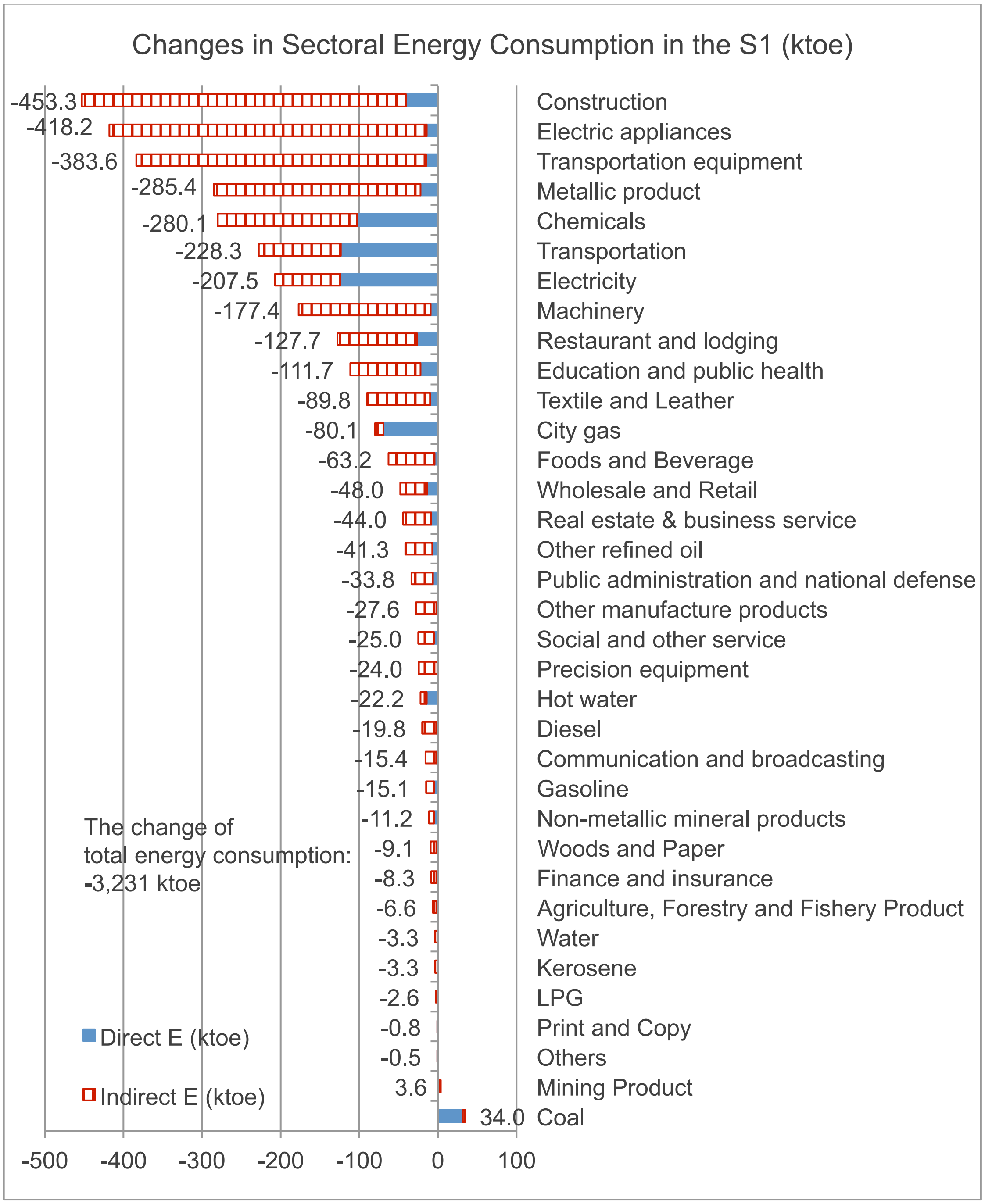

Figure 5.33 Changes in Sectoral Energy Consumption in the S1 Scenario

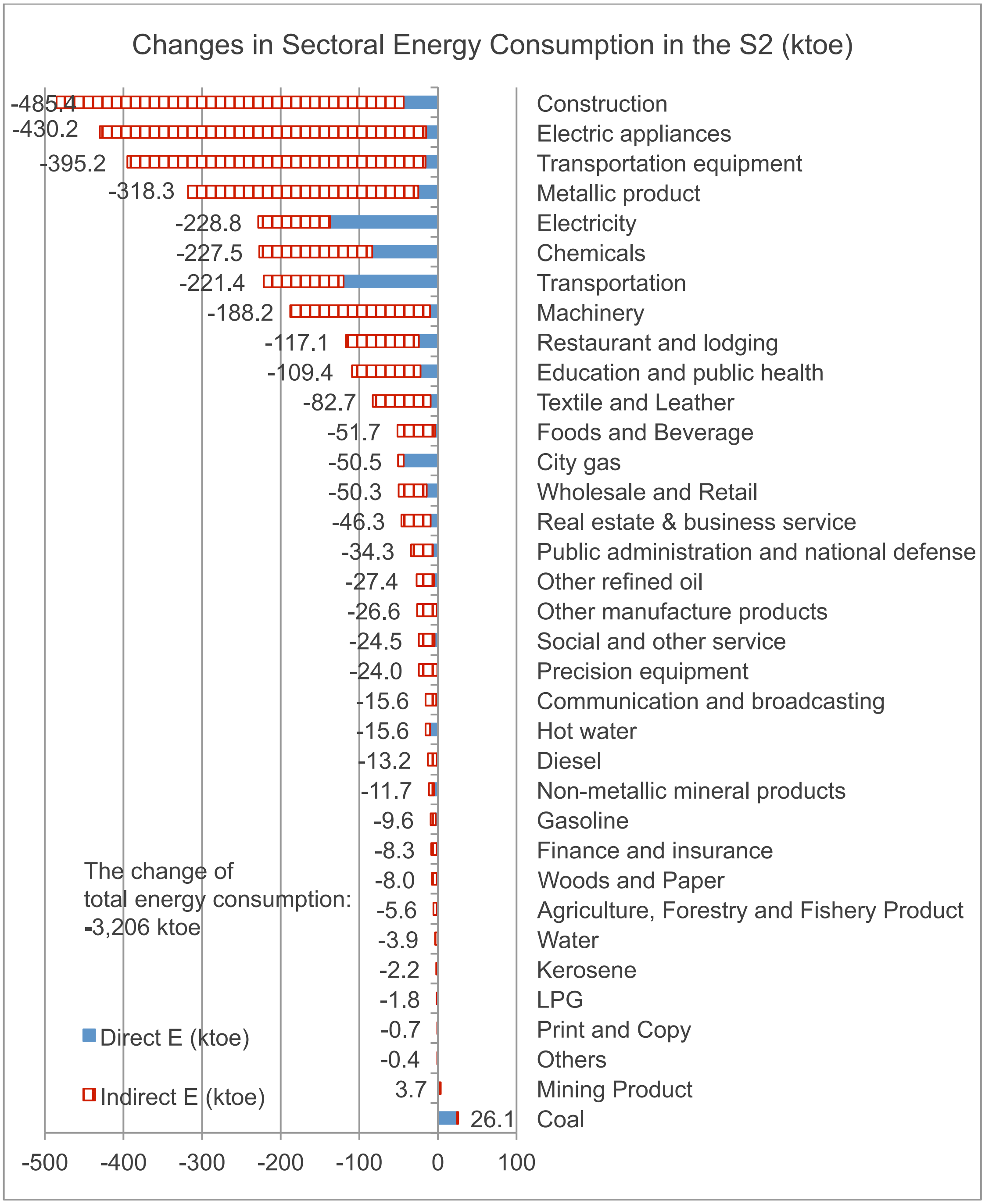

Figure 5.34 Changes in Sectoral Energy Consumption in the S2 Scenario

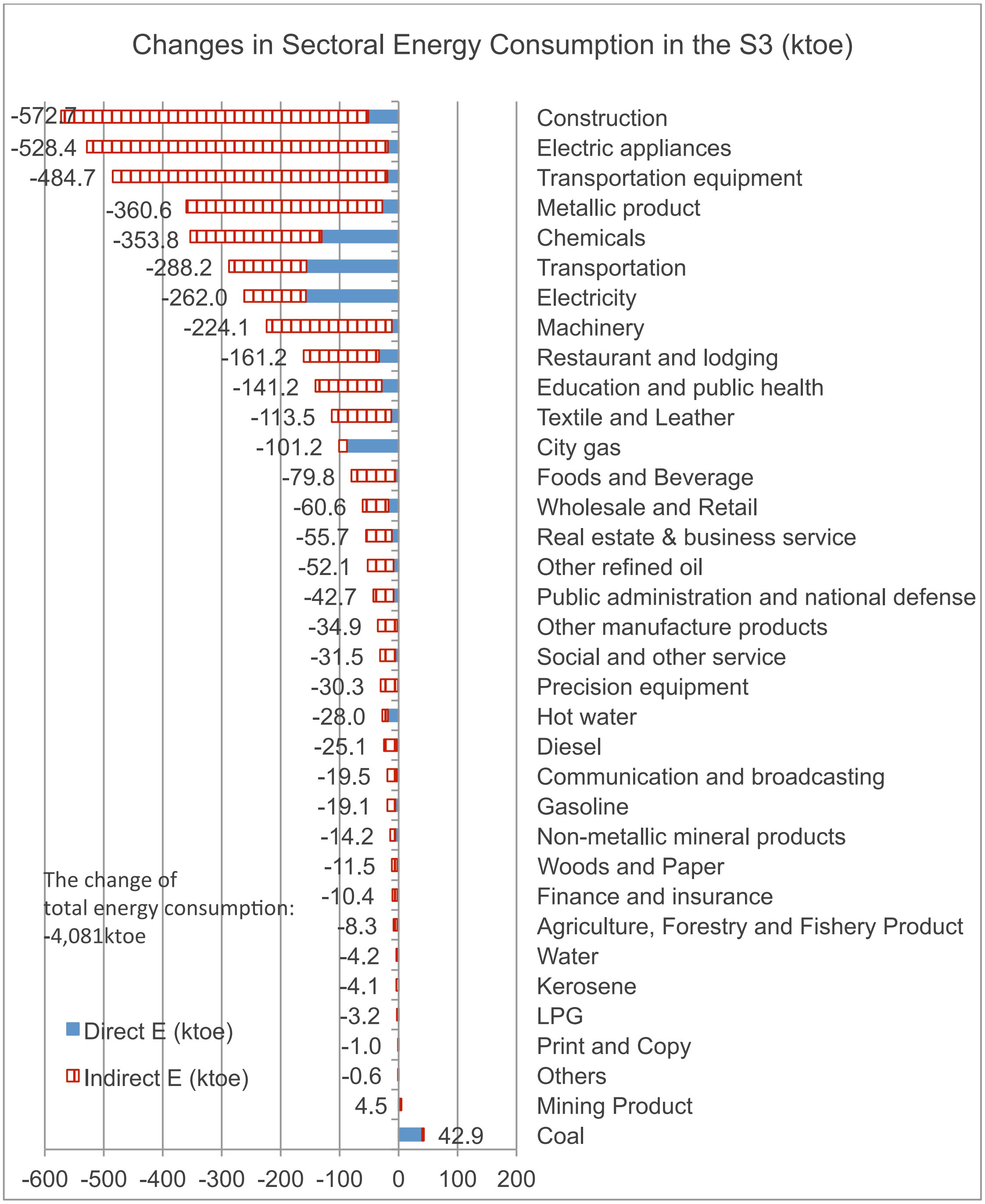

Figure 5.35 Changes in Sectoral Energy Consumption in the S3 Scenario

The changes in energy requirements by energy sources are as follows. The sectoral energy requirements/consumption are generally decreasing according to the decreases in final demands. Of the reduction in the total energy consumption, the bituminous coal consumption decreases the most followed by naphtha and diesel regardless of scenarios. In the S1 and S3, the reduction in bituminous coal accounts for 28.2% of the reduction in the total energy consumption. Together with anthracite, the reduced consumption of coal contributes to more than 30% of the reduced energy consumption.

Energy demands for zero-emitting energy sources, such as hydropower and nuclear power, appear to decrease. This occurs because an I-O model does not allow the substitution between energy sources according to the changes in producer prices of energy. Rather, it assumes that energy requirements by sector and fuel are based on the fixed proportion technologies. In other words, the proportions of the energy sources used for production of the outputs remain constant regardless of the changes in the energy prices. These results cannot imply the long-term effect on energy systems. If the substitution between energy sources is allowed, the demand for zero-emitting energy sources or for less-emitting energy sources might be increased or reduced less and the demand for heavy-emitting energy sources might be decreased more. Therefore, the reduction in high-emitting energy consumption is understated due to this intrinsic feature of the IO model. In addition, since the renewable energy sources were not included when the energy input I-O table was constructed, changes in renewable energy sources are not estimated in this study.

In sum, energy consumption decreases most in the S3, which means the largest reduction in coal, oil and nuclear consumption. This is a preferable result in terms of the total amount of energy reduced. Although the higher carbon price can result in a greater reduction in energy consumption, it will more adversely impact the economy. Therefore, it is necessary to consider the impacts on other dimensions and weigh those implications in a balanced manner. A comparison between reductions in energy consumption by fuel in the S1 and the S2 shows that the S2 case is better than the S1 when the policy aims to reduce coal consumption more than other energy sources. In addition, if the policy makers aim to reduce energy consumption in the electricity sector, the S2 case will be favored.

Table 5.2 Disaggregation of Reduction of Energy Consumption by Energy Sources

	Initial Energy Demand	S1			S2			S3		
		Δ Direct E (kTOE)	Δ Indirect E (kTOE)	Δ Total E (kTOE)	Δ Direct E (kTOE)	Δ Indirect E (kTOE)	Δ Total E (kTOE)	Δ Direct E (kTOE)	Δ Indirect E (kTOE)	Δ Total E (kTOE)
Anthracite	5,406	-12	-110	-123	-14	-115	-129	-16	-139	-155
		2.0%	4.2%	3.8%	2.4%	4.4%	4.0%	2.0%	4.2%	3.8%
Bituminous	59,194	-93	-818	-912	-108	-842	-949	-118	-1034	-1152
		14.8%	31.5%	28.2%	18.1%	32.2%	29.6%	14.8%	31.5%	28.2%
LNG	34,066	-69	-275	-344	-43	-280	-323	-87	-347	-435
		11.0%	10.6%	10.6%	7.3%	10.7%	10.1%	11.0%	10.6%	10.6%
Naphtha	40,532	-96	-496	-592	-77	-483	-560	-121	-627	-748
		15.2%	19.1%	18.3%	13.0%	18.5%	17.5%	15.2%	19.1%	18.3%
Gasoline	11,024	-13	-26	-38	-12	-26	-38	-16	-32	-48
		2.0%	1.0%	1.2%	2.1%	1.0%	1.2%	2.0%	1.0%	1.2%
Jet oil	4,246	-20	-32	-52	-19	-31	-51	-25	-40	-65
		3.1%	1.2%	1.6%	3.2%	1.2%	1.6%	3.1%	1.2%	1.6%
Kerosene	3,667	-11	-17	-28	-10	-17	-28	-14	-22	-36
		1.7%	0.7%	0.9%	1.7%	0.7%	0.9%	1.7%	0.7%	0.9%
Diesel	25,178	-105	-280	-385	-105	-273	-377	-132	-354	-486
		16.6%	10.8%	11.9%	17.6%	10.4%	11.8%	16.7%	10.8%	11.9%
Heavy oil	14,853	-67	-168	-235	-65	-167	-232	-84	-213	-297
		10.6%	6.5%	7.3%	10.9%	6.4%	7.2%	10.6%	6.5%	7.3%
LPG	10,355	-39	-71	-110	-37	-71	-109	-49	-90	-139
		6.2%	2.7%	3.4%	6.3%	2.7%	3.4%	6.2%	2.7%	3.4%
Other petroleum products	7,683	-26	-91	-118	-25	-91	-116	-33	-115	-149
		4.2%	3.5%	3.6%	4.2%	3.5%	3.6%	4.2%	3.5%	3.6%
Hydro	1,211	-3	-8	-11	-3	-8	-11	-4	-10	-14
		0.5%	0.3%	0.3%	0.5%	0.3%	0.3%	0.5%	0.3%	0.3%
Nuclear	31,715	-75	-208	-283	-75	-208	-283	-95	-263	-358
		12.0%	8.0%	8.8%	12.6%	8.0%	8.8%	12.0%	8.0%	8.8%
Total	249,131	-628	-2,602	-3,231	-594	-2,612	-3,206	-794	-3,287	-4,081
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

5.3.2 CO_2 Emissions Implications

As mentioned previously, the profile of sectoral CO_2 emissions is different from that of sectoral TPEC. This is because the amount of energy used as a raw material, such as naphtha or other petroleum products, is excluded from the estimation of CO_2 emissions because the carbon content in those energy sources is not combusted but remains in the product. The S1 and S2[41] cases will reduce about 1.4% (6.20 Mt) of the emissions from industries in 2009. Of this reduction, the direct emission reduction is only 23% (1.4Mt) while the indirect emission reduction in S1, which is from reduction in intermediate input demands caused by reduction in the output. In the S2, the reduction in indirect emissions is slightly less than that in the S1. The S3 reduces CO_2 emissions by 7.83 Mt.

Except for the mining product and coal sectors, the emissions from every other sector are reduced. As explained in the previous chapter, the increase in the emissions in these two sectors is attributed to the increase in the final demands in these sectors. The largest emission reduction is achieved in the construction sector followed by the electric appliances sector in all three scenarios. This result is compatible with the reduction in the total energy consumption explained above. In the S1 and S3 cases, the third largest reduction in emissions is obtained in the transportation equipment sector followed by electricity, transportation and metallic product sectors. The pattern

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[41] At first, this study set up both scenarios, which aimed to reduce the same amount of CO_2 emissions.

of changes in sectoral CO_2 emissions in the S2 is different from that of the rest of the scenarios. In the S2, the third largest reduction in emissions is obtained in the electricity sector.

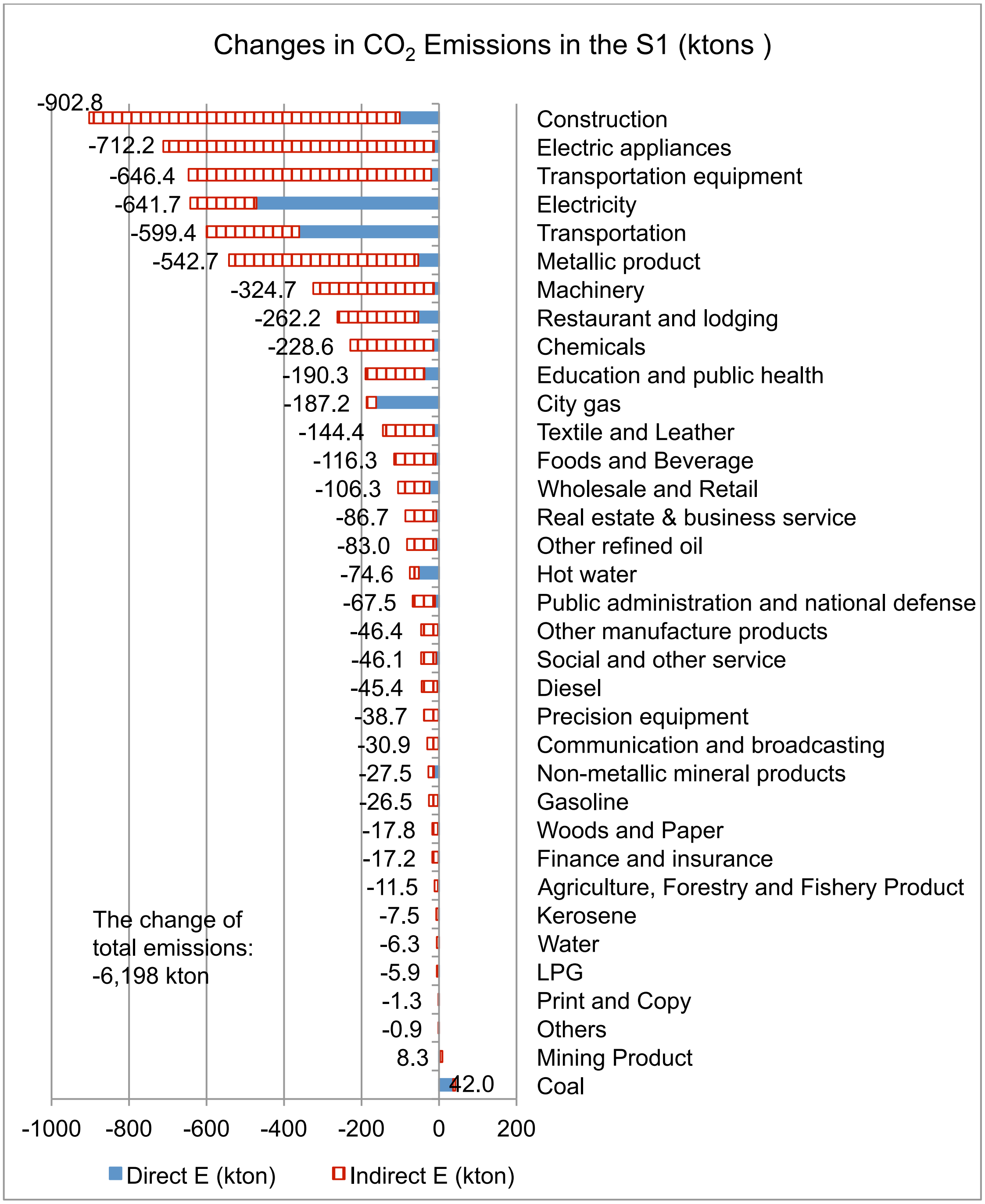

Figure 5.36 Changes in Sectoral CO_2 Emissions in the S1 Scenario

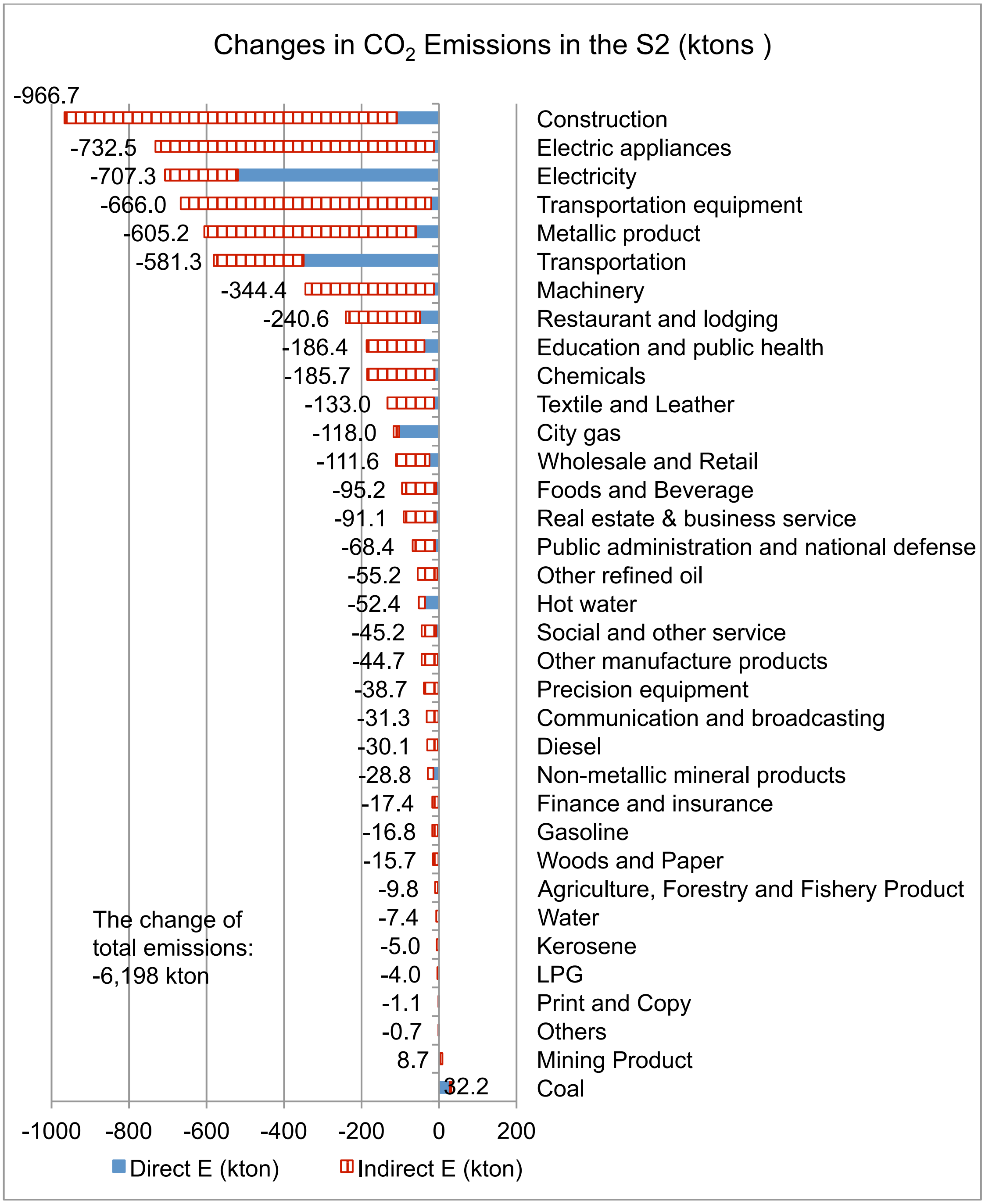

Figure 5.37 Changes in Sectoral CO_2 Emissions in the S2 Scenario

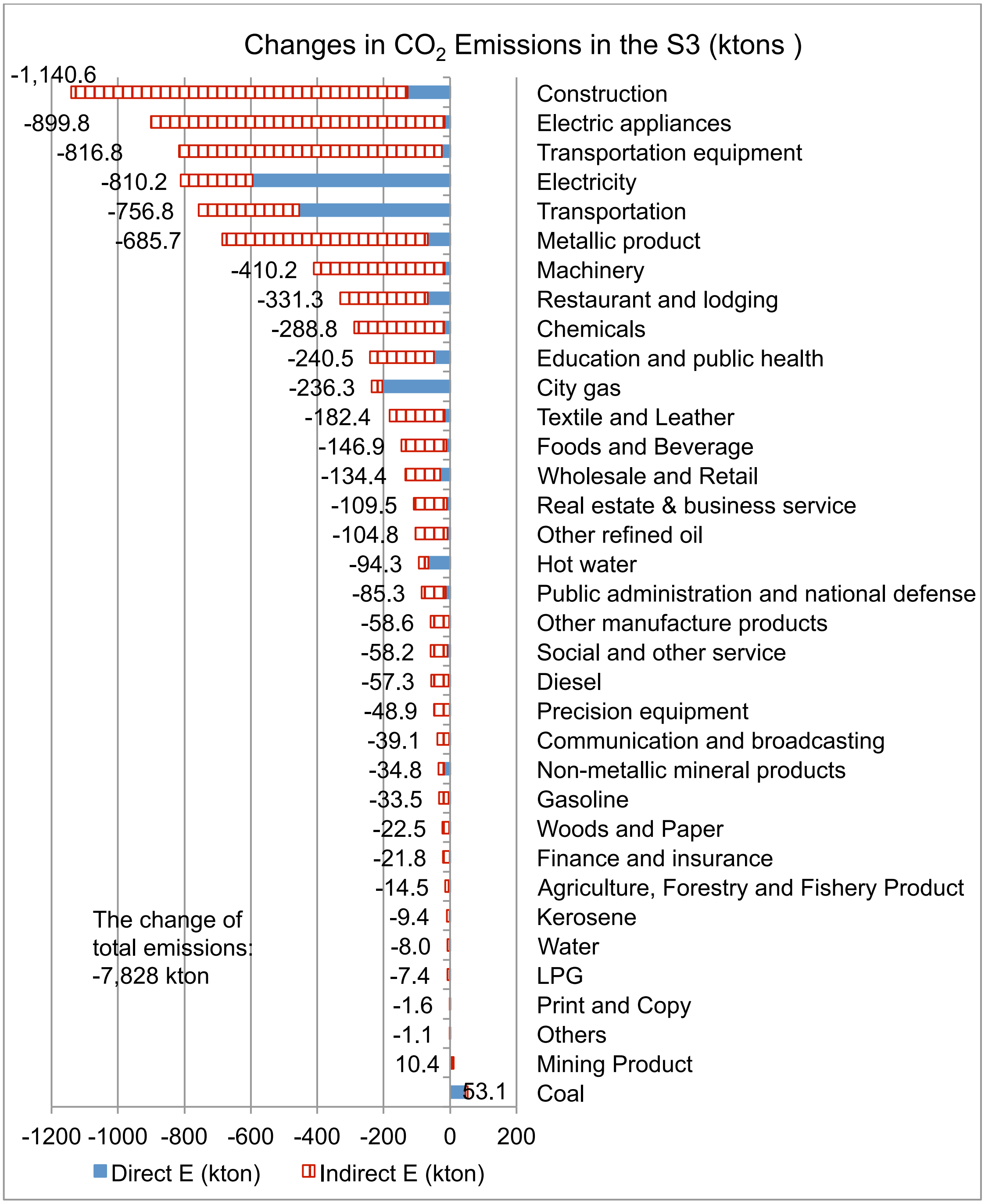

Figure 5.38 Changes in Sectoral CO_2 Emissions in the S3 Scenario

Figure 5.38 shows how the total emission reductions (including direct and indirect emissions) are different by sector and energy source. This pattern is identical in all three scenarios, which is attributed to the fixed sectoral CO_2 intensities by fuels. As a result, although the amount of the reduced emissions is different between sectors, the profile of the reduced emissions in a sector – how much the emissions are reduced by fuels - is equivalent regardless of scenarios.

The emissions from bituminous coal is, on average, reduced the most by 38% followed by diesel by 19%, LNG by 13% and heavy oil by 12%. The sectoral reduction pattern by energy type is different from this overall reduction pattern. For instance, the total emissions of the construction sector (25) decreases by 39% from bituminous coal and by 24% from diesel, while most of the reduction in the coal sector (7) comes from reduction in coal demands – 73% from bituminous coal and 18% from anthracite coal.

In sum, the S3 case achieves the largest reduction in emissions. The reduction in coal emissions contributes to about 50% of the reduction in the total emissions and the reduction from LNG contributes to about 10% of the reduction in total emissions regardless of scenarios. In addition, the S1 and the S2 are designed to achieve the same amount of reduction, but reductions in CO_2 emissions are different between sectors. The large reduction in the electricity sector is achieved in the S2.

As mentioned earlier, as the I-O model does not allow the substitution of inputs according to changes in prices, the results might understate the reduction from coal and overstate the reduction from LNG.

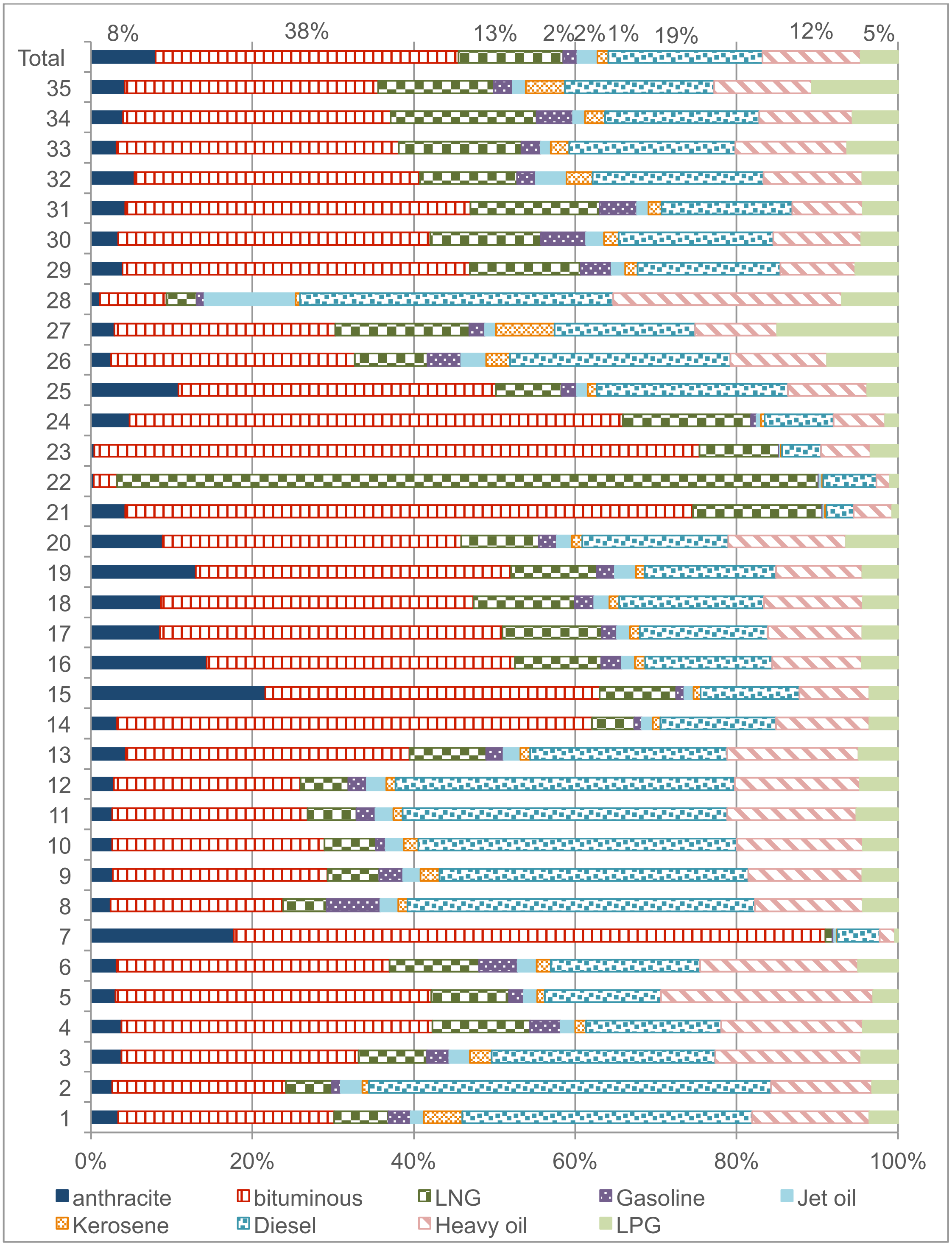

Figure 5.39 Sectoral Emissions Reduction by Fuel

In this chapter, the comprehensive impacts of a carbon pricing policy are analyzed. Three scenarios are tested. The first two scenarios aim to reduce the same amount of CO_2 emissions and are designed to compare the impacts of the comprehensive implementation with those of the partial implementation of the policy. The third scenario assumes the comprehensive implementation at the higher carbon price to examine how the stronger policy impacts economy, CO_2 emissions, energy consumption and equity.

Since the comprehensive implementation of a carbon pricing policy (the S1 and the S3 scenarios) increases producer prices and in turn increases consumer prices more than the partial implementation case (the S2 scenario), as a result, the final demands decrease more in the S1 than the S2. Even with more reduction in final demands, the outputs, employment and value-added are less adversely impacted in the S1. Due to the higher increases in consumer prices, the S1 without the revenue-recycling adversely impacts the distribution – the difference between the relative burdens on different groups is slightly larger in the S1 than in the S2. However, the inequity caused by the implementation can be relieved together with the revenue-recycling. In addition, since the revenue is recycled through the equal per household dividend, the rural, oldest and poorest households are more effectively protected because these households have less family members.

In terms of the energy dimension, since these two scenarios are designed to reduce the same amount of CO_2 emissions, the reductions in the total energy consumption are similar. More specifically, the reduction in energy consumption—

because of the use of raw materials, such as naphtha or other petroleum products—is larger under the S1 scenario while coal consumption is reduced more under the S2 scenario. Since the reduction in energy consumption used as raw materials does not contribute to the reduction in the emissions while the reduction in coal consumption is significant for the CO_2 emissions reduction, it can be said that the S2 scenario reduces the energy consumption more effectively.

In terms of CO_2 emissions, the emissions reduction by fuel shows that the emissions from coal combustion is reduced slightly more under the S2 scenario. It also results in more reduction from the electricity sector.

Of the three scenarios, the S3—the comprehensive implementation of the strengthened policy—can reduce CO_2 emissions the most. However, it more adversely affects the economy compared to the rest of the scenarios. Without additional countermeasures, this scenario aggravates the equity status. However, the proceeds collected are larger in the S3 and is enough to relieve the larger difference between the relative burdens of different groups and to protect the vulnerable groups, such as the poorer and the older households, more than the rest of the scenarios.

Chapter 6

POLICY IMPLICATIONS AND THE LIMITATIONS OF THE STUDY

Chapter 5 evaluated the comprehensive impacts of a carbon pricing policy on various dimensions of our society including economy, energy, environment and equity using an I-O model.

A higher carbon price or the permit price (S3) induces more reduction in CO_2 emissions and energy consumption, but it will adversely impact the economy and aggravate equity or income distribution. When the policy aims to reduce the same amount of CO_2 emissions, the partial participation of industries (S2) leads to less of an increase in both producer and consumer prices than the comprehensive participation scenario (S1). As a result, the partial participation scenario without revenue recycling exacerbates the equity status less. However, partial participation more adversely impacts economy (outputs, employment and value-added). If the priority of the policy makers is a prompt response to climate change, a higher carbon price should be imposed. In addition, if impacts on the economy are emphasized more than impacts on equity when the policy is designed, comprehensive participation will be prioritized. If the proceeds are recycled to relieve inequitable distribution of the burden, the comprehensive participation scenario can be better in terms of the equity dimension as well. The greater difference between the burdens on the 1^{st} and 10^{th} deciles or on the youngest and oldest groups or on the urban and rural households can be relieved through revenue-recycling in the comprehensive participation scenario.

In this chapter, this thesis discusses the effectiveness of a recycling method in terms of alleviation of fuel poverty as well as the regressivity. In order to reduce the CO_2 emissions in households' energy consumption while protecting the vulnerable group from the changes in energy prices induced by the implementation at the same time in the long term, relieving energy poverty is also an important issue. This chapter looks into the effectiveness of the lump-sum transfer of the proceeds to the households and aims to suggest a more systemic way to support the vulnerable group such as the poor or elderly households in response to the implementation of a carbon pricing policy. In order to achieve the objective of this chapter, I disclose the limitations of lump-sum transfer methods by exploring the causes of fuel poverty and review the multilateral achievement of energy efficiency projects in low-income households. Based on this, this chapter will discuss the limitations of the revenue-recycling scenario and suggest future research topics.

In this study, it is confirmed that recycling a part of the proceeds can relieve the regressivity induced by carbon pricing policy and can enhance the current inequity of income distribution. In other words, the incidence of the burden becomes progressive and the poorest and most elderly households can experience a reduction in expenditure through the dividend provided. However, this approach has limits to tackle fuel poverty.

This is because there are several factors that affect energy poverty besides income. The government of the United Kingdom identifies the causes of fuel poverty as poor energy efficiency of buildings, size of the building, the number of people living in them, low incomes and fuel cost (Department for the Environment Transport and the Regions & Department of Trade and Industry, 2001). In addition to these factors, Dresner and Ekins (2005) claimed that climate change is one of the causes impacting fuel poverty as well. In general, higher energy prices, lower energy efficiency, lower household income and colder temperatures will exacerbate fuel poverty. Jin, Park, and Hwang (2009) specifically identified the factors: [1] household's income; [2] specific households such as households with the old or the disabled or single-parent household[42]; [3] energy efficiency of buildings; [4] energy efficiency of the appliances; [5] energy prices; [6] awareness of the energy welfare program and [7] accessibility to clean and cheap energy[43].

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[42] For example, the old or disabled tend to stay home longer, which is likely to result in relatively higher heating demand.

[43] As mentioned earlier in Chapter 4, poor households depend more on expensive energy sources, such as kerosene and LPG, and locations of these households are sometimes in remote or hilly areas making them not suitable for access to city gas.

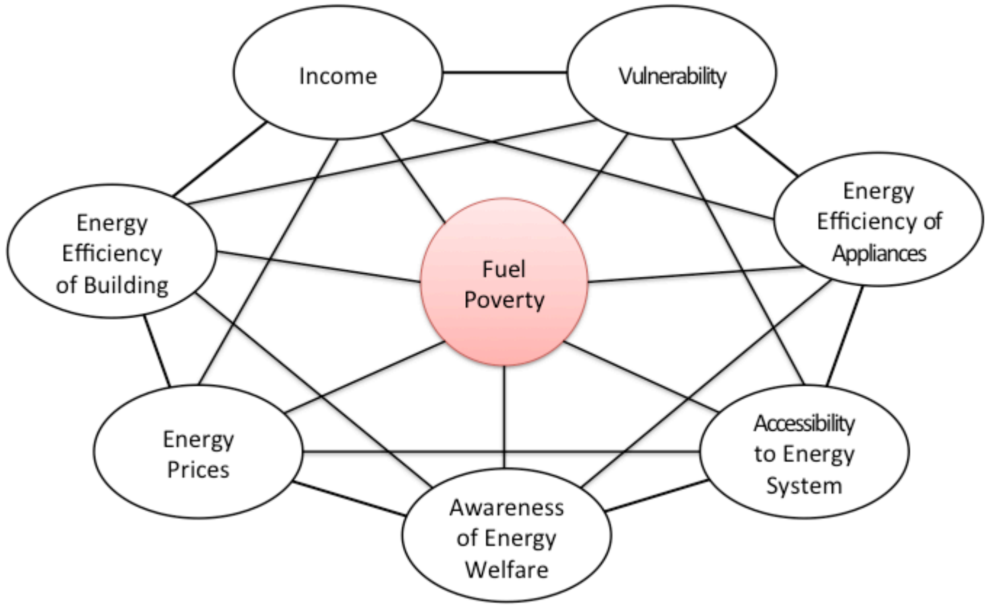

Figure 6.1 Seven Factors of Fuel Poverty

Source: (Jin et al., 2009)

Therefore, fuel poverty may not be relieved only through income approaches, such as lump-sum transfers. Although the lump-sum transfer contributes to increasing the budget constraint of consumers, it may not increase the consumption of the targeted items in the way that in-kind support measures or voucher program does (Kim, 2007). In addition, without enhancement of the accessibility to energy systems or building energy efficiency, CO_2 emissions from the residential sector including the bottom rung will either remain unchanged or increase. Therefore, a systemic approach considering all of these factors simultaneously is required in order to relieve fuel poverty. Lump-sum transfers used to relieve only the regressivity induced by a carbon pricing policy are likely to have a limited effectiveness to reduce the number of people suffering in fuel poverty unless they are carried out together with other programs in order to tackle other causes of fuel poverty, such as energy efficiency improvement.

According to the UK Fuel Poverty Strategy, fuel poverty is defined as follows:

> A fuel poor household is one that cannot afford to keep adequately warm at reasonable cost. The most widely accepted definition of a fuel poor household is one which needs to spend more than 10% of its income on all fuel use and to heat its home to an adequate standard of warmth. This is generally defined as 21˚C in the living room and 18˚C in the other occupied rooms – the temperatures recommended by the World Health Organization (Department for the Environment Transport and the Regions & Department of Trade and Industry, 2001: p.6).

Although a law that would define fuel poverty and specify energy welfare programs does not yet exist, the definition above has prevailed in South Korea. Based on the definition, 10.97 % of the 10,882 households were in fuel poverty in 2009. The more vulnerable households, with less capacity to respond to increased energy prices due to limited access to various and cheap energy sources and low income, suffer fuel poverty the most. 54% of the poorest households suffer from fuel poverty while the wealthiest group that has energy expenditures that exceed 10% of disposable income is only 0.18%. 39% of the "75+" households, 28% of the "65-74" households, 11% of the "50-64" households and 5% of the "under 49" households suffer fuel poverty. In addition, 15% of rural households and 10% of urban households suffer fuel poverty (See Appendix C).

Due to the limit of the current model and data, this study did not evaluate the equity implication or benefit (such as CO_2 emissions reduction) of the case if the proceeds are recycled to finance the energy efficiency enhancement projects in low-income households or to install renewable energy facilities in these households. However, the impact of the investment of the revenue in low-income households can be imagined based on the current practices in the U.S. and South Korea.

In the U.S., the Weatherization Assistance Program (WAP), a well-known energy efficiency improvement for low-income households, has been in practice since 1976. In order to protect the vulnerable households to the sharp increase in fuel costs due to the oil crisis in 1973, this program began in accordance with Title IV of the Energy Conservation and Production Act. Initially, the program was primarily based on temporary, cheap and emergent measures, such as the caulking of windows and doors. The WAP has been improved and has been successfully extended by using more permanent and cost-effective measures, such as improving efficiency of insulation and heating systems, extending the scope of the project to cooling measures, such as air conditioner replacement and screening and shading devices, and the adoption of an advanced home energy audit (Department of Energy, n.d.).

For the past 33 years, the WAP has provided energy efficiency measures to more than 6.4 million low-income households and serves about 100,000 homes every year (Department of Energy, n.d.). According to the DOE (2008), the annual energy bills of the homes receiving the services from this program have been reduced on average about $413. The returns of $1.65 from energy saving was realized for every $1 invested in the WAP. Besides the direct benefit/energy saving from the WAP, indirect/non-energy benefits, such as job creation and GHG emission reductions were achieved. In fact, the avoided CO_2 emissions by this program are estimated as 1.79 tons per house. In addition to the creation of about 8,000 jobs nationwide, the multiplier effect of this project is estimated at around \$3 per \$1 invested. The WAP is also claimed to support the local economy by stimulating the investment in local industries (See the Figure 6.2) (Department of Energy, 2008).

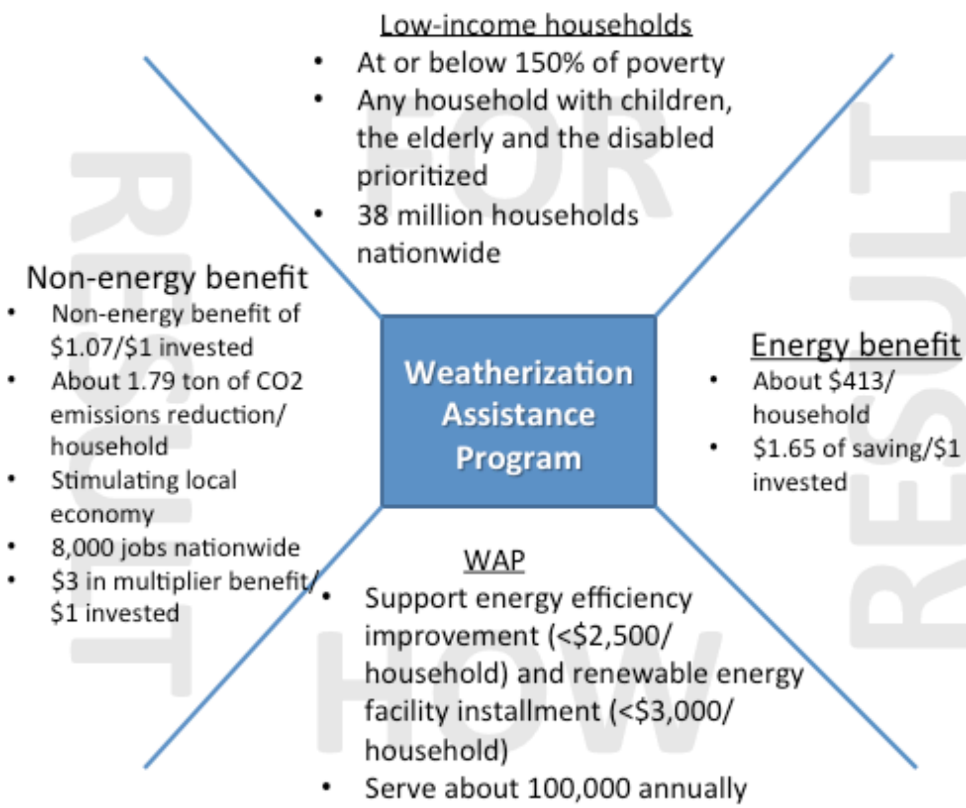

Figure 6.2 The Snapshot of the WAP: Measures and Results

Source: Constructed using information in (Department of Energy, 2008)

The success of the WAP illustrates the performance of energy efficiency measures provided to the low-income households. In addition to energy savings, collateral benefits are accompanied, which cannot be realized under the one-time distribution of the proceeds to the low-income or the elderly.

In South Korea, energy efficiency improvement programs for low-income households are also in operation. Energy efficiency measures consist of [1] energy efficiency improvement for low-income households, [2] high efficient light deployment for low income households and social welfare facilities, [3] inefficient appliance replacement for social welfare facilities, [4] new and renewable energy (NRE) deployment for rental apartment for low-income households and [5] NRE deployment for social welfare facilities (Jung, 2011).

Energy efficiency improvements for low-income households is run by the Korea Energy Foundation, which was established by the Ministry of Knowledge Economy in 2006 to eradicate fuel poverty. The fund of the Foundation is raised through voluntary donations of 16 energy companies including electricity generation, refineries and city gas companies and support from the Ministry[44] using Special Accounts for Energy and Resources-related Projects. During the past six years from 2007 to 2012, energy efficiency measures including insulation, floor retrofit, window and door insulation measures and heating measures support, such as boiler, heating

[44] At first, the Ministry of Knowledge Economy (now Ministry of Trade, Industry and Energy) financed the fund using the Special Accounts for Energy and Resources-related Projects. However, the government supported this Foundation using Lottery Fund since 2009.

mat, curtain, etc., has been provided to 244,272 households and the total amount of fund invested is about 138 billion KRW (about 131 million USD). Since the performance of these projects is not evaluated like the WAP, it is hard to know the exact achievement of each measure but the Foundation expects that the energy efficiency measures will reduce energy expenditure of households by 8 % in windows and doors insulation projects to 32% in wall insulation projects and if both measures are operated at the same time, 40% of energy can be saved (Korea Energy Foundation, n.d.).

In addition, an environmental NGO, Eco Justice, has provided energy efficiency measures to more than a hundred low-income households from 2006 to 2009 and has evaluated the performance of the measures, such as old boilers replacement, wall insulation, etc. According to the evaluation of Eco Justice, the measures enhanced the airtightness by 37%~50%. In addition to the additional evaluation of the projects in 30 low-income households in Seoul, the total natural gas savings and CO_2 emissions reduction was estimated at 1,862 m^2 and 3,715 kg respectively. Together with the non-energy benefits, the B/C ratio was equivalent to 1.47 (Energy & Climate Policy Institute, 2010).

As reviewed, the energy efficiency improvement projects for low-income households can achieve not only the relief of fuel poverty but also additional benefits, such as CO_2 emissions reduction, local economic stimulation, job creation and public health enhancement.

In South Korea, the current policy measures for eradicating fuel poverty are currently focused on fuel expenditure support and energy rates discounts, such as briquette coupons, emergency fuel support, electricity rate discounts, gas rate discounts and heat rate discounts. These measures contribute to fuel poverty reduction, but the achievement is temporary or valid for the year invested and does not accompany a variety of collateral benefits.

The Energy & Climate Policy Institute classified current energy welfare programs in South Korea into three categories: [1] supply-side programs; [2] energy efficiency measures; and [3] transition measures. The measures such as fuel expenditure support and energy rates discount are classified to supply-side programs. Energy efficiency measures such as the WAP permanently reduce energy expenditure of households and result in additional benefits. The Institute classified renewable energy deployment project and natural gas or district heating service deployment into transition measures, which results in more comprehensive benefits than the other two categories. It is clear for the policy to orient towards and emphasize more on the later two categories than on supply-side programs.

Table 6.1 Classification of Energy Welfare Programs in South Korea

Category	Supply-side measures	Energy efficiency measures	Transition measures
Programs	Support directly / indirectly fuel or fuel cost through cash, goods or vouchers	Provide energy efficiency measures such as home efficiency improvement, appliance replacement	Deploy city gas and district heating and renewable energy facilities for low-income households
Features	• Focused on energies • Fossil-fuels oriented • Short-term approach • Emergent aid oriented approach	• Energy-efficiency-enhancement oriented • Energy demand-side approach • Limit to housing welfare	• Energy-transition and self-sufficient-energy-system oriented • Extend housing welfare effect
Welfare effect (energy cost saving)	Small or Medium	Medium	Large
Environmental effect (GHG emissions reduction)	N.A.	Medium	Large
Employment effect (job creation)	Negligible	Medium or Large	Large

Source: (Energy & Climate Policy Institute, 2010)

From this perspective, the lump-sum transfer of the proceeds collected from a carbon pricing policy cannot result in additional benefits in the way that energy efficiency and transition measures do. In addition, it is a resolution for only one of the causes of fuel poverty: income. Therefore, revenue-recycling methods need to be tailored to achieve comprehensive and permanent benefits. The policy implications of the empirical analysis results are summarized in Table 6.2.

Table 6.2 Summary of Policy Implications

- To achieve more CO_2 reduction, a higher carbon price needs to be imposed.
- To meet a CO_2 emission reduction target more cost-efficiently, a more comprehensive implementation of the policy is recommended.
- To achieve more reductions in the consumption of or the emissions from coal, partial participation of high-emitting industries in the policy is recommended.
- Regardless of carbon prices or the scope of the participation in the policy, the poor households and the households with elderly heads would bear relatively heavier burdens.
- By recycling a small proportion of the revenue, the inequity induced by the disproportionate distribution of the burdens between different socioeconomic groups can be relieved.
- When the revenue is recycled on the equal per household basis, the poor, elderly and rural households will be more effectively protected than the equal per capita dividend.
- The effectiveness of the lump sum transfer revenue recycling is valid for the year invested and do not accompany additional benefits.
- Different from the lump sum transfer method, energy efficiency measures or renewable energy deployment can result in additional benefits, such as job creation, CO_2 reduction in residential sectors, etc.
- Although this study did not evaluate the effectiveness of other recycling methods, the investment of the revenue in other measures, such as energy efficiency projects or renewable energy deployment needs to be considered.

Although this study has enlightened the detailed equity implications of the implementation according to households' income levels, heads' age and locations in addition to the impacts on other dimensions, this study has some limitations. Due to the nature of the IO analysis, the substitution of goods and services according to changes in producer or consumer prices is not allowed. As a result, some impacts are overstated and other impacts are understated. For example, CO_2 emissions reduction is understated. If the model allows the substitution between energy sources, fossil fuel energy consumption will decline more drastically and the avoided CO_2 emissions is much larger than this model estimates. In addition, since the IO model cannot simulate cap-and-trade or allows only static analysis, this study cannot but virtually and statistically analyze the impacts of cap-and-trade policy. Even with the results from a static analysis, this study is meaningful in that it illuminates the more multilateral equity issues in relation to a carbon pricing policy and it achieves evaluation of the comprehensive impacts of the policy from the perspectives of energy, economy, environment and equity. The stated limitations need to be tackled by studies in the near future.

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Appendix A

INPUT-OUTPUT TABLE IN PRODUCER PRICES (2009)

Table A.1 Input-Output Table 1/5

	1	2	3	4	5	6	7	8
1	2,998,939	2,485	31,979,082	513,432	1,148,254	-	-	-
2	1,665	-	41,751	6,082	69,083	-	3,934,672	8,226,433
3	9,058,725	-	16,411,411	770,812	69,397	-	-	-
4	374,157	3,291	117,141	13,845,929	213,831	22,264	572	716
5	510,261	7,685	1,493,514	464,347	9,678,979	1,415,013	3,294	542
6	19,607	832	237,089	100,255	83,107	953,506	1,153	3,504
7	109,976	-	-	-	-	-	34,463	-
8	97,421	4,052	94,377	167,970	39,120	36,085	8,478	171,304
9	160,272	1,471	18,695	16,110	6,903	4,628	94	6,874
10	1,042,858	241,961	216,394	93,744	56,571	13,546	14,221	63,147
11	30,768	3,981	66,216	53,367	15,309	10,049	1,639	31,251
12	178,888	20,209	239,678	284,140	354,918	21,374	63,118	703,035
13	4,210,287	92,333	3,330,443	5,893,766	1,819,717	709,441	19,822	240,990
14	31,275	1,046	583,005	20,524	91,775	2,448	17,605	2,362
15	129,377	59,666	1,289,308	435,100	177,019	18,983	17,727	28,323
16	251,129	65,421	262,565	235,607	151,646	41,815	27,202	36,040
17	83,367	13,903	35,654	46,985	38,991	31,841	6,130	4,055
18	43,857	338	12,493	4,948	7,751	2,582	709	4,970
19	248,270	128,990	75,452	33,488	46,763	13,600	1,264	3,049
20	7,762	485	106,521	474,420	9,628	464	108	210
21	325,206	83,576	492,611	902,910	726,710	63,506	89,373	19,083
22	7,510	85	83,227	107,612	16,174	14,716	1,383	-
23	203	-	33,364	104,092	155,432	-	-	42,917
24	6,284	15,907	35,837	128,879	7,431	1,370	505	682
25	30,900	3,884	27,390	29,035	9,057	812	1,647	1,349
26	1,505,336	34,460	4,776,982	1,807,989	964,217	346,103	18,459	50,362
27	-	-	-	-	-	-	-	-
28	477,977	398,335	2,850,024	1,013,988	831,961	233,090	107,344	47,317
29	188,426	10,303	189,484	262,290	91,081	68,304	7,358	13,420
30	686,559	81,550	870,955	1,028,037	359,986	83,986	38,337	28,101
31	501,242	97,254	2,938,213	2,463,216	634,476	426,407	72,778	92,674
32	80,965	-	-	-	-	-	-	-
33	239,620	8,048	335,624	169,784	79,761	21,999	1,706	9,560
34	47,839	10,361	117,314	117,474	36,401	157,280	2,372	6,538
35	739,464	154,354	638,533	959,444	294,420	222,799	27,454	17,922
Labor	3,377,956	834,295	6,070,445	6,602,229	3,193,765	1,273,119	107,645	84,926
Capital	22,399,246	1,419,614	6,714,712	5,661,245	3,108,879	1,416,447	140,442	147,691
Tax	844,150	-73,581	11,089,963	1,566,997	616,043	459,329	-160,498	7,055,901
Total	51,047,744	3,726,594	93,875,467	46,386,247	25,204,556	8,086,906	4,608,576	17,145,248

Table A.2 Input-Output Table-continued 2/5

	9	10	11	12	13	14	15	16
1	-	-	-	-	1,381,715	-	71	-
2	2,549,893	20,154,205	2,362,792	35,080,158	830,416	3,450,502	12,591,704	10,330
3	-	-	-	2,826	897,464	8,635	-	-
4	1,657	7,834	625	4,476	913,384	81,784	203,153	155,406
5	430	2,502	695	17,776	1,212,662	475,457	541,611	403,172
6	2,391	16,123	1,960	24,378	327,403	32,611	85,426	57,999
7	-	-	-	-	181,614	123,732	4,936,464	2,078
8	19,200	24,942	12,060	152,324	184,362	77,562	206,228	214,264
9	11,754	49,884	2,637	31,843	54,905	63,838	144,207	28,255
10	5,138	72,117	13,959	96,102	353,924	503,372	485,775	179,041
11	11,557	80,391	15,365	161,431	243,524	253,547	725,656	90,122
12	26,515	227,876	35,095	2,118,912	27,529,925	1,422,068	1,048,862	358,402
13	46,658	559,342	41,086	1,129,256	85,083,112	1,542,252	4,803,780	2,818,976
14	1,361	5,477	742	8,156	1,164,963	6,158,475	1,830,139	338,978
15	22,854	138,330	17,450	442,026	3,030,413	1,103,529	138,846,385	21,979,854
16	26,023	143,661	22,910	225,095	2,082,698	419,551	2,883,878	23,122,439
17	3,544	33,711	3,522	18,424	171,960	115,980	1,006,450	5,469,787
18	3,289	23,595	2,622	37,530	90,837	13,261	156,108	1,521,661
19	3,331	17,790	1,968	16,236	187,877	209,404	190,314	696,804
20	92	516	93	458	21,255	3,617	4,246	26,845
21	35,297	236,914	30,411	202,566	1,900,679	616,840	4,895,788	458,488
22	-	-	-	51	282,034	220,774	1,184,239	139,108
23	27,398	221,185	10,533	136,348	594,280	-	-	4,367
24	731	3,127	627	2,886	28,117	10,657	63,501	10,095
25	1,084	3,729	735	4,192	53,536	13,576	95,770	35,283
26	24,337	80,944	17,588	238,392	5,703,879	1,012,262	5,545,858	3,740,187
27	-	-	-	-	-	-	-	-
28	27,083	206,725	24,296	489,234	3,530,147	2,679,634	4,451,322	1,417,610
29	8,208	48,810	6,811	73,523	440,248	195,148	441,109	253,228
30	22,522	115,863	18,477	240,029	1,769,904	493,790	2,561,268	1,165,716
31	53,244	416,093	55,622	566,765	7,604,072	1,132,890	5,970,998	4,612,697
32	-	-	-	-	-	-	-	-
33	5,293	59,299	6,690	67,453	674,321	115,734	739,216	347,365
34	5,516	34,835	3,789	35,842	235,100	86,612	298,073	170,080
35	11,085	80,043	8,476	138,434	1,602,196	486,226	2,126,672	1,090,506
Labor	40,792	389,749	22,589	647,705	15,777,091	3,870,831	18,904,064	14,506,615
Capital	70,818	793,713	46,003	1,251,585	19,396,927	5,972,874	24,355,221	9,125,695
Tax	543,975	9,401,289	662,676	377,057	2,567,296	241,820	888,055	1,553,756
Total	3,613,070	33,650,614	3,450,904	44,039,469	188,104,240	33,208,845	243,211,611	96,105,209

Table A.3 Input-Output Table-continued 3/5

	17	18	19	20	21	22	23	24
1	-	-	5,218	23,865	-	-	-	90
2	46,553	5	3,657	5,159	6,202,179	18,061,221	404,429	-
3	-	-	-	1,092	-	-	-	-
4	378,574	63,145	505,828	1,357,251	42,666	176	375	1,893
5	1,486,494	89,128	424,489	1,784,092	4,349	31	-	-
6	312,535	13,173	59,394	38,020	12,430	308	583	4,271
7	-	-	2,853	-	992,963	-	-	-
8	134,815	14,609	202,819	19,795	19,179	289	311	1,508
9	29,186	1,280	19,204	5,458	66,985	774	304	401
10	171,185	23,011	262,326	55,034	138,741	1,238	69,530	14,193
11	159,471	2,957	104,046	69,614	174,904	160,479	112,784	1,201
12	398,456	16,371	503,586	25,462	1,549,790	820	119,558	2,567
13	18,613,130	1,451,500	11,874,943	1,923,771	1,194,683	4,404	5,783	125,892
14	9,203,086	195,192	1,067,671	263,697	23,310	21	13	12,999
15	18,864,922	1,158,326	27,544,512	2,409,967	219,211	10,323	2,085	69,449
16	3,859,946	144,422	12,905,845	137,420	551,457	14,821	32,556	50,017
17	114,420,421	2,520,114	9,303,549	195,675	710,081	991	1,291	7,468
18	2,920,247	2,224,429	2,355,997	4,921	165,420	1,766	3,062	19,044
19	115,645	12,927	50,249,245	20,980	19,487	1,291	203	2,200
20	33,080	11,479	3,141,311	1,787,206	3,346	53	139	183
21	1,753,937	69,450	848,316	94,865	420,501	12,304	126,905	317,745
22	654,584	37,530	166,600	12,718	7,716,550	4,189	279,934	9,188
23	57,854	-	-	-	-	-	381,312	-
24	24,616	3,397	7,129	4,631	147	27	1,735	683,142
25	82,335	2,250	19,865	4,252	510,507	185	1,179	13,747
26	8,730,020	803,005	6,112,766	931,451	258,183	21,960	22,460	35,532
27	-	-	-	-	-	-	-	-
28	2,199,167	200,169	1,355,149	342,176	153,835	6,225	8,618	15,838
29	799,545	58,720	317,586	61,933	116,100	1,101	1,873	21,189
30	2,402,145	181,196	1,442,361	257,890	301,107	22,183	38,578	31,331
31	22,314,611	1,790,513	6,777,209	542,196	2,314,257	23,520	32,805	153,831
32	-	-	-	-	-	-	-	-
33	352,876	63,188	386,673	58,526	147,095	759	5,780	8,983
34	239,544	23,667	136,737	26,332	19,505	674	722	4,773
35	1,544,752	170,774	724,838	173,099	201,872	3,007	14,721	41,726
Labor	22,365,833	2,178,614	20,038,336	2,945,795	4,022,384	942,550	326,375	812,007
Capital	31,596,245	1,248,352	18,244,267	1,326,487	7,170,544	890,947	882,027	1,666,468
Tax	2,652,041	461,132	4,975,758	684,927	1,392,428	706,585	85,461	-132,367
Total	268,917,851	15,234,025	182,090,083	17,595,757	36,836,196	20,895,222	2,963,491	3,996,509

Table A.4 Input-Output Table-continued 4/5

	25	26	27	28	29	30	31	32
1	409,727	-	5,150,619	-	-	-	12,390	193,339
2	415,585	-	18,510	-19	-	-	930	6,935
3	-	2,569	24,827,592	-	-	-	57,377	18,490
4	307,120	548,307	178,378	145,342	44,439	96,609	217,287	256,323
5	2,357,468	1,521,932	360,318	76,479	14,220	15,210	248,832	-16,784
6	79,486	301,059	57,640	87,360	316,947	760,982	1,213,067	405,763
7	-	155	47,793	1,210	-	-	-	283
8	258,575	601,630	54,356	186,112	95,930	226,591	721,416	65,791
9	46,508	267,829	502,344	63,637	8,441	22,216	78,248	111,741
10	2,921,084	1,589,373	134,515	8,861,839	129,935	194,287	612,660	405,223
11	101,928	828,416	1,289,130	1,825,551	56,078	34,110	203,284	34,732
12	357,124	139,737	54,638	9,888,749	23,566	30,288	64,615	413,802
13	5,887,729	873,565	497,635	952,461	57,575	46,356	1,955,414	376,587
14	15,963,189	33,235	163,686	10,215	6,716	2,553	65,706	38,053
15	38,295,615	154,861	259,679	208,418	22,460	85,754	340,547	229,879
16	7,004,708	204,844	111,155	219,976	23,173	24,327	624,691	4,211,586
17	8,841,926	389,718	346,069	382,798	2,535,746	314,447	5,023,660	504,111
18	407,363	55,374	3,153	37,995	73,704	1,982	616,593	206,580
19	254,565	306,829	28,747	5,212,201	89,405	81,979	502,686	2,475,734
20	1,368,818	241,778	622,250	36,795	125,682	99,584	344,609	146,028
21	324,968	2,413,539	954,232	531,347	860,211	831,005	4,000,181	925,826
22	114,577	72,618	885,819	403,297	56,823	90,673	666,339	121,789
23	12,448	37,805	5,169	3,098	372	13,939	3,550	5,076
24	5,507	66,696	278,863	27,484	24,827	103,875	337,630	164,735
25	26,990	162,933	169,061	39,435	151,430	60,391	6,119,095	2,291,663
26	6,175,814	3,310,922	4,381,351	1,144,912	5,825,680	373,529	1,357,254	858,499
27	-	-	-	-	-	-	-	-
28	1,581,019	9,280,374	353,866	19,413,612	523,824	1,617,384	2,325,319	1,555,705
29	513,498	7,349,967	374,148	529,143	8,854,827	3,511,385	6,864,981	978,594
30	2,769,017	4,010,417	1,018,683	3,029,233	1,029,939	30,796,165	13,751,106	2,526,908
31	12,514,309	15,760,606	3,435,311	7,010,668	8,500,303	12,040,907	19,852,622	4,663,123
32	-	-	-	914,140	-	-	-	-
33	1,130,888	809,846	695,395	376,078	214,923	396,123	1,352,876	616,159
34	793,939	644,222	125,940	672,244	1,225,184	435,112	3,465,743	478,097
35	1,645,031	4,898,757	388,130	1,214,625	1,199,118	2,911,064	10,143,387	5,349,023
Labor	45,633,658	32,924,266	14,073,627	22,107,360	9,694,391	26,403,599	62,616,139	43,227,830
Capital	17,757,134	45,839,635	8,251,365	16,806,910	13,118,737	36,599,656	95,144,862	19,536,710
Tax	12,173,031	1,179,735	6,895,214	-825,871	2,599,861	5,846,505	17,933,487	4,156
Total	188,450,346	136,823,549	76,994,381	101,594,834	57,504,467	124,068,587	258,838,583	93,388,089

Table A.5 Input-Output Table-continued 5/5

	33	34	35	Private Demand	Government Demand	Investment	Net Export
1	397,851	29,845	933,459	15,295,838	-	76,061	-9,504,536
2	4,876	183	14,905	15,516	-	-2,286,011	-108,497,705
3	61,025	126,895	2,807,326	48,241,284	-	1,694,776	-11,182,229
4	231,294	371,510	792,905	23,020,185	-	698,621	1,181,799
5	-1,340	1,530,546	1,610,489	564,846	-	-818,603	-2,275,580
6	843,158	1,166,657	520,026	85,870	-	73,558	-212,725
7	9,092	998	572	100,512	-	-1,312,879	-623,303
8	262,409	299,477	13,460	10,364,258	-	-1,200,367	3,292,536
9	182,746	86,880	7,033	1,613,554	-	-785,942	681,873
10	1,234,039	420,716	14,339	2,781,215	-	-545,349	10,709,610
11	542,689	170,481	25,774	2,207,089	-	-978,415	-5,469,572
12	594,518	446,380	25,904	39,212	-	-2,187,753	-3,100,936
13	14,989,871	2,458,726	1,891,751	10,571,820	-	-9,943,333	9,952,716
14	86,723	108,104	334,014	428,277	-	-371,372	-4,684,574
15	161,299	231,301	729,899	814,244	-	-15,935,046	-402,438
16	412,272	304,343	194,889	1,482,939	-	37,737,311	-4,145,169
17	507,537	979,543	651,805	16,268,493	-	21,759,091	76,169,013
18	2,248,502	83,376	146,978	1,808,702	-	7,035,559	-7,113,273
19	471,571	3,738,971	137,271	14,272,945	-	25,760,535	76,460,066
20	965,062	561,259	1,149,018	5,010,010	-	2,703,280	-1,411,933
21	2,755,909	905,582	94,270	7,545,745	-	-	-30,600
22	844,282	597,288	15,985	6,137,366	-	-	-49,840
23	156,366	32,959	6,777	926,057	-	-	-9,410
24	381,463	217,775	8,391	1,364,961	-	-	-27,158
25	456,703	154,982	-	-	-	177,452,860	418,504
26	2,450,326	1,388,308	2,143,313	46,453,159	-	6,438,035	11,739,715
27	-	-	29,891,875	50,450,022	-	-	-3,347,516
28	1,225,185	770,715	128,519	21,536,727	-	580,743	17,634,578
29	1,153,258	1,143,145	748,249	22,730,281	-	-	-922,807
30	4,187,994	1,687,404	69,844	43,999,560	-	-	950,446
31	7,203,265	8,086,515	149,882	78,048,366	3,939,811	33,632,019	-17,586,707
32	-	-	432,438	826,175	91,489,408	-	-355,037
33	3,122,401	372,783	29,456	86,567,679	73,086,867	-	-3,989,966
34	1,115,401	2,989,242	5,226,899	54,407,387	1,808,612	7,687	-1,528,085
35	7,516,057	4,613,667	33	-10,092	-	-	-393,869
Labor	88,399,654	19,269,418	-				
Capital	23,277,215	11,319,359	-				
Tax	236,188	7,019,671	-				
Total	168,686,861	73,685,004	50,947,748				

Appendix B

Z MATRIX

Table B.1 The Classification of 403 Industries into 26 Customer Goods and Services for Construction of Z Matrix

	Consumer Goods and Services (26)	Industries in IO table (403)
A	Food and non-alcohol beverage	3-10, 16, 21-22, 25-28, 43, 45-58, 60-76, 81-83, 153-154, 161, 321-322
B	Alcohol and tobacco	78-80, 84
C	Clothing and shoes	91-95, 99-106, 110-113, 397
D	Housing and Related Service	114-117, 159, 166-167,170, 172, 178-183, 185, 191-192, 195, 209, 211, 214-216, 244, 304, 354, 356, 364, 382-383,
E	Electricity	298-300
F	City Gas	302
G	LPG-Heating	139
H	Kerosene	136
I	Diesel-Heating	137
J	Briquettes	131
K	Multi-housing heating	303
L	Other fuels	138, 141
M	Housing supplies and service	107, 118-119, 127-128, 165, 168, 171, 174-176, 213, 218-219, 224-228, 245-247, 255, 264-267, 288-290, 296-297, 369, 396, 399
N	Public health	155, 268, 270, 377-379
O	Cars and related service	140, 169, 274-275, 279, 286-287, 395
P	Gasoline	134
Q	Diesel-Car	137
R	LPG-Car	139
S	Other fuels-Car	138, 141
T	Mass Transportation	327, 329, 332, 333, 334
U	Logistics	328,330,331, 335-340
V	Communication	259-261, 341-345,
W	Leisure and cultural activities	14, 122-123, 126, 129-130, 160, 162-164, 256-258, 262-263, 271-272, 291-294, 346-347, 366-367, 384-387, 389-392,
X	Education	374-376
Y	Restaurant and lodging	323-326
Z	Other commodities and Services	124-125, 156-157, 273, 295, 348-353, 361, 363, 365, 368, 370-373, 380-381, 394, 398, 400, 403

Table B.2 Z Matrix (35X25) –1/3

	A	B	C	D	E	F	G	H	I
1	0.2371	0.0998	0.0010	0.0095	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0013	-0.0004	0.0000	0.0206	0.2762	0.9840	0.8688	0.8622	0.8738
3	0.1336	0.2403	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0068	0.0110	0.4422	0.0033	0.0019	0.0000	0.0002	0.0006	0.0003
5	0.0239	0.0448	0.0174	0.0153	0.0001	0.0000	0.0003	0.0001	0.0001
6	0.0028	0.0356	0.0038	0.0021	0.0005	0.0000	0.0007	0.0008	0.0007
7	0.0005	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0052	0.0019	0.0059	0.0026	0.0009	0.0000	0.0044	0.0065	0.0011
9	0.0031	0.0001	0.0006	0.0006	0.0029	0.0000	0.0010	0.0040	0.0022
10	0.0183	0.0023	0.0033	0.0088	0.0035	0.0001	0.0051	0.0017	0.0031
11	0.0066	0.0001	0.0017	0.0019	0.0064	0.0087	0.0056	0.0039	0.0035
12	0.0036	0.0047	0.0054	0.0080	0.0597	0.0000	0.0129	0.0090	0.0099
13	0.0716	0.0489	0.1661	0.2063	0.0534	0.0002	0.0151	0.0158	0.0242
14	0.0025	0.0676	0.0008	0.0292	0.0011	0.0000	0.0003	0.0005	0.0002
15	0.0084	0.0756	0.0165	0.3090	0.0098	0.0006	0.0064	0.0077	0.0060
16	0.0039	0.0155	0.0067	0.0221	0.0250	0.0008	0.0084	0.0088	0.0062
17	0.0035	0.0010	0.0015	0.0453	0.0322	0.0001	0.0013	0.0012	0.0015
18	0.0006	0.0003	0.0003	0.0025	0.0075	0.0001	0.0010	0.0011	0.0010
19	0.0042	0.0016	0.0011	0.0050	0.0009	0.0001	0.0007	0.0011	0.0008
20	0.0018	0.0232	0.0192	0.0006	0.0002	0.0000	0.0000	0.0000	0.0000
21	0.0220	0.0037	0.0243	0.0177	0.0191	0.0007	0.0112	0.0119	0.0103
22	0.0012	0.0005	0.0033	0.0034	0.3187	0.0002	0.0000	0.0000	0.0000
23	0.0006	0.0015	0.0001	0.0000	0.0000	0.0000	0.0039	0.0093	0.0096
24	0.0007	0.0006	0.0014	0.0058	0.0000	0.0000	0.0002	0.0002	0.0001
25	0.0014	0.0010	0.0011	0.0336	0.0232	0.0000	0.0003	0.0004	0.0002
26	0.0631	0.0555	0.0627	0.0359	0.0110	0.0012	0.0065	0.0082	0.0035
27	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28	0.0893	0.0669	0.0329	0.0405	0.0064	0.0003	0.0089	0.0092	0.0090
29	0.0542	0.0071	0.0101	0.0048	0.0052	0.0001	0.0025	0.0028	0.0021
30	0.0380	0.0156	0.0351	0.0874	0.0134	0.0012	0.0068	0.0076	0.0050
31	0.1336	0.1242	0.0924	0.0425	0.1049	0.0013	0.0205	0.0180	0.0180
32	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
33	0.0085	0.0124	0.0040	0.0084	0.0064	0.0000	0.0025	0.0018	0.0026
34	0.0055	0.0046	0.0042	0.0026	0.0008	0.0000	0.0014	0.0019	0.0015
35	0.0419	0.0326	0.0349	0.0237	0.0088	0.0002	0.0031	0.0037	0.0035

Table B.3 Z Matrix (35X25) – Continued 2/3

	J	K	L	M	N	O	P	Q	R
1	0.0000	0.0000	0.0000	0.0016	0.0149	0.0088	0.0000	0.0000	0.0000
2	0.7917	0.2422	0.8839	0.0017	0.0001	0.0210	0.8346	0.8738	0.8688
3	0.0000	0.0000	0.0001	0.0003	0.0053	0.0000	0.0000	0.0000	0.0000
4	0.0008	0.0002	0.0001	0.0194	0.0029	0.0091	0.0001	0.0003	0.0002
5	0.0024	0.0000	0.0009	0.0569	0.0098	0.0020	0.0001	0.0001	0.0003
6	0.0000	0.0003	0.0003	0.0022	0.0055	0.0004	0.0004	0.0007	0.0007
7	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0036	0.0002	0.0014	0.0024	0.0022	0.0022	0.0174	0.0011	0.0044
9	0.0000	0.0002	0.0005	0.0006	0.0003	0.0002	0.0007	0.0022	0.0010
10	0.0033	0.0416	0.0009	0.0039	0.0055	0.0024	0.0064	0.0031	0.0051
11	0.0037	0.0676	0.0019	0.0033	0.0018	0.0010	0.0032	0.0035	0.0056
12	0.0006	0.0716	0.0499	0.0065	0.0032	0.0187	0.0713	0.0099	0.0129
13	0.0015	0.0035	0.0165	0.1544	0.3864	0.1218	0.0244	0.0242	0.0151
14	0.0000	0.0000	0.0003	0.0138	0.0084	0.0079	0.0002	0.0002	0.0003
15	0.0021	0.0012	0.0079	0.2389	0.0234	0.1168	0.0029	0.0060	0.0064
16	0.0021	0.0195	0.0027	0.0919	0.0033	0.0362	0.0037	0.0062	0.0084
17	0.0005	0.0008	0.0003	0.1617	0.0347	0.0533	0.0004	0.0015	0.0013
18	0.0001	0.0018	0.0004	0.0083	0.0616	0.0070	0.0005	0.0010	0.0010
19	0.0012	0.0001	0.0003	0.0021	0.0037	0.4309	0.0003	0.0008	0.0007
20	0.0000	0.0001	0.0000	0.0203	0.0021	0.0297	0.0000	0.0000	0.0000
21	0.0080	0.0760	0.0029	0.0091	0.0179	0.0066	0.0019	0.0103	0.0112
22	0.0037	0.1677	0.0000	0.0034	0.0080	0.0014	0.0000	0.0000	0.0000
23	0.0000	0.2284	0.0018	0.0005	0.0004	0.0000	0.0044	0.0096	0.0039
24	0.0007	0.0010	0.0000	0.0003	0.0035	0.0001	0.0001	0.0001	0.0002
25	0.0002	0.0007	0.0000	0.0006	0.0023	0.0002	0.0001	0.0002	0.0003
26	0.0008	0.0135	0.0047	0.0585	0.0558	0.0412	0.0051	0.0035	0.0065
27	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28	0.1283	0.0052	0.0056	0.0215	0.0199	0.0122	0.0048	0.0090	0.0089
29	0.0032	0.0011	0.0007	0.0046	0.0071	0.0024	0.0014	0.0021	0.0025
30	0.0129	0.0231	0.0037	0.0162	0.0506	0.0118	0.0029	0.0050	0.0068
31	0.0167	0.0196	0.0074	0.0723	0.1531	0.0443	0.0094	0.0180	0.0205
32	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
33	0.0002	0.0035	0.0016	0.0044	0.0426	0.0025	0.0010	0.0026	0.0025
34	0.0032	0.0004	0.0004	0.0029	0.0058	0.0011	0.0007	0.0015	0.0014
35	0.0086	0.0088	0.0027	0.0152	0.0579	0.0067	0.0018	0.0035	0.0031

Table B.4 Z Matrix (35X25) – Continued 3/3

	S	T	U	V	W	X	Y	Z
1	0.0000	0.0000	0.0000	0.0000	0.0014	0.0002	0.1078	0.0029
2	0.8839	0.0000	0.0000	0.0000	0.0010	0.0000	0.0004	0.0002
3	0.0001	0.0000	0.0000	0.0000	0.0030	0.0000	0.5197	0.0045
4	0.0001	0.0009	0.0059	0.0012	0.0063	0.0018	0.0037	0.0068
5	0.0009	0.0001	0.0040	0.0019	0.0911	-0.0031	0.0075	0.0255
6	0.0003	0.0005	0.0037	0.0043	0.0324	0.0369	0.0012	0.0147
7	0.0000	0.0000	0.0001	0.0000	0.0004	0.0000	0.0010	0.0001
8	0.0014	0.0013	0.0071	0.0013	0.0051	0.0063	0.0011	0.0052
9	0.0005	0.0010	0.0010	0.0001	0.0005	0.0089	0.0105	0.0018
10	0.0009	0.0575	0.3504	0.0019	0.0075	0.0245	0.0028	0.0078
11	0.0019	0.0389	0.0027	0.0010	0.0016	0.0235	0.0270	0.0022
12	0.0499	0.2088	0.0194	0.0006	0.0050	0.0247	0.0011	0.0049
13	0.0165	0.0078	0.0336	0.0202	0.0715	0.0105	0.0104	0.0343
14	0.0003	0.0001	0.0002	0.0009	0.0041	0.0025	0.0034	0.0050
15	0.0079	0.0036	0.0026	0.0171	0.0151	0.0008	0.0054	0.0079
16	0.0027	0.0031	0.0044	0.0028	0.0051	0.0060	0.0023	0.0342
17	0.0003	0.0044	0.0101	0.4832	0.2360	0.0191	0.0072	0.0137
18	0.0004	0.0007	0.0003	0.0051	0.0140	0.0208	0.0001	0.0047
19	0.0003	0.0709	0.1108	0.0013	0.0028	0.0014	0.0006	0.0220
20	0.0000	0.0005	0.0009	0.0007	0.0101	0.0438	0.0130	0.0046
21	0.0029	0.0054	0.0159	0.0119	0.0187	0.0885	0.0200	0.0188
22	0.0000	0.0087	0.0003	0.0014	0.0067	0.0184	0.0185	0.0044
23	0.0018	0.0000	0.0001	0.0000	0.0023	0.0080	0.0001	0.0005
24	0.0000	0.0002	0.0010	0.0003	0.0012	0.0084	0.0058	0.0035
25	0.0000	0.0004	0.0013	0.0021	0.0018	0.0141	0.0035	0.0188
26	0.0047	0.0153	0.0250	0.1060	0.0456	0.0334	0.0917	0.0221
27	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28	0.0056	0.3722	0.1349	0.0122	0.0219	0.0202	0.0074	0.0391
29	0.0007	0.0040	0.0194	0.0986	0.0453	0.0389	0.0078	0.0737
30	0.0037	0.0437	0.0579	0.0163	0.0246	0.0756	0.0213	0.2641
31	0.0074	0.1139	0.1013	0.1857	0.2118	0.1665	0.0719	0.2053
32	0.0000	0.0189	0.0029	0.0000	0.0000	0.0000	0.0000	0.0032
33	0.0016	0.0031	0.0133	0.0026	0.0061	0.0303	0.0146	0.0114
34	0.0004	0.0057	0.0231	0.0027	0.0491	0.0420	0.0026	0.0288
35	0.0027	0.0085	0.0464	0.0166	0.0511	0.2272	0.0081	0.1034

Appendix C

THE PROPORTION OF THE HOUSEHOLDS IN FUEL POVERTY

Table C.1 The Percentage of Households in Fuel Poverty in Each Decile

	The Number of Each Decile	The Number of Households in Fuel Poverty	The Percentage of the Number of Households in Fuel Poverty	The Percentage of Households in Fuel Poverty in Each Decile
Decile1	1,089	646	54%	59%
Decile2	1,088	294	25%	27%
Decile3	1,088	138	12%	13%
Decile4	1,098	60	5%	5%
Decile5	1,078	28	2%	3%
Decile6	1,088	12	1%	1%
Decile7	1,088	5	0%	0%
Decile8	1,088	6	1%	1%
Decile9	1,088	3	0%	0%
Decile10	1,088	2	0%	0.18%
The Total Number or Percentage of Households in Fuel Poverty	10,881	1194	100%	

Table C.2 The Percentage of Households in Fuel Poverty in Each Age Group

	The Number of Each Decile	The Number of Households in Fuel Poverty	The Percentage of the Number of Households in Fuel Poverty	The Percentage of Households in Fuel Poverty in Each Age Group
under49	6,079	327	27%	5%
50-64	3,078	325	27%	11%
65-74	1,170	328	27%	28%
75+	554	214	18%	39%
The Total Number or Percentage of Households in Fuel Poverty	10,881	1,194	100%	83%

Table C.3 The Percentage of Households in Fuel Poverty in the Urban or Rural Area

	The Number of Each Decile	The Number of Households in Fuel Poverty	The Percentage of the Number of Households in Fuel Poverty	The Percentage of Households in Fuel Poverty in Urban or Rural Area
Urban	8,653	857	72%	10%
Rural	2,228	337	28%	15%
The Total Number or Percentage of Households in Fuel Poverty	10,881	1,194	100%	25%