Optimal Energy Taxation for Sustainable Development in Korea: Focusing on the double dividend hypothesis

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ABSTRACT

One of the most enduring problems which we face in 21^{st} century is the continuous deterioration of natural environment. The concerns about environmental deterioration and natural resource depletion has driven many economic development strategies into the controversial and vulnerable plans in most countries where various development strategies have been implemented. In this milieu, the sustainability condition has become an important issue since environmental conservation has been emphasized in the studies of economic growth with sustainability.

From this point of view, the double dividend hypothesis shows us how environmental protection and economic growth can be reconciled in terms of welfare. The double dividend hypothesis claims that environmental tax can improve simultaneously environmental quality and economic efficiency if the revenue from environmental taxation is used to reduce the efficiency burden of pre-existing distortionary taxation. Energy taxes are generally distortionary and regressive even though it can correct externalities. However, it provides policy remedies for the market failure in energy sector. Double dividend hypothesis suggest us how those energy taxes or subsidies can be used to encourage energy conservation or increase the supply of alternative fuels.

Main purpose of this research is to investigate about how to use energy tax system to reconcile environmental protection and economic growth, and promote sustainable development with the emphasis of double dividend hypothesis in Korea. As preliminary work to attain this target, this study will investigate what are the specific conditions under which double dividend hypothesis can be valid, and set up the basic model for optimal energy taxation in terms of overall welfare. The model will be

used in the simulation process in the latter part of this study.

Therefore, this research will focus finding the specific conditions where the double dividend hypothesis can be possible in Korea and find out which environmental taxes can provide efficiency gains besides environmental improvement in Korean economy. In other words, this study will evaluate the welfare impact of environmentally motivated tax reforms in terms of efficiency. Then it will seek to find the applicability and validity of the double dividend hypothesis to Korean economy.

To explore this issue, in the first part, the current situation about energy taxation scheme will be reviewed. In chapter 2, the analysis will be focused on the energy taxation as environmental taxation in terms of optimal taxation and the alternative nature of environment. This chapter will reveal the how the optimal taxation theory can be connected to the optimal environmental taxation, and show us how different natures of environment can alternate optimal environmental taxation scheme. In chapter 3, the environmentally motivated tax reform will be examined in terms of welfare improvement with the emphasis on double dividend hypothesis. Also, there will be theoretical analyses on how pre-existing inefficiencies in the tax system can induce the realization of the double dividend.

After all these theoretical analyses about optimal energy taxation and the related issues, in chapter 4, there will be detailed descriptions on the model that is used for the further analysis of the optimal energy taxation. This chapter will provide what conditions we need to realize double dividend from the energy taxation and identify those conditions in rigorous fashion. In chapter 5, there will be the incorporating Korean energy-related tax system into the model. To do that I will review necessary parameters in energy-related tax system and describe the possibility of double dividend under the Korean energy tax system. In chapter 6, I will show detailed process of simulation based on the model and Korean energy-related taxation system and describe the three tax recycling options. In chapter 7, I will show the simulation results from three tax recycling processes and evaluate the simulation results in terms of double dividend hypothesis.

The simulation process reveals us that the tax rate reduction induce some efficiency gains and the transfer payment increase results in more distortion to the economy. In terms of double dividend hypothesis, the strengthened environmental taxation with other distortionary tax rate reduction can make double dividend to be realized in Korea even though the magnitude of the second dividend is dependent on the tax recycling method. However, since the transfer payment increase could not induce efficiency gain, the double dividend of this case cannot be realized in Korea.

After this process is confirmed as relevant for the test of the applicability of double dividend hypothesis to Korean economy, we need to extend this analytical testing method of double dividend hypothesis to more complicate economic system. In previous analysis, we considered the interdependence between non-energy goods sector and energy goods sector only in terms of equilibrium condition in each factor market such as labor, clean intermediate, and polluting intermediate market. However, in real world the interdepences between each sector are more complicated. Also when we divide both energy goods sector and non-energy goods sector into more sub-sector, the economic impact of interdepences between sectors becomes more significant.

Besides the more complicated interdependence, another significant extension of this study will be the investigation of welfare impacts of other tax recycling method such as the increased subsidies to energy-saving technology R&D and the heavy taxation on energy-intensive industry. When those extensions are implemented and find some concrete results about the applicability of the double dividend hypothesis, the conclusion about the validity of double dividend hypothesis to Korean economy becomes more meaningful and significant in determining what is the appropriate direction for the next Korean energy price reform which is scheduled to be started in 2006.

국문요약

21세기에 각국이 처한 가장 시급한 문제중의 하나가 자연환경의 훼손 문제이다. 이러한 환경오염과 자원의 고갈문제가 각국의 경제개발전략에 심각한 방향전환을 요구하고있다. 이러한 상황에서 지속가능한 발전의 문제가 각국의 경제발전 전략의 주요 관심사가 되고 있다.

이러한 관점에서 이중배당이론은 환경보호와 경제성장의 동시적 추구가 어떻게 가능한가에 대한 주요한 시사점을 제시하고있다. 이중배당이론에 따르면 환경세수입이 기존 조세체계의 비효율성 완화의 목적으로 적절히 민간부문에 환급될 경우 환경개선과 경제의 효율성향상이라는 두 가지 효과를 동시에 달성할 수 있는데 환경보호와 경제성장의 동시달성의 가능성을 환경세수입의 운용방식을 통해 제시한 이론이다.

환경보호와 경제성장의 동시실현 전략의 필요성에 의해 시작된 본 과제의 목표는 환경과 효율성 측면에서 가장 바람직한 에너지세제가 무엇인가 하는 것을 이중배당이론을 중심으로 밝히고자 하는 것이다. 이를 위해 본 과제는 이중배당이 가능한 경제적 상황 및 여건을 파악하고 적정에너지조세의 경제적 효과분석을 위한 기본모형을 수립하고, 이를 바탕으로 모의실험을 통해 우리나라에서 이중배당현상을 실현시킬 수 있는 조세환급 방법을 찾아내고자 함을 그 구체적 목적으로 두고 있다.

이를 위해 본 과제는 제2장에서는 에너지조세이론의 개관을 살펴보고, 제3장에서는 환경보호를 위한 세제개혁과 이중배당이론과의 관계를 살펴본 후, 이러한 분석을 바탕으로 제4장에서는 본 과제 수행의 바탕이 될 모형을 수립하고 있다. 이러한 모형을 바탕으로 제5장에서는 우리나라의 구체적 에너지세제를

수립된 모형에 적용한 후 제 6장에서는 각종 에너지세 환급방법의 경제적효과를 모의실험을 통해 밝히고 있으며, 제7장에서는 그러한 모의실험의 결과를 분석하고 있다. 이러한 분석의 결과 우리나라에서는 법인세의 인하를 통한 에너지세의 환급이 미약하나마 이중배당의 가능성을 보여주고있다. 또한 근로소득세 인하를 통한 환급도 모델가정상의 문제에도 불구하고 약간의 이중배당가능성을 보여주고 있다.

마지막 결론부문에서는 본 연구에서 수립된 일반균형 모형의 단순성의 극복방법과 다양한 방법의 에너지세 환급 방법을 통해 보다 폭 넓은 이중배당 달성가능성에 대한 분석을 향후 과제로 제시하고 있다.

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Chapter 1
Introduction

Among many research areas in environmental economics, the market-based instruments of environmental control to improve social welfare received more attentions because the traditional environmental control has shown many intrinsic limits. One of the market-based instruments is taxation on environment polluting source. However, the introducing of new taxes has always been harmful in terms of economics as well as politics even though there is introduced another kind of compensating instrument. Since the public economics has received much attentions from policy makers, many public economists have made an efforts to introduce a market-based fiscal instrument with implementing policy target and the harmless indirect impacts. The double dividend hypothesis is derived from one of the recently introducing harmless fiscal instruments. Even though the double dividend hypothesis is based on the introduction of new tax, the attractiveness of environmental protection without dampening economic growth has driven many economists to find the relevant way to realize the double dividend.

The main reason for this new academic trend is that one of the most enduring problems which we face in 21st century is the continuous deterioration of natural environment. The concerns about environmental deterioration and natural resource depletion has driven many economic development strategy into the controversial and vulnerable plans in most countries where various development strategies have been implemented. In this milieu, the sustainability condition has become an important issue since environmental conservation has been emphasized in the studies of economic growth with sustainability. Since the main goal of environmental conservation has been on how each economic growth can be sustained without serious setback, sustainability of resources becomes a main concern in this economic development period.

Environmental protection has been an interesting, but hard-to-grasp issue to most economists. Since the environmental issues have been considered as the problems of market failure due to missing markets, it is believed that government interventions are necessary to solve the issues. They include government's specific activities like various taxation. Among many environmental issues, air pollution has been main target from the starting point when people becomes more concerned about environment since greenhouse gases and ozone-depleting chemicals have been incessantly accumulated in the atmosphere through traditional manufacturing sectors since Industrial Revolution. Among the input factors, energy consumption is most closely related to these types of air pollution. Since Industrial Revolution period, the energy consumption has been considered as the major input of production process because manufacturing sector demands more amount of energy than agricultural sector needs . While at the first stage in Industrial Revolution coal consumption had the role of main energy source, oil consumption has been main contributor to the industrial development in the last century. However, the more developed the industry structure becomes, the more harmful impact to environment energy consumption produces.

In the initial economic growth stage, the low energy price policy promoted energy consumption since the abundant and secure energy supply is the primary factor to economic development. However, because the rapid economic growth can accelerate the harmful impact of energy consumption, the control of energy consumption is desperately necessary through appropriate mechanisms for the sustainable economic development. Since energy consumption is intrinsically contributing to pollution as well as production, it is believed that energy consumers must pay social cost, which includes both market price and pollution cost of energy consumption for the environment protection. However, the energy pricing system based on its own cost and externality cost will produce the wide and languid impact on industrial production. Because energy is main production factor in every industry sector, the cost increase due to pollution cost payment tends to result in lower production and lower employment. This trade-off between environmental protection and economic growth makes every government hesitate to implement relevant energy pricing system which reflects pertinent social cost including externality cost.

From this conflicting role of government, the double dividend hypothesis shows us how environmental protection and economic growth can be reconciled in terms of welfare. The double dividend hypothesis claims that environmental tax can improve simultaneously environmental quality and economic efficiency if the revenue from environmental taxation is used to reduce the efficiency burden of pre-existing distortionary taxation. Energy taxes are generally distortionary and regressive even though it can correct externalities. However, it provides policy remedies for the market failure in energy sector. Double dividend hypothesis suggest us how those energy taxes or subsidies can be used to encourage energy conservation or increase the supply of alternative fuels.

In each country, the energy policies has induced the broad economic impacts on allocation efficiency, income distribution, and overall energy demand. Because of these broad effects of energy policies, there are many constraints in the real world, limiting each energy policy explicitly or implicitly. Each constraint has the specific pre-conditions which are necessary to be satisfied for the successful implementation of each government energy policy. To overwhelm those constraints we need more compelling reason for environmental protection. Traditionally there has been much discussion over what is the best policy measure for controlling environmental pollution. This discussion has mainly focused on two alternative policies such as regulation and market incentives. Even though traditionally the actual dominant measures for environmental protection have been the environmental regulatory standards, economists have insisted the superiority of the pollution taxes over the regulation because the tax system induces the polluter to internalize all external pollution cost and provides several tax incentives for polluter to develop cheaper forms of pollutant abatement technology. The double dividend hypothesis seems to suggest a third reason for the advantages of pollution taxes over regulatory standard on efficiency ground.

Main purpose of this research is to investigate about how to use energy tax system to reconcile environmental protection and economic growth, and promote sustainable development with the emphasis of double dividend hypothesis in Korea. As preliminary work to attain this target, this study will investigate what are the specific conditions under which double dividend hypothesis can be valid, and set up the basic model for optimal energy taxation in terms of overall welfare. The model will be used in the simulation process in the latter part of this study.

Therefore, this research will focus finding the specific conditions where the double dividend hypothesis can be possible in Korea and find out which environmental taxes can provide efficiency gains besides environmental improvement in Korean economy. In other words, this study will evaluate the welfare impact of environmentally motivated tax reforms in terms of efficiency. Then it will seek to find the applicability and validity of the double dividend hypothesis to Korean economy.

To explore this issue, in the first part, the current situation about energy taxation scheme will be reviewed. In chapter 2, the analysis will be focused on the energy taxation as environmental taxation in terms of optimal taxation and the alternative nature of environment. This chapter will reveal the how the optimal taxation theory can be connected to the optimal environmental taxation, and show us how different natures of environment can alternate optimal environmental taxation scheme. In chapter 3, the environmentally motivated tax reform will be examined in terms of welfare improvement with the emphasis on double dividend hypothesis. Also, there will be theoretical analyses on how pre-existing inefficiencies in the tax system can induce the realization of the double dividend.

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Chapter 2
Energy Taxation as Environmental Taxation

1. Traditional Optimal Environmental Taxation

The conflicting interests among many interest-groups in each society have made the environmental deterioration to be one of major challenges which each government must face in implementing current multi-folded public policies. Since energy-intensive industries are so concerned about the environmental protection that even a little more burdensome intervention of government for environmental protection is likely to induces serious capital flight for avoiding the lower rate of return as well as heavy income losses due to lower output and higher prices in the overall economy.

In contrast, environmental groups tend to insist that a more ambitious environmental policy, which requires higher standards of air and water qualities and is believed to increase overall production cost, may not need the large economic cost that economists have calculated in the past because of recent advances in environmental protection technology, but induce higher environmental quality which provides various economic benefits in terms of output and income level if some economic conditions are met. Facing with these contradicting arguments and evidences, we need to investigate what is real cost of environmental protection in economic opportunity cost. The economic opportunity cost can be estimated through the investigation about the interactions between the environmental externalities and the optimal environment-related taxes. This investigation tends to ask us to find the optimal relationship between environmental quality improvement and public spending because the comparison between the cost of public expenditure and the benefit of environmental quality improvement makes it possible to reveal the real cost of environmental protection.

Natural environment has many aspects of public goods since environmental resources like air and water are shared among people with non-rivalry and non-exclusiveness and the property rights for environment are often difficult to define. In general, the lack of private ownership of some commodities implies the absence of markets in which such commodities are produced and consumed. This absence of market of a specific commodity tends to induce inefficient production and consumption of the commodity. The decentralized market economy is inclined to provide imbalance between the demands for ordinary goods and environmental goods if there is no government intervention.

When a market failure is caused by the lack of appropriate ownership of natural resources, government intervention is necessary to induce efficient use of the resources. The government policy converting the inefficient use of environmental goods into the efficient use can be described as the public action for the improving existing distortionary market functions. As the response to the problem of the absence of appropriate connecting agents market between demand and supply, government environmental policies can provide the missing market for environmental goods because most environmental problems are caused by missing ownerships. Up to date most government have tended to follow a command-and-control approach that sets the lofty environmental targets and requires needlessly expensive responses for attaining the targets.

Therefore many economists have insisted that the command-and-control approach for environmental protection become more expensive instrument because the implementation of command-and-control induce many inefficient use of resources. Even the recognized environmental gains can be considered as attained at a needlessly high price. Particularly the disregard of pollution abatement cost between individual companies tends to make environmental protection policy implementation to be more expensive. In particular, since environmental laws have many specification in the particular technological standards for only achieving pre-targeted goals, they didn't consider the differences from the cost discrepancies due to different local environmental conditions and marginal cost of pollution abatements among individual companies.

As an alternative environmental protection instrument, more attention have been paid to environmental taxes because market-oriented environmental policy based on externalities-correcting taxes could induce the improvement of environmental quality at much less cost than the command-and-control approach because tax-incentive system are more flexible in reducing pollution abatement cost. Many economists have argued that pollution taxes are the efficient instrument for achieving environmental objectives since environmental quality improvement can be achieved through alternative lower method by tax-incentive. Theoretically pollution levies are used to improve economic efficiency by charging a polluter for the true opportunity cost of the polluted resources because polluting input prices of polluter are priced too low since polluter consider only his/her own polluting input cost without counting his/her production activities' additional cost to the society. Pigou's classic theory on externalities showed us that the pollution tax employed to correct environmental problems could induce the efficient level of output through raising private marginal cost up to social marginal cost.

However, the implementation of the Pigovian taxation scheme have revealed many problems such as measurement difficulty and insufficient information about pollution. Since the estimating of marginal damage in each pollution level is difficult, the locating and specifying of correct tax rate to reflect appropriate social cost of pollution is hard to find. Also because the tax approach basically assumes the pre-existing knowledge about who is polluting and how much the polluter does, the incompleteness of these knowledge make the optimal taxation to the externality to be difficult to implement.

2. Optimal Environmental Taxation with Pre-Existing Distorting Taxes

Because in actual policy settings the pre-existing tax distortions may induce more inefficiency with introduction of another tax and the incomplete information about the costs and benefits of the this tax policy, the identifying of appropriate instrument for environmental protection becomes very difficult to find. Under these circumstances, the pollution taxation following Pigovian rule becomes no longer the optimal instrument because the influences of the presence of other distortionary taxes are not counted. This omission of other taxes impacts induces very serious efficiency loss because net efficiency effect of the introducing new environmental tax depends on the level of other pre-existing distortionary taxes such as labor income tax and commodity taxes. Therefore, many economists have investigated the importance of evaluating environmental policy in general equilibrium model which can identify the secondary effects of the policy in other related distorted markets.

The interaction between the carbon tax and pre-existing taxes plays an important role in Goulder(1995b)'s evaluation of the net effects of pollution taxes in a dynamic general equilibrium framework. In this framework, welfare impacts of carbon tax is deeply dependent on the initial conditions of pre-existing tax structure. It is shown to us that the higher marginal rates of pre-existing taxes, the positive effect of carbon tax on welfare becomes more weakened. Therefore the model disregarding the pre-existing taxes tends to underestimate negative welfare costs of environmental tax initiatives.

The relationship between emission and production, which has a significant effect on pollution tax base, can alter the implications of optimal pollution tax structure when emissions has impact on production side. Cremer and Gahvari (2001) claimed that the externality-correcting Pigovian tax rule must be modified through equating marginal emission tax with marginal social damage plus an adjustment term reflecting the impact of marginal emissions on incentive inducing comparability constraints.

The inverse relationship between the optimal environmental tax rate and the marginal cost of public fund (MCPF) is explained under the framework of the pre-existing distortionary taxes in Bovenberg and Goulder (2001). Since both raising revenues efficiently and correcting environmental externalities effectively at the same time is the main targets which the environmental tax system intends to accomplish, environmental taxes directly affect both objectives. If raising public revenues becomes more costly, the balance between the raising-revenue and environmental-quality objectives is accomplished well at a lower rate for the environmental tax because raising-revenue marginal cost makes it necessary to make tax base broader and lower environmental tax rate. Therefore, the higher social cost of raising revenue need to be matched with the higher marginal social benefits from pollution abatement. Thus high estimates for the efficiency costs of existing taxes imply lower values for the optimal environmental tax rate.

Recent works analyzing optimal commodity taxation including goods with externality emphasized two important effects of environmental taxation. First environmental taxes play a role of implicit taxes on input factors of production because environmental taxation raises the production costs and output prices, thereby lowers real factor returns. Second, these implicit taxes tend to complicate the distortions caused by pre-existing explicit factor taxes. These two results have provided profound implications for the net costs of revenue-neutral environmental taxation and the optimal environmental tax rate. With these impacts into consideration, Goulder, Parry, Williams III, and Butraw (1998) compared the costs and overall efficiency impacts of emission taxes, emission quota, fuel taxes, performance standards, mandated technologies and found that while the impacts of pre-existing taxes is particularly large for non-auctioned emission quotas, the lowest impact is for emissions tax policy. For a given amount of environmental improvement, while the quota policy induces only interaction effect with pre-existing distortionary taxes without income effect because the quota policy does not raise tax revenue, environmental tax policy causes not only interaction effect but also income effect. This asymmetry in welfare effect makes the environmental tax to be potentially more welfare-improving than the environmental quota policy. Also Goulder, Parry, and Butrow (1996) showed us that the presence of distortionary taxes raises the welfare cost of both environmental instruments and imposes more welfare burden on non-revenue-raising instrument like environmental quota. In particular, as the amount of pollution abatement increased, the relative disadvantages of environmental quota in terms of welfare becomes larger. Using a numerical general equilibrium model in a second-best setting with pre-existing tax distortions in the labor market, Parry and Williams III (1999) examined a carbon emission tax, a BTU tax, a gasoline tax, a broad-based and narrow-based emissions quota, a quota requiring an equal proportionate emissions reduction, and both broad-based and narrow-based performance standards. Pre-existing distortionary taxes raise the welfare cost of all the abatement policies. Among them the welfare potential of the quota policies are dramatically reduced by pre-existing taxes. The potential welfare gain is greatest under the revenue-neutral carbon tax. Even in that case, the welfare potential is still significantly lower by around 30 percent.

With the health effect of pollution taxes, Williams III (2000) examined the implications of health effect on the level of optimal pollution tax. When leisure and environmental quality are assumed substitutes in utility function, it can be said that health damage from pollution may affect labor supply through two channel such as increasing spending medical care and causing individuals to spend time for sickness, thus reducing the labor supply. This assumption implies that the enhancing environment quality by pollution tax has additional positive effect on production, inducing the efficiency improvement in the overall economy. Even in this case, it can be shown that the optimal pollution tax rate doesn't exceed marginal damages from pollution as previous studies which assumed separability between leisure and environmental quality..

3. Impact of Environment on Consumer and Producer

3.1 Role of environmental quality variable in utility function

Since environmental quality has a broad impact on goods consumption and labor supply, it can be assumed that environmental quality is separable in utility function from consumption and leisure. If the environment is a complement to leisure, then improvements in environmental quality come at higher cost because the environmental taxes lead to a greater reduction in labor tax base due to the increase of leisure consumption.

In this case, the environmental benefits negatively affects labor supply and thereby magnify the adverse employment effects associated with pollution taxes. Therefore the social value of environmental protection is reduced because of output reduction, then the optimal environmental tax need to be fallen.

Also we need to account for environmental quality's feedback effect on energy consumption demand. After environmental taxation, the reduction of energy consumption is expected since the reduction of energy demand is induced for environmental improvement. However, in reverse way, if the improvement in environmental quality raises the demand for energy consumption, the net benefit from improved environmental quality can be reduced. Traffic congestion case provides a good example. Even though the higher gasoline tax rate tends to reduce traffic congestion through raising the cost of the individual car driving, the overall impact of gasoline tax on congestion can be mitigated by the feedback effect of reduced congestion because less traffic congestion is likely to encourage more traffic. Therefore, even though environmental taxation is expected to induce the improvement of environmental quality, the improvement can worsen the environment through feedback impact of different channel.

3.2 Role of environmental quality in production function

In the preceding sections, the environment quality has been treated as a public consumption good because we can attain more utility from environmental quality improvement such as cleaner air and less contaminated water. However, environmental quality also can be considered as a public input into production. For example, since certain types of agricultural production benefit from a cooler climate, the better control of global warming problem can avoid some losses of agricultural productivity. Also reduced air pollution provides improvement in public health and thereby boost labor productivity.

Bovenberg and Van der Ploeg(1994b) made an extension about environmental quality into production. They found the optimal energy taxation formula with additional term representing the adverse effect of pollution on productivity. The additional term does not involve the marginal cost of public funds, which may have important implication on the tax rate on energy consumption.

3.3 Role of uncertain environmental quality

For certain types of pollution, environmental quality can be viewed as directly connected to the pollution flow. Noise pollution provides a pertinent example. But in most circumstances, environmental quality is more closely connected to the stock of pollution, in such cases the relationship between pollution emissions and environmental quality is inherently dynamic. These dynamic connections imply a more complex formulation of the optimal environmental tax rate. One of pertinent examples is the climate-related economic damage associated with atmospheric accumulation of carbon dioxide. The problem is how to obtain the optimal taxes on carbon dioxide to maximize net environmental gains after subtracting abatement costs induced by the tax.

The earlier analytical study of this problem is implemented by Nordhaus(1982). He asked how fast the global economy should allow a buildup of atmospheric carbon dioxide from combustion of fossil fuels if we intend to sustain the economic development with reasonable balancing of cost and benefit from a significant modification of the global climate. The carbon dioxide problem presents a classical problem in intertemporal choice. The carbon dioxide emissions released from the combustion are distributed through a process of diffusion over the oceans and biosphere. Since the rate of diffusion is so slow that a large proportion of carbon dioxide from industrial production remains in the atmosphere for centuries, the solutions for carbon dioxide buildup problem request us the intertemporal optimization process examining the implication for the consumption and real income of different generations.

Therefore carbon dioxide problem becomes an externality problem across space and time, thus its abatement cost calculation is different from conventional pollutants. First, it must be emphasized that there are enormous uncertainties about the ultimate impact of accumulated carbon dioxide. It is believed that the global climate will become warmer from the elevation of carbon dioxide level, and that this warming will be greatest near the poles. Most climatologists expect major changes in important climate factors, in particular rainfall, wind patterns, and the change in the level of oceans. However, the specific impacts in particular regions are not known because the many geographical complicating factors make mutual effects in each regional climate. These uncertainties make it difficult for environmental policy to attain the goals.

Second, the economic impacts of carbon dioxide accumulation are much less known. Even though major impacts would be on agriculture and coastline-industries, the overall effect on the economy has been ambiguous because previous studies about employment effect, labor productivity impact through health effect, and capital plight inducing effect from the improved environmental quality have not been obvious in providing the convincing evidences.

Recently the information problems such as real environmental protection cost becomes so burdensome that many government results in several government failure cases in the implementing of environmental protection policies. Specifically, as a fundamental problem in enforcement of environmental protection, government agencies lack perfect information as to the extent to which particular firms follow the specific pollution-abatement rules. Due to the absence of perfect information, each firm would violate the pollution standards intentionally or under-report emissions in submitting emission tax payments. To prevent these violations, the government imposes fines on firms that are detected to violate pollution regulations. The expected penalty is an increasing function of the level of violation. The uncertainty related to monitoring leads to the circumstance in which emission tax is more advantageous over emission quotas because emission tax generates the efficient level of actual pollution, while emission quota cannot induce an efficient pollution level in a simple way.

4. Energy Taxation

Currently there are many attractive characters attached to energy taxation. To many policy makers, certain type of energy taxes seem more acceptable to the public opinion than labor income taxes. Environmental consideration is another relevant reason for the voters to accept the new taxes. Many economists have argued that both consumption and production of energy have contributed disproportionately to the generation of various pollution forms than other economic activities Therefore taxing energy is a sensible and righteous way to discourage environmentally damaging activities.

Enhancing economic efficiency becomes another attractive reason for the advancing of energy taxation. Some economists consider that energy taxes are relatively cost-efficient instruments for obtaining government revenue in comparison with other taxes. The main reason for the efficiency is that energy supply and demand are relatively inelastic in comparison with other commodities. When energy is supplied more inelastically than other commodities, then a given taxation can potentially lead to a smaller efficiency cost. Under these circumstances a tax on energy can potentially improve efficiency in commodity taxation. Since energy is main input in producers’ sector as well as one of necessary goods in consumers’ sector, the demand for energy is considered to have a relatively lower price elasticity.

The optimal tax system requires that the compensated demand for each good be reduced by the same proportion because same proportional change can induce minimal total excess burden. In other words, to minimize total excess burden, tax rates should be set so that the percentage reduction in the quantity demanded of each commodity must be the same.

This result is called the Ramsey rule. But what is the reason why optimal taxation should induce equiproportional changes in quantities demanded rather than equiproportional changes in prices? Because excess burden comes form the distortions in quantities, all these changes should be the same proportional to minimize total excess burden. The intuition behind the inverse elasticity rule is that because the potential for distortion is greater in the commodity with more elastic demand, efficient taxation requires the relatively high rates of taxation on relatively inelastic goods.

5. Economic Distortions By Energy Taxes

Energy taxes have different effects on economic choices. For the energy taxes, there are direct impact on input choice and consumer good choice. While genera fuel tax influences intertemporal choice and labor-leisure choice in factor markets, gasoline tax generates distortions only at labor-leisure choice. Even though energy taxes are not imposed directly on labor, they still distort labor-leisure choice like implicit taxes on labor. To the extent that general fuel tax raises the cost of producing consumer goods, it raises the overall cost of commodities and thereby lowers the real after-tax wage. It therefore creates a labor market distortion by widening the gap between the marginal social value of labor like real wage before taxes and the private return to labor like real wage after taxes. In similar fashion the gasoline tax raises the overall cost of the consumer’s basket of commodities by raising the price of one commodity, gasoline. Thus it also serves to reduce the after-tax real wage.

Moreover, energy taxes can directly distort the intertemporal choice as well. Even though energy taxes may not appear to be taxes on the return to capital, they play a function as capital taxes and affect the intertemporal choice to the extent that they raise the costs of producing capital goods. Energy is an important input into the production of capital goods, and thus the general fuel tax, which is a tax imposed on the use of energy, will raise input costs. Other things being equal, this tax will reduce the rate of return to investment, because purchasing prices of capital goods will rise for the increase of producing costs. However, gasoline tax does not directly affect the cost of producing capital goods or directly alter the returns from investments in such goods. Hence it dose not introduce any distortion on the intertemporal choice. In this respect, a gasoline tax shares the attraction associated with a more general consumption tax of avoiding intertemporal distortions. These features indicate that energy taxes may have very different economic efficiency impacts depending on whether they are imposed at the production stage or at the level of household consumption.

Comparing with income taxes, energy taxes have narrower tax base. The narrowness of the energy tax base actually works toward greater gross distortions in factor markets from energy taxes in comparison with income taxes. In addition, the narrower the base of an energy tax, the larger the distortion introduced by the tax in the market for intermediate goods or consumer goods. Because a basic principle of public finance is that broader-based taxes tend to be more efficient than narrow-based ones, a narrow-based tax has a higher tax rate than a broad-based tax to attain a given revenue target.

6. Environmental Impacts of Energy Taxes

More environmental concerns might seem to provide more favor in the restructuring of the energy taxation system. Since energy consumption is considered to be generally more damaging to the environment than other activities, then an energy tax may be superior to other taxes because it targets the source of the damage. Energy tax can induce the household of firm to find the less expensive way to reduce energy consumption by installing new equipment, switching fuels, using labor-intensive methods, or just reducing production of the polluting good. In theory energy tax has two intended incentive effects. First, it raises production costs and makes the good more expensive, so the output effect reduces production and therefore the consumption of the good. This output effect induces less energy consumption. Second, it makes the energy more expensive than other inputs, so the substitution effect reduces the amount of energy per unit of output.

However, environmental regulations complicate the connection between energy taxes and changes in energy use. To the extent that pre-existing regulations constrain emissions of certain pollutants, higher energy taxes need not always lead to further reductions in these pollutants below the levels mandated by regulations. For example, in the United States sulfur dioxide emissions, which come from coal-fired electric power plants, are regulated through provisions of 1990 Clean Air Act Amendments. Since an energy tax for electricity reduces demands for electricity, the output of power plants is falling. This reduction of electricity output induces the compliance with the limits on the total amount of sulfur dioxide emission even though the sulfur dioxide per unit of output is still high. Therefore the environmental target of energy tax on sulfur dioxide emission cannot be implemented because pre-existing environmental regulation.

Another potential benefit from energy taxes is an increased national security associated with reduced reliance on oil imports. Since energy tax induces energy input to be more expensive than other inputs, energy taxation is expected to reduce the demand for energy. This reduction of demand for energy will result in reduction in energy import. Among the energy importation, oil import is the most significant component. The argument for national security benefits turns on the idea that reduced importation of oil implies smaller economic costs in the event of supply disruption. However, this benefit is extremely difficult to quantify, in part because of the difficulty of calculation the probability and magnitude of oil supply disruptions.

In general, the complete connection between the use of energy associated with pollution and the ultimate damages to the environment involves three-stage steps. Primary connection is the impact of the use of energy to emissions of given pollutants. Second level connection is the effect of emissions of pollutants to concentrations. The final connection is the translation of concentrations into environmental damages. These connections suggest that it may be more effective to impose taxes on emissions of specific pollutants rather than on given inputs or products associated with pollution like energy consumption, since emissions are more closely linked to the ultimate environmental damages.

However, it can be more costly to monitor emissions than the use of energy. The monitoring of emissions needs all kinds of checking devices because even same amount of energy use results in different level of emission, which depends on the production process and consumption pattern. Since all the implementation of monitoring on every stage of production process and consumption pattern requires huge cost, the actual monitoring process becomes a simplified and uniformly constructed system. Comparing the emission monitoring, the energy use monitoring is relatively simple to implement. Since the energy use can be measured as a specific proportion of the supplied amount to the firm, environmental regulation through energy use monitoring can be implemented more easily than emission monitoring.

The second connection is a stage in which emissions are transformed into concentration. If the concentration-damage relationship is nonlinear, the finding of the specific functional form about how concentration influences environmental damages becomes very difficult. In addition, the second connection between emissions and concentrations can depend on geographical conditions and climatic factors. All of these indicates a lot of complexity and heterogeneity in the relationship between emissions of given pollutants and the marginal environmental damages. Therefore, any estimate of average damages per ton of pollutant therefore will implicitly represent a lot of spatial and temporal variation.

Chapter 3
Double Dividend From
Environmentally Motivated Tax Reform

Because the production cost increase due to the environmental taxation makes each government to be reluctant to strengthen the environmental taxation system, environmental tax reforms have recently received increasing attention. One reason for this attention seems to be more concern about environmental quality from the more diversified and intensive environmental protection groups. Another reason is a growing recognition of the benefits for substituting environmental taxes for other distortionary taxes because environmental taxes are more acceptable and enormous revenue potential sources for rapid growing government expenditure.

1. Double Dividend Hypothesis

The reconciliation between environmental protection and economic growth have currently received more attention that ever since the sustainable development has become the more politically critical issue among the developed countries. One of the answers to this attention is the possibility of double dividend from the strengthened environmental taxation. The double dividend hypothesis, which explains two-way benefits of environmental taxation, suggests that increased taxes on polluting activities can provide two kinds of benefits. The first dividend is an improvement in the environment, and the second dividend is an improvement in economic efficiency from the use of the environmental tax revenues to reduce other taxes such as income taxes that distort labor supply and saving decisions. These income tax distortions reduce the efficiency of the market economy because an additional dollar of revenue from the income tax impose a burden more than a dollar on the private sector. The difference between an additional income tax revenue and a resulting burden on private sector is defined as excess burden of income taxation. Therefore the second dividend amounts to be a reduction in excess burden.

In this way, environmental taxes may yield not only a cleaner environment and but also less distortionary tax system. Since environmental taxes lessens excess burden rather than increasing it, the substitution of environmental tax revenue for other distortionary tax revenue results in a net efficiency gain. Terkla(1984) reported that annual efficiency gain of revenue raised by pollution taxes is estimated to range from $0.63 to $3.05 billion expressed in 1982dollars if pollution tax is substituted for federal income tax revenue. If it is substituted for corporate income tax revenue, the efficiency gain becomes more like the range from $1 to $4.87 billion. However, recently there has been a lot of debate among academic economists and policy makers about the interactions between environmental policies and the tax system. These debates have come from the responses to the double dividend hypothesis which is the claim that environmental taxes could simultaneously improve the environment and reduce marginal excess burden of current tax system. The debates on the interaction has contributed to the current skepticism about the applicability of double dividend hypothesis.

In addition to the less dead weight loss due to reduced tax distortion in the domestic economy, the encouraged international cooperation for global environmental protection can be considered as another attractiveness of double dividend hypothesis. When Pearce(1991) explained the role of carbon taxes in reducing the damages from the global warming, he emphasized the importance of double dividend claim in the international cooperation context. Given the pervasive use of fossil fuels and their critical role in economic development process, the international cooperation for the mitigating of global warming is hardly expected. However, if double dividend claim can be relevantly justified, the introduction of carbon taxes in each country can be proceeded with less political resistances due to concerns about new taxes. Even though many countries try to look for another politically easily acceptable measure for environmental protection like energy saving campaigns, the effect of the new protection measure seems to be ambiguous because the past evidence suggests strongly the ineffectiveness of those new measure. For these advantages, Pearce strongly insisted that double dividend hypothesis must be a important factor in the decision process for the best environmental policy against global warming.

2. Cost-Benefit Analysis of Revenue-Neutral Environmental Tax Reforms

Classification of the welfare impacts of the revenue-neutral environmental tax reform would identify two impacts associated with labor supply and energy demand . The efficiency-related impact is derived from the distortionary effect in the labor market due to the pre-existing labor income tax. Another environmental impact can be associated with the change in the demand for the indirect energy consumption and the energy input in the industrial sector. This welfare impact from a marginal increase in the demand for indirect energy goods is equivalent to the difference between the environmental tax rate, which measures the social benefits of additional tax revenue due to a broader revenue base, and the marginal social damage from pollution. Also the welfare impact from a marginal increase of energy input comes from the difference between energy tax rate, which represents the social benefit from a broadened tax base, and the marginal social damage from energy input use.

The welfare effects of changes in environmental quality and the impact on the tax base are classified as two main impacts of environmental taxation. The welfare effect from environmental improvement is the first dividend. The tax base effect as the second welfare effect represents the consequences of a different tax mix for the efficiency of the tax system as an instrument to raise revenue, i.e. the tax-induced changes in the allocation of resources. The tax base effect is calculated through the summation of each product of the induced tax base change and the corresponding tax rate. This effect can be expressed as the change in real private after-tax income hold by households. The substitution environment taxes for pre-existing taxes causes the reduction of tax bases because environment taxes are the implicit labor income taxes. The reduction of tax base results in gross cost of environmental taxation. If this gross cost is negative, the environmental reform offers a second dividend in the form of a less costly tax system on non-environmental grounds. Whether the tax base effect is positive or negative is dependent on the tax-recycling methods and the complementary or substitutionary relationships between utility variables in utility function and factors in production function.

3. Environmental Tax Reform and Employment

During the 1990s the unemployment rate in United States has been drastically reduced from the booming economy and the structural change in American labor market. Compared with United States with this favorable economic trend, European governments are increasing concerned about unfavorable social and financial consequences of the unemployment rate increase in their economies because the high level of unemployment requests each government more public assistance burden to each economy and induces more social restless circumstances. One politically attractive European plan to reduce unemployment is the advancing the tax system changes in which shift partially the tax burden away from labor income towards undesirable pollution. The tax reform is expected to boost employment and tax base of the public sector. In particular, shifting the tax structure away from labor towards polluting sources is expected to induce employers to substitute labor for capital and other inputs, therefore making production more labor intensive at the aggregate economy. This is a one of the possible double dividend cases that can be achieved by appropriate tax recycling method. However, the theoretical studies on the employment double dividend hypothesis has so far been unable to reach unambiguous conclusion.

With the imposed small environmental tax in the initial equilibrium, the introduction of pollution tax does not influence employment rate even though the revenue from pollution taxes allow the lower taxes on labor income. The key reason is that environmental taxes are implicit taxes on labor. Swapping environmental taxes for labor taxes amount to substituting implicit labor tax for the explicit labor tax. While the imposition of the environmental taxes tends to increase labor’s tax burden, the reduction in the labor tax tends to reduce it. When the environmental tax is small, these two effects exactly offset each other. Hence the real wage is not changed, which implies that labor supply is unchanged as well.

This logic becomes totally different in the case of imposing large environmental tax. We can analyze the impact of large pollution tax when environmental taxes are raised from the initial equilibrium in which environmental taxes are positive. In this case an increase in the pollution tax leads to a reduction in the real wage and a corresponding drop in employment. The negative effect on the real after-tax wage comes about because the lower tax rate on labor income does not fully compensate workers for the adverse effect of pollution tax on their after-tax wage. This incomplete offset reflects the fact that environmental taxes tend to be less efficient instruments for raising revenue than a broad-based labor tax. In contrast to a labor tax, pollution taxes on energy consumption not only affect the labor market but also distort the composition of the consumption basket. Furthermore those pollution taxes on intermediate inputs will distort the input mix into the production. These distortions account for the net reduction in real after-tax income following the revenue-neutral environmental tax policy.

Two elements such as the initial levels of pollution taxes and the substitution elasticities between ordinary commodities and energy-related commodities are main determinants about the additional tax burden to the economy. The initial pollution taxes regulate the marginal abatement costs. The higher the initial pollution taxes, the larger the marginal costs of increasing environmental quality, since higher initial environmental taxes intensify the adverse revenue effects associated with the erosion of the base from the increment to these taxes. Also the larger substitution elasticities between ordinary and energy-related commodities yield a higher tax burden from a given increment to the pollution tax. Larger substitution elasticities imply larger distortions from a given pollution tax.

Since recently the societies concerned more about unemployment are likely to pay more attention from the environmental issues to the unemployment problem, the double dividend hypothesis becomes more attractive even though the hypothesis cannot provide unambiguous answer for the effectiveness of environmental taxation to the employment. One sub-group concerned with unemployment have found that environmental taxation are a politically acceptable way of raising the relevant tax revenue with which government expenditure for public projects can be financed. Since the public projects for the construction of infrastructures in particular tend to provide enormous job opportunities to the unemployed, the environmental taxation becomes an attractive instrument for the solution of unemployment problem. Another sub-group concerned with the environment have found that if environmental taxation provides the employment relief, it can achieve political consensus and can be implemented easily. Therefore, the employment double dividend hypothesis becomes attractive and ideal scenario to both the employment-concerning group and the environment-concerning group. These expected beneficial outcomes have induced many economist to focus more on the effects of several ways of tax recycling in environmental taxation rather than the specific effects of environmental policies.

However, the academic analytical results about the favorable effects to the employment from double dividend hypothesis have been disappointing. Bovenberg and van der Ploeg (1994a) analyzed a tax-recycling method for raising employment through higher pollution tax and lower payroll tax in the second-best setting. Their model assumes a closed economy and emissions are a by-product of consumption activities. All markets are assumed to be perfectly competitive and attain relevant equilibriums. Under this framework, a higher environment tax rate causes the reduction in employment contrary to the expectation. Another study of Bovenberg and Van der Ploeg (1994b) investigated the employment double dividend hypothesis in the open economy model. In their model emissions assumed to be a by-product of production rather than of consumption activities. Also the substitutions between labor, capital and natural resources are allowed for. Under this framework, they derived simulation result from the more ambitious environmental policy such that a higher pollution tax on natural resources generates more tax revenue with a lower tax rate on labor. Even though the factor substitution is induced by a lower tax on labor and a higher tax on natural resources, the conclusion of the study is that the higher pollution tax encourage the reduction of employment like the result of another closed economy model.

From these studies we can find that the conditions for the validity of the employment double dividend hypothesis become more restrictive. Mitigating tax burden on labor can be attained when the distribution of the tax burden can be shifted away from workers to others such as capital owners, the owners of resources, and the recipient of income transfer. The shift to capital owners implies that labor must be a better substitute for natural resources than the capital stock and that the capital stock is main factor in production. With the international capital mobility, taxing capital need international coordination on the global level.

Specifically, we have several reasons to advance an empirical analysis of the employment double dividend hypothesis although the given these theoretical results are very disappointing. First, there are some empirical evidence in favor of the double dividend hypothesis. Bosquet(2000) examined the evidence for a double dividend from 139 simulations of the impacts of carbon/energy tax sifts in 56 countries. Energy taxes reduced carbon emissions in 84% of the simulations. Concerning a second dividend, 73% of simulations predicted the rise of employment. The mode of tax recycling matters significantly. Cuts in social security contributions produced higher employment than cuts in personal income tax. Also with long-term simulations it is more likely to predict negative employment impacts than short-term simulations.

As a second reason we need to recognize that theoretical simplified models tend to neglect many relevant interaction. In particular, the lack of dynamics in those models prevent the differential assessment of the validity of the employment double dividend hypothesis in the short and in the long run. In addition, many empirical studies do not contain a detailed description of the functioning of the labor market, its institutional setup and imperfectly competitive feature due to collective bargaining.

For the third reason, we can identify the effect of tax-recycling on the lowering pollution emissions. Since the tax recycling could lower the effect of taxation on emission reduction, lower environmental benefits can be traded off with higher employment benefits. Therefore, the accompanying econometric study can provide additional and more precise information on the employment double dividend issue. In particular, the differentiation the short-run effects from the long-run effects, and the quantitative assessment of the environment-employment trade-off will provide more precise information about the validity of the employment double dividend hypothesis. With consideration of above theoretical defects, Carraro, Galeotti and Gallo (1996) presented a new general equilibrium model for the European Union. Since the model is designed to more general and disaggregated than corresponding theoretical model, their model provide a more reliable empirical assessment of the employment double dividend hypothesis.

4. Environmental Tax Reform and Welfare

As for the problem of the efficiency cost of environmental taxation, a number of recent analytical and numerical analysis have raised a question on the validity of the double dividend hypothesis. The primary reason for the doubt is that the hypothesis ignores an important source of interaction between environmental taxes and pre-existing taxes. If the interaction is incorporated into the calculation of efficiency, the introduction of pollution taxes can itself exacerbate these distortions with a resulting increase in the level of excess burden because the various linkages between the consumption demands and productions of different goods can be the source of additional excess burden. In other words, since environmental taxes cause the costs and prices of commodities to rise, they induce the decrease in labor supply and investment, and therefore exacerbate the efficiency costs associated with tax distortions in labor and capital markets.

The initial academically serious challenge to the double dividend hypothesis was raised by Bovenberg and de Mooij(1994). Using a simple general equilibrium model with competitive firms, they showed that pollution taxes typically exacerbate, rather than alleviate, pre-existing tax distortions even if revenues are employed to cut pre-existing distortionary taxes. The model of Bovenberg and de Mooij (1994) has two goods, one of which is a dirty good whose consumption adversely affects the environment. Taxes are collected from labor income and the dirty good consumption. The starting point is where the tax rate equals the social marginal damage from pollution. Let's suppose that there is a small increase in the tax on the dirty good, and we can find that a revenue-neutral tax-mix change can affect utility of typical consumer in two ways. First, this tax change can affect the real net wage and labor supply. Second, it can affect against pollution through consumption of the dirty good. This decrease in pollution has both cost and benefit. While the social cost of reducing pollution is the value of output which pollution-generating activity produces, the social benefit is the averted environmental damages. Moreover, while if the tax reform reduces labor supply, then society is worse off, if the reform increases labor supply then society is better off.

Starting at a point where the tax on the dirty good equals social marginal damage, they show that an increase in the tax on the dirty good increases welfare if and only if it increases labor supply. To investigate employment effects, they make a series of assumptions about consumption preferences that imply that in the absence of environmental externalities, the optimal tax would be a uniform commodity tax or a equivalent wage tax. Starting at this point, they illustrate us that an increase in the pollution tax would induce a decrease in labor supply. Although the revenues from the environmental tax are used to lower the tax on labor supply, the resulting real net wage declines because the increase in the after-tax nominal wage cannot entirely make up for the increase in the price of goods. This results comes from the fact that the tax base erodes as consumers substitute away from the dirty good. Since raising the tax above social damages reduces welfare, lowering the tax below Pigovian level will raise welfare. Therefore, in the second-best case with distortionary taxation, the optimal environmental tax lies below the social damage from pollution. Also they point out that if revenue from the environmental tax are returned as lump-sum fashion rather than through a reduction in the labor tax, then the adverse impact on employment will be larger. Hence a non-environmental cost reduction can be achieved by using revenues from pollution taxes to cut distortionary taxes rather than returning those revenues in a lump-sum fashion.

Among the exploration about the implications of tax-favored consumption for the general equilibrium costs, Parry and Bento(2000) demonstrated that in the presence of tax-favored consumption the efficiency cost of environmental taxes with revenue used to cut personal income taxes can be substantially reduced up to at least 50 percent. When part of consumer spending is deductible from labor taxes, the tax system distorts the allocation of consumption in addition to the labor market. Also it is assumed that some of the polluting input is used in the production of tax favored goods and the level of pollution taxes is not too high. In this setting the welfare gain from using environmental tax revenue to reduce labor taxes can be significantly higher. As a result the cost savings from using revenue-neutral environmental taxes can be dramatically higher, and the validity of double dividend hypothesis can be easily justified.

Goulder(1995a) investigates different claims of double dividend and examines the theoretical and empirical evidence for each. He introduced two double dividend claims such as weak form and stronger forms.

A weak double dividend claim is that returning tax revenue through reductions in distortionary tax rates leads to cost savings relative to the case where revenues are returned as lump sum. Even though they showed that environmental taxes typically exacerbate preexisting tax distortion, Bovenberg and de Mooij(1994) demonstrated that in the presence of preexisting distortionary taxes, pollution taxes become more attractive if the revenues are used to cut distortionary taxes. In Goulder's model, the stronger versions contend that revenue-neutral substitutions of environmental taxes for ordinary distortionary taxes result in zero or negative gross costs. It is believed that even though weak double dividend claim is easily defended on theoretical ground and receives wide support from numerical simulations, more doubts are cast on the stronger claims from the theoretical analyses and numerical results. In his model, he showed that stronger double dividend claims can be possible if the initial tax system is highly inefficient in factor markets, leading to significant differences across factors in terms of value of marginal products, and the environmental tax serves to shift the burden of taxes to more efficient factors.

Also, Bovenberg and Goulder(1997) demonstrated that the efficiency cost of environmental tax reform depends on the magnitudes of prior inefficiencies in the relative taxation of labor and capital and on the extent to which the reform shifts the tax burden from the overtaxed to the undertaxed factor. They found that the substitution of environmentally motivated taxes for ordinary income taxes usually produces efficiency cost because environmental taxes are implicit factor taxes which not only generate factor market distortions like income taxes, but also impose additional distortions in other markets. With these findings, they illuminated that gasoline taxes tended to lower significantly the efficiency cost of tax reform through the burden-shifting effects, comparing with BTU taxes.

5. Inefficiencies in the Tax System and Possibility of the Double Dividend

5.1 Inefficient factor taxation

If there are differences in the marginal excess burdens of various taxes under the initial tax system involved, an environmental tax reform can boost private incomes by shifting the tax burden away from factors with high marginal excess burdens to factors with low marginal excess burdens. If in the initial tax system, the differences in marginal efficiency costs are large, the gross cost of a revenue-neutral environmental tax will be lower. Also when the burden of the environmental tax falls primarily on the factor with relatively low marginal efficiency cost and the revenues from the tax are devoted to reducing tax rates on the factors with relatively high marginal efficiency cost, the efficiency cost of environmental tax will be lowered. These conditions ensure that the efficiency gains from shifting the tax burden from overtaxed to the undertaxed factor can be sufficiently large to offset the costs associated with environmental quality improvement. Also these conditions may be relevant for the mix between capital and labor taxation. To illustrate welfare improvement, most studies with dynamic general equilibrium models of the economy suggest that, compared to taxes on labor income, taxes on capital income tend to produce larger marginal efficiency losses. The most direct way to improve the efficiency of the tax system as a revenue raising device would be to finance a cut in capital taxes with higher taxes on labor. However, if the government does not want to adopt labor taxes, it can use environmental taxes that is primarily borne by labor because environmental tax is intrinsically implicit labor tax.

The suboptimality of the initial tax system raises the question why governments have not reformed their tax systems to deal with these inefficiencies. The efficiency issue for such a tax reform is independent of environmental concerns. However, in some cases, political constraints from distributional concerns may prevent the government from introducing strictly non-environmental tax reforms that enhance the efficiency of the tax system as a revenue-raising device. Under these circumstance, there may be advantages to introduce a package deal in which environmental taxes generate revenues that are used to eliminate particularly inefficient taxes. This combination of environmental and non-environmental tax reforms may be necessary to generate sufficient political support for either type of reform. When environmental taxes are introduced as the devices for removing the inefficiency, the welfare cost of environmental taxation can be negative, which induces double dividend to be materialized.

5.2 Environmental tax and employment dividend

Since employment issue is the most concerned issue in each country, all the policy makers have been especially interested in the possibility that environmental tax reforms could raise employment. Many politicians tends to support reforms in which pollution taxes would be introduced and the revenues devoted to cuts in labor taxes because the reform aims at both environmental protection and reduction of labor income tax burden, which are very sound in terms of political campaign. In models with only labor as a primary factor of production, the employment impacts of a revenue-neutral environmental tax reform are directly related to the impacts on the non-environmental component of welfare. However, in models which consist of more than one primary factor of production, revenue-neutral reforms can produce an increase in employment without raising real incomes and non-environmental –related welfare.

The crucial requirement for an increase in employment is that the reforms shift the tax burden from labor to the other primary factors. Specifically, in models with capital and labor, the prospects for an employment increase are dependent on the extent that the pollution-intensive industries have a relatively low labor intensity comparing with other industries and how much revenues from the revenue-neutral environmental tax policy are devoted primarily to cuts in labor taxes rather than taxes on capital. This employment impacts are quite sensitive to the specifications of the features in labor market. Even though results vary widely, they indicate that employment dividend can be materialized when revenues are recycled through cuts in labor taxes and when the industries facing the environmental tax are not extremely labor-intensive.

Also an employment dividend can arise if the revenue-neutral reform tends to shift the burden of taxation from labor to public assistance recipients. The environmental tax raises the real cost of output, but labor receives benefit like a reduction in the labor tax that more than offset this cost increase. However, the public assistance recipients are not compensated for the reduction in the real value of their transfers. Under these circumstances, labor enjoys an increase in real income from the revenue-neutral reform because the tax burden is shifted to public assistance recipients.

5.3 Environmental tax as a spur to energy-saving technology improvement

As the international negotiation concerning climate change proceed step by step, the climate change policies in many countries are likely to raise the prices of conventional fuels which are carbon-based energy sources and are major emission source of carbon dioxide. Higher fuel prices can create economic incentives to involve in more intensive research and development (R&D) aimed to find a new fuel-saving production technology. In addition, climate policies may induce more R&D oriented to discover a new, economic way to produce the reliable and alternative, non-carbon-based fuels. These R&D eventually are likely to lead technological progress which are focusing on less-fuel-dependent production methods. Therefore, climate policies, R&D, and technological progress are forming a close inter-relationship, which induces eventual cost reduction in carbon dioxide abatement per unit. These relationship implies that real cost of carbon abatement may be overestimated because the tax incentive from carbon abatement induces energy-saving technological progress which produces a significant reduction in production cost in overall economy.

Goulder and Schneider (1999) investigate how the cost increase from greater carbon abatement can be justified through induced technological progress. They begin a simple two-period partial equilibrium model that shows the connection between technological change and cost of carbon abatement, then proceed into the numerically solvable general equilibrium model. Their study provides some insights about how induced technological change affects the attractiveness of carbon abatement policies.

Since a carbon tax raises fossil fuel cost directly, the carbon tax tends to stimulate R&D in fuel-intensive industries for reducing total fuel costs to maximize profit in the production side. However, this change does not necessarily imply that overall economic costs of a carbon tax are lower with technological change than they would be in an economy where technological change does not happen. Since the economy with induced technological progress is likely to respond more elastically to the climate policy, a given carbon tax can induce a greater reduction in carbon emission, which results in higher gross costs of carbon abatement. Therefore, without prior distortions in R&D markets, it can be said that the additional abatement induces higher gross costs of a given carbon tax with induced technological progress.

The potential net benefits from a carbon tax tend to rise with the technological progress, even though the induced technological change usually implies higher gross costs from a carbon tax,. Therefore, when we analyze the impact of technological progress on the policy cost, we must differentiate the costs of an abatement target with the costs of a given carbon tax. When the costs of a given carbon tax is focused, the amount of abatement will be varied according to the equality condition between marginal cost of abatement and marginal damage from emissions. However, when the costs of an abatement target is considered, the positive impact of technological progress becomes obvious through the reduction of marginal cost of abatement.

Under theoretical analysis, a carbon emission lowering policy can provide incentives both energy suppliers and energy demanders for investment into R&D. While the energy suppliers are motivated to find cost-saving ways of producing alternatives to fossil fuels such as biomass or solar energy, the energy demanders are stimulated to invest in the discovery of energy-efficient production processes which can lead a significant reduction in carbon emission and tax burden.

The advancement of technological progress implies two important points for optimal policy design. First, since technological progress implies more environmental net benefits even after consideration of enlarged abatement cost, the recognizing of technological progress can help the environmental policy overcome the obstacles of implementing of an abatement policy such as a given administrative cost and distributional impacts. The second key point is the implication for the optimal carbon tax rate. Since the efficient carbon tax rate is determined by the marginal environmental benefits, a technological progress does not have any impact on the size of optimal carbon tax. Even though technological progress make a carbon tax more attractive, the subsidizing R&D cannot be justified because there is no warranty for the net social benefit increase from the technological progress. All these cases are based the assumption that there is no prior distortions in R&D markets.

Because all of the knowledge from private R&D investments tend to make significant spillover effects to other firms, R&D investments are likely to produce positive externalities. Originally, efficiency condition requires that the market price of R&D in private firm must be equal to the social cost of producing cost of R&D. Therefore R &D must be subsidized at the rate equal to the marginal external benefit from knowledge spillovers. Then the private cost and social cost of R&D are the same. Inefficiencies in R&D markets are reflected in differences between private cost and social cost of R&D. For example, when the pre-existing subsidy to R&D in alternative energy is less than the spillover effect in this industry, the social cost of R&D in alternative energy becomes lower than after-subsidy private cost of it. This difference in social and private cost of R&D in alternative energy tends to discourage R&D in the industry. Under this circumstances, the introduction of carbon tax is likely to spur more R&D in alternative energy. Because the carbon tax generates more tax burden in the use of fossil fuel energy, the R&D in the alternative energy is likely to get comparative advantage in terms of private cost. Therefore, the carbon tax can induce more R&D in alternative energy because of comparative advantage in terms of private cost.

This spurring impact of the carbon tax on the research and development in the alternative energy industry can be applied to the energy-saving technology progress. It can be said that many industries seem to prefer the energy-saving technology rather than alternative energy because all the production processes have been optimally adjusted to pre-existing energy use pattern. If the carbon tax provides some cost edge to the alternative energy industry in terms of tax burden, the energy-saving technology progress can have same edge because energy-saving technology and alternative energy technology are well-known substitutes.

When the carbon tax spur more R&D in energy-saving technology, the tax base of carbon tax is likely to be diminished because the development of energy-saving technology induces less carbon emissions from the use of fossil fuel. Even though this diminishing tax base means less carbon tax revenue, it is likely to reduce the negative externality due to the carbon emissions. This reduction of negative externality implies less inefficiencies in the overall economy.

The tax recycling of carbon tax revenue to the sector of R&D in energy-saving technology will intensify this inefficiency reducing tendency because the development of energy-saving technology helps each industry reduce externalities due to the carbon emissions. In addition, the development of energy-saving technology induce the reduction of energy cost , which results in the reduction of total production cost, which induces each industry to produce more output. Therefore, tax recycling to energy-saving technology sector is likely to induce the reduction of carbon emissions and total production cost. These efficiency improvements raise the possibility of double dividend of the carbon tax. Since output reductions from a given carbon tax are dependent on the costs of attaining knowledge-generating resources, the energy-saving technology progress mitigates the output reduction effect of the carbon tax and furthermore new energy-saving technology can reverse the output reduction effect.

5.4 Transfers enhancing equity

Since most economic theories have focused on the raising efficiency, those previous discussions about the possibility of the double dividend hypothesis have focused on the efficiency enhancing cases. However, environmental policy often has concerned about the equity issue as well as efficiency issue. One of most prevalent equity enhancing distribution policy is public assistance program like transfer payment. When transfer payment is considered, we can find another relevant case under which double dividend is possible.

When we identify two types of households whose have different income sources, there will be active household and inactive household. While the active household obtains income entirely from labor earnings, the inactive household acquires its income through government's transfer payment. If we assume transfers are not subject to labor income tax but to consumption tax, higher consumption taxes tend to lower the income of the inactive household.

Suppose environmental tax to be imposed on dirty good consumption. Even though the active household is affected by higher commodity prices and consequently the active household's real income is reduced for the imposition of the higher environmental tax, government can compensate the active household more than the income loss due to the higher environmental tax because the tax reform for equity shifted the tax burden from labor income earners to transfer beneficiaries. In this case the incremental environmental tax raises real wages and employment and it seems that the improvement of environmental quality becomes accompanied by a higher level of employment. Therefore the double dividend like higher environmental quality and more efficiency in labor market can be realized.

Chapter 4
The Model

1. Overview

The following two-sector model in this section has a main purpose to provide the evaluation way for each energy taxation policy option using general equilibrium model which generates paths of equilibrium prices, rates of return, output, and income under specified policy options. The model will provide a unique basis in combining a complicated taxation mechanism of the Korean tax system with a close investigation of Korean industrial energy demand pattern. This section employs a simple general equilibrium model to examine the optimal tax rate structure related the taxation on environmentally damaging activities such as energy consumption.

In this model there are two manufacturing sectors like non-energy good sector and energy good producing sector. Non-energy good sector consists of various non-energy manufacturing goods which are final output that use fossil fuel not intensively. Currently, IT products, electronics and other ordinary consumer products are good examples. Energy good sector represent the industry which produces energy-intensive manufacturing goods like steel, pulp, and cement. In this economy primary energy good sector encompasses crude petroleum and natural gas, coal mining, synthetic fuels, petroleum refining, electric utilities, and gas utilities.

This model also assumes two kinds of consumption goods such as energy-goods and non-energy goods. Energy goods represent the final consumption good from industries that use fossil fuel (F) intensively, which include utilities, transportation, and motor vehicles. Also non-energy goods are ordinary goods from industries that use fossil fuel not intensively, which means they are cleaner commodity with the broad-based demands.

2. Household Behavior

In this model, the economy consists of only two sector such as energy good and non-energy good. Therefore the representative household maximizes the utility from consumption of non-energy goods and energy goods. Usually it is assumed that the labor supply (L) comes from the time endowment ($\bar{L}$) and the leisure (l) is the remnants from time endowment after providing labor time. However, in this model labor supply is determined exogenously. Therefore in this model leisure is not included as utility source variable in the utility function.

Also the environmental quality can be assumed as another utility source. To specify the impact of environmental quality on utility level, in this model it is assumed that utility level is negatively dependent of the consumption level of energy such as fossil fuels. In this model, the environmental quality can be deteriorated by the level of use of fossil fuel. It is assumed that the utility is reduced proportionately by the amount of usage of fossil fuel. The reduction of utility can be assumed as $\alpha \cdot F$ where α is a coefficient representing the impact of fossil fuel consumption level on environmental quality. Since the main factor of environmental deterioration is the energy consumption, the linear relationship between fossil fuel amount and environmental quality can be considered as relevant.

A better environmental quality requires less pollution, which means less consumption of energy. This interdependence between energy consumption and environmental quality makes the derivation of optimal consumption level of each utility source variables to be complicated. Since the consumption demands of non-energy goods and energy goods are significantly dependent to the change of relative price of two goods and the consumption substitution between two goods is significantly different from one, it can be assumed CES utility functional form with respect to two goods. The environmental quality can be assumed to have impact on the utility level separately and to be negatively dependent on the consumption of fossil fuels.

In this household model, the utility function of representative household is followings. When C_N represents aggregate of non-energy goods, C_E is an aggregate of energy good, environmental damage is $\alpha \cdot F$, we can define following utility function of a representative household.

$$U = U(C_N, C_E) - \alpha \cdot F \qquad (1)$$

$$\text{where} \quad U(C_N, C_E) = [\delta_1 \cdot C_N^{-\rho_1} + (1-\delta_1) \cdot C_E^{-\rho_1}]^{-\frac{1}{\rho_1}} \qquad (2)$$

In general form $U = U(C_N, C_F, l) - \alpha \cdot F$, where U(.) is continuous and quasi-concave, α is coefficient of disutility caused by the consumption of fossil fuel (*F*). In the real environment setting, this damage actually represents the present discount value of utility losses due to induced changes in future global climate. The separability of environmental quality in (1) implies that future environmental damage does not affect the current tradeoffs between energy goods consumption and non-energy goods consumption.

Government budget is assumed to be balanced and any revenue change will be neutralized by adjusting labor income tax rate. Also when we assume wage is normalized as one, the household budget constraint for above maximization problem is given by,

$$Y = p_N \cdot C_N + p_E \cdot C_E = w \cdot (1 - t_L) \cdot L + GE \qquad (3)$$

where p_N is price of C_N
p_E is price of C_E
w is wage rate
t_L is labor income tax rate
GE is exogenous government spending.

Therefore household choose C_N , $C_{E,}$ and L to maximize utility (1) subject to (3)and time endowment ($\overline{L}$). From the resulting first-order conditions and the household budget constraint, we obtain uncompensated Marshallian demand for non-energy commodity and energy commodity like followings.

$$C_N = C_N\,(\, p_N\,,\, p_E\,,\, Y\,) \qquad (4)$$

$$C_E = C_E\,(\, p_N\,,\, p_E,\, Y\,) \qquad (5)$$

When we substitute these demand functions for C_N and C_E and supply of leisure into the utility function (1), we can find the indirect utility function like following.

$$V = V(p_N, p_E, t_L) - \alpha \cdot F \qquad (6)$$

From Roy's identity, we can find the effects of incremental changes of p_N , p_E , t_L on indirect utility like followings.

$$\frac{\partial V}{\partial p_N} = -\lambda \cdot C_N \qquad (7)$$

$$\frac{\partial V}{\partial p_E} = -\lambda \cdot C_E \qquad (8)$$

where λ is the marginal utility of income.

3. Producer Behavior

In supply side we assume that a simple model of an economy in which firms maximize profits under perfect competition. In each industry there is a production function which accounts for potential substitutions between fuels and other inputs like followings.

$$C_N = f(L_N, R_N, F_N) \qquad (9)$$

$$C_E = g(L_E, R_E, F_E) \qquad (10)$$

where L is labor supply
R is clean (non-polluting) intermediate good
F is polluting intermediate good
Subscript N represents non-energy sector
Subscript E represents energy sector

In non-energy good sector, the production function can be assumed to be a CES functional form since the increase in each factor price yields substantial influence to the composition of actual factor usage. In this setting we can specify the non-energy production function like followings.

$$C_N = [\delta_2 \cdot L_N{}^{-\rho_2} + \delta_2^{'} \cdot R_N{}^{-\rho_2} + (1 - \delta_2 - \delta_2^{'}) \cdot F_N{}^{-\rho_2}]^{-\frac{1}{\rho_2}} \quad (11)$$

When total cost in non-energy good sector is defined in terms of factor prices such as wage, price of clean intermediate good, and price of energy like following.

$$TC_N = w_N \cdot L_N + r_N \cdot R_N + p_F \cdot F_N$$
$$(= 1 \cdot L_N + r_N \cdot R_N + p_F \cdot F_N) \quad (12)$$

where w_N is wage rate in non-energy sector, which can be normalized as one.
r_N is rental rate of clean intermediate good in non-energy sector
p_F is price of fossil fuel used in non-energy sector

With this total cost function, we can derive a supply function in non-energy sector using cost minimization condition. When we assume no technological progress, the sole source of production expansion is the change of the amount of supplied labor and available intermediate inputs such as clean and polluting inputs in non-energy good sector. When total cost is defined as $w_N \cdot L_N + r_N \cdot R_N + p_F \cdot F_N$ and constant return to scale through parameter constraint is assumed, we can derive a horizontal supply curve in non-energy sector through cost minimization process like following.

$$P_N = P_N(r_N, w, p_F) \qquad (13)$$

In energy good sector, we can also assume that production function has another CES functional form since it is expected that the substitutions between factors after the change of relative factor price are significant. Therefore the energy sector production functional form is following.

$$C_E = [\delta_3 \cdot L_E^{-\rho_3} + \delta_3^{'} \cdot R_E^{-\rho_3} + (1 - \delta_3 - \delta_3^{'}) \cdot F_E^{-\rho_3}]^{-\frac{1}{\rho_3}} \qquad (14)$$

Also when total cost is defined in energy good sector like following.

$$TC_E = w_E \cdot L_E + r_E \cdot R_E + p_F \cdot F_E$$
$$(= 1 \cdot L_E + r_E \cdot R_E + p_F \cdot F_E) \qquad (15)$$

where w_E is wage rate in energy sector, which can be normalized as one.

r_E is rental rate of clean intermediate good in energy sector
p_F is price of fossil fuel used in energy sector

With this total cost function in energy good sector, the horizon supply curve in energy sector can be derived through cost minimization condition like following through the same process in non-energy good sector. This horizon supply curve implies that all potential firms are equally efficient. If the firms are different in their efficiencies, the supply curve slopes upward.

$$P_E = P_E(r_E, w, p_E) \qquad (16)$$

As another step, from these production functions we can derive factor demand functions. If we assume that the available amount of labor is given, we can derive two intermediate input demands in each sector. When we derive the cost minimization condition in each sector under perfect competition, we can find the first order condition such that each firm hires labor and intermediate inputs so that the value of marginal product of each input is equal to its price. Then using this first order condition, we can derive the two ratios among the rates of return of three factors. The first ratio is the ratio between wage rate and rate of return of each sector's clean intermediate input. The second one is the ratio between wage rate and rate of return of each sector's polluting input.

Using these cost minimization conditions, we can derive the demand function for two intermediate inputs in each sector. In these demand functions, we assume that labor is given in the economy.

Following these steps, we can derive following factor demand functions in each sectors.

In non-energy sector, two intermediate input demands functions can be described as

$$R_N = R_N(r_N, w, L_N) \quad (17)$$
$$F_N = F_N(p_F, w, L_N) \quad (18)$$

In energy sector, two intermediate input demands functions can be described as

$$R_E = R_E(r_E, w, L_E) \quad (19)$$
$$F_E = F_E(p_F, w, L_E) \quad (20)$$

After deriving clean intermediate input demand in each sector, we can find the equilibrium rate of return of clean intermediate in each sector since the clean intermediate input is sector-specific factor. Since in each sector there is a clean intermediate input market, we can find the equilibrium rate of return of sector-specific clean intermediate input through the equating demand and available supply of the clean intermediate input in each sector.

Also the polluting input market clearing condition can induce the equilibrium price of the polluting input. After deriving fossil fuel demand in each sector, we can find the equilibrium fossil fuel price (p_F) in fuel market through the equating demand and available supply of fossil fuel. Aggregation of fossil fuel use is a summation of the polluting input demand in each sector, which is defined as following.

$$F = F_N + F_E \tag{21}$$

Using above market clearing condition, we can find the equilibrium price of polluting input.

4. Energy Taxation

When we talk about the environmental protection, the reduction of energy consumption seems to be the first target to be focused because the emissions from the energy consumption. To implement this target, the raising of energy prices will be the main instrument because the energy consumption demand is usually dependent on the energy price. The effective policy instrument of raising of energy price is the augmentation of taxes imposed on energy consumption. That is the main reason why the energy tax is the most effective instrument for environmental protection.

Suppose an environmental policy like energy tax, which creates additional burden of τ_E per unit to supply price of fossil fuels.

Given constant return to scale, total payments to inputs in energy good industry must be equal to total value of product from Euler's theorem like following.

$$p_E \cdot C_E = w \cdot L_E + r_E \cdot R_E + (p_F + \tau_E) \cdot F_E \tag{22}$$

Total differentiating (22) and (12), and the first order conditions for profit maximization provide the formula for increase in final product prices from an incremental increase in τ_E is followings.

$$\frac{dp_E}{d\tau_E} = \frac{F_E}{C_E} \qquad (23)$$

$$\frac{dp_N}{d\tau_E} = \frac{F_N}{C_N} \qquad (24)$$

That is, the ratio of fossil fuel input to final output determines the increase rate in final product prices from increase of τ_E .

From the cost minimization problem in non-energy and energy industries, we can derive the demands for inputs, conditional on the output level and input prices. Since input prices like w , r_N , p_F can be influenced by τ_E , and the changes in product prices are determined by changes in τ_E , the conditional demands for fossil fuel in each sector are followings.

$$F_E = F_E(\tau_{E,} C_E) \qquad (25)$$

$$F_N = F_N(\tau_{E,} C_N) \qquad (26)$$

In market equilibrium, the final outputs are equal to demands of households. Since $C_N = C_N (p_N , p_E , Y)$, $C_E = C_E (p_N , p_E , Y)$, the equilibrium condition in fuel market will be following.

$$F(\tau_E, Y) = F_N(\tau_E, Y) + F_E(\tau_E, Y) \qquad (27)$$

where $\frac{dF}{d\tau_E} < 0$.

The effect of changes in τ_E on fossil fuel are the combined effect of the substitution effect and the output effect.

When the government collects both environmental tax and labor income tax, the government budget constraint is following.

$$\tau_E \cdot F + t_L \cdot (w \cdot L) = GE \qquad (28)$$

If the government collects additional taxes imposed on clean intermediate input, the resulting government budget constraint becomes different like following.

$$\tau_E \cdot F + t_L \cdot (w \cdot L) + t_E \cdot (r_E \cdot R_E) + t_N \cdot (r_N \cdot R_N) = GE \qquad (29)$$

where t_E is tax rate imposed on polluting intermediate input in energy sector

t_N is tax rate imposed on polluting intermediate input in non-energy sector

Consider budget-neutrality change, which involves the simultaneous changes in τ_E and t_L. Totally differentiating (28) holding G constant and using (27), we can find the formula of the relationship between τ_E and t_L like following.

$$\frac{dt_L}{d\tau_E} = -\frac{F + \tau_E \cdot \dfrac{dF}{d\tau_E} + t_L \cdot \dfrac{\partial L}{\partial \tau_E}}{L + t_L \cdot \dfrac{\partial L}{\partial t_L}} \tag{30}$$

The welfare effect of the environmental tax is obtained by differentiating the indirect utility function with respect to τ_E, allowing t_L to vary. The differentiating result provides following formula.

$$\frac{dV}{d\tau_E} = \frac{\partial V}{\partial p_E} \cdot \frac{dp_E}{d\tau_E} + \frac{\partial V}{\partial p_N} \cdot \frac{dp_N}{d\tau_E} + \frac{\partial V}{\partial t_L} \cdot \frac{dt_L}{d\tau_E} - \alpha \cdot \frac{dF}{d\tau_E} \tag{31}$$

Substituting above results, we can derive the functional form for the welfare effect of environmental tax like following.

$$\frac{dV}{d\tau_E} = h\left(\frac{dF}{d\tau_E}, \frac{\partial L}{\partial \tau_E}, \frac{\partial L}{\partial t_L}; \lambda, \tau_{\mathrm{E}}, t_L\right) \tag{32}$$

From above functional form, the welfare effect of the environmental tax can be decomposed into three parts. The first welfare effect is the effect within the fossil fuel market or primary welfare gain. This gain comes from the difference between marginal social cost and marginal social benefit of fossil fuel use. The second part is revenue-recycling effect or efficiency gain from using additional environmental tax revenues to reduce labor income tax. It is calculated through the multiplication of marginal environmental tax revenue by marginal welfare cost of taxation. The third part is tax-interaction effect. It consists of welfare loss from the reduction in labor supply and the resulting reduction in labor tax revenue multiplied by the marginal welfare cost of taxation.

While the primary welfare gain and the revenue-recycling welfare effects are influenced by $\frac{dF}{d\tau_E}$, the tax-interaction welfare effect is dependent on $\frac{\partial L}{\partial \tau_E}$.

Therefore, the relevant welfare impact of environmental tax can be found through the identification of the signs of following partial derivatives.

$\frac{dF}{d\tau_E}$ = impact of environmental tax on total fossil fuel demand

$\frac{\partial L}{\partial \tau_E}$ = impact of environmental tax on labor supply

$\frac{\partial L}{\partial t_L}$ = impact of labor income tax on labor supply

However, since in this model the available labor supply is assumed as fixed, those impacts of environmental tax and labor income tax on labor supply can be ignored. Rather, the impacts of environmental tax and labor income tax on the supply of clean intermediate input in each sector becomes more meaningful since the supply of sector-specific clean intermediate can be altered through the substitutions between production factors in each sector and the changes of ratio between rates of return of those factors.

That is, in non-energy sector we can identify those impacts on sector-specific clean input like followings,

$\frac{\partial R_N}{\partial \tau_E}$ = impact of environmental tax on non-energy sector-specific clean input

$\frac{\partial R_N}{\partial t_L}$ = impact of labor income tax on non-energy sector-specific clean input

Also, in energy sector we can identify those impacts on sector-specific clean input like followings,

$\frac{\partial R_E}{\partial \tau_E}$ = impact of environmental tax on energy sector-specific clean input

$\frac{\partial R_E}{\partial t_L}$ = impact of labor income tax on energy sector-specific clean input

With relevant identifications of each sign and magnitude, we can determine how much environmental tax has an effect on welfare level. If the total effect becomes positive, we can say that double dividend hypothesis is valid in this model. However, the reliable testing about double dividend hypothesis requires many available estimates about the parameters in the specifications in household's and producers' behaviors.

Chapter 5
Korean Energy-Related Tax System and Possibility of Double Dividend

1. Current Korean Energy-Related Tax System

1.1 Overview

Comparing with United States and European Union, Korea has a complicated energy-related tax system. While US and EU have the general excise taxes on fuel which are used in general account budget, Korea has many ear-marked taxes in energy tax system which are collected into special account budget. The ear-marked taxes in the energy tax system are transportation tax and education tax. The transportation tax is applied to the consumption of gasoline and diesel. The special consumption taxes are collected through the imposition to the consumption of kerosene, LPG, and LNG. Educational tax is collected as an additional tax to all these taxes. Besides those taxes, while value-added-tax and local mileage tax are imposed to the consumption of gasoline and diesel, the additional sales levy are imposed to LPG and kerosene.

Those ear-marked taxes and additional levies has been criticized for their inflexibilities to the need of government budget. However, the presence of specific-fund through those ear-marked taxes has contributed to implementation of specific government policies. Even though ear-marked taxes induce the distortion in resource allocation, the specific targets like construction of social overhead capital(SOC) are less likely to implement without the financial support of ear-marked taxes. In this respect, transportation tax has had an important role in the national build-up of various types of road services. In the end of 2003, the transportation tax is expected to be repealed and transformed into general excise tax. However, since the need of maintaining and expanding of the quality of transportation service is expected to be raised, the scheduled abolition of transportation tax in 2003 has a relatively high possibility to be avoided. At least the replacement of transportation tax with a new specific tax aiming for the provision of up-graded transportation service.

Recently, many government ministry are providing a new tax plan after the abolition of transportation tax. While Ministry of Environment provides the new tax plan emphasizing environmental protection, Ministry of Finance emphasizes the incorporating of transportation tax into general excise tax system. However, since the demands of transportation service are increasing due to the economic growth, the demand for good quality of road service will be incessantly sustained. Therefore, the transportation tax will be maintained even after 2003 even though the detailed structure is changed.

Education tax is expected to have a similar status in future tax system because of the incessant education demand increase. Currently the most concerned issue is the collapse of public education in Korea. Although the deterioration of public education is a most painful issue of all kinds of government regardless of the economic situation. Rather the rich countries are experiencing more pain from the deterioration of public education. Most European countries and US government has spent a huge amount of budget to the education sector through various ways. In Korea the educational situation seems to be more frustrating, which tends to enforce the government to find more financial source for increased investment to educational sector. Under this circumstance, the education tax is less likely to be abolished in near future. Therefore all the ear-marked taxes imposed to energy consumption are expected to continue an important role in Korean energy taxation system.

Another tax like the special consumption tax imposed on kerosene, LPG, and LNG seems to have a little different future. Originally when the special consumption tax is imposed the consumption of kerosene, LPG, and LNG, those consumption was treated as a little luxurious consumption. However, since current energy tax system is initiated, the energy consumption pattern has been deeply changed and the living standard has been drastically increased. Therefore, the currently imposed special consumption tax on those fuels can be transformed into new tax type for the adjustment of fuel consumption pattern.

Also the energy price reform started from July, 2001 has a deep impact on the energy tax system. Originally the energy price reform has multiple targets such as the restoration of the price mechanism in energy market, the energy saving for energy security, the environmental protection through the reduction of carbon dioxide, the relevant congesting cost payment, and the adjustment of relative prices between fossil fuels. Among the targets the main contribution of the energy price reform is the implementation of the adjustment of relative prices between fossil fuels. Because the energy price reform will be continued until July, 2006, the energy consumption pattern changes such as more substitution between diesel and LPG are expected to be sustained. This energy consumption pattern change is expected to be maintained until 2006.

1.2 Transportation Tax

The transportation tax is a kind of ear-marked taxes whose main purpose is the provision of transportation fund for the construction of new roads, the maintenance and repair of national main roads and the expansion of transportation-related social overhead capital (SOC). This taxation is imposed the consumption of gasoline and diesel from 1994 and is scheduled to be terminate in the end of 2003. The current tax rates are 588 won per liter of gasoline and 234 won per liter of diesel after another increase of tax rate imposed on diesel in July, 2002.

Even though the transportation tax is initially made up as an ear-marked tax for transportation fund, the transportation tax has another characteristics such as congestion tax and environmental tax because the transportation tax can induce less traffic for the increased opportunity cost of driving a car and this reduction of traffic can result in less pollution. Also the transportation tax can be considered as a penalty payment for destruction of road because the driving a car would naturally result in some destruction of the road.

However, since the degree of traffic congestion is different across the regions, the transportation tax needs to be adjusted according to the degree of traffic congestion in that region. Also the penalty payment of the transportation tax such as destruction fee is not considered as correctly imposed according to the destruction degree of the vehicle. Because the road destruction is done proportionally to the cube of vehicle weight, a heavy weight vehicle would induce more serious damage to a road than the damage proportional to its weight. Therefore the transportation tax does not seem to implement satisfactorily its correcting role in the transportation-related externalities.

1.3 Special Consumption Tax

The special consumption tax on the consumption of LPG and kerosene is a kind of consumption taxes whose main purpose is the collecting taxes efficiently and the correcting of externalities induced by the consumption of LPG and kerosene. Since the demand elasticity of fuel consumption is relatively low, the tax imposition on the fuel consumption induce less dead weight loss. Therefore the fuel taxes are considered as the efficient way to raise the tax revenue with less economic distortion. Also because the fuel consumption make many pollution problems, the special consumption taxes on LPG and kerosene are considered as the externality-correcting taxes. The current tax rates are 226 won per kilogram of LPG and 82 won per liter of kerosene after another increase of tax rate imposed on LPG and kerosene in July, 2002.

1.4 Mileage Tax

The mileage tax is a kind of local government taxes whose main purpose is the provision of another financial source to the local government. The taxation of mileage tax is initialized from December, 1999 and the current tax rates are 11.5% of the transportation tax rate of gasoline and diesel after another increase of tax rate imposed on diesel in July, 2002.

Even though the mileage tax is initially made up as a provision for a new local government financial source, the mileage tax has another characteristics such as congestion tax and environmental tax like the transportation tax because the mileage tax can induce less traffic for the increased opportunity cost of driving a car and this reduction of traffic can result in less pollution. Also the mileage tax can be considered as a fee for destruction of road because the longer mileage would naturally imply more destruction of the road.

2. Incorporating Possibility of Double Dividend into Korean Economy

2.1 Lower corporate or labor income tax for adjusting inefficient factor taxation

In Korea, the tax recycling method for the reduction of corporate income tax rates can be applied for the attainment of double dividend. Since the corporate income tax rate in Korea is relatively higher than the competing developing countries such as Taiwan, Korean corporate income seems to be relatively overtaxed in terms of competitiveness of exporting industry.

If labor income is relatively undertaxed than corporate income, the tax recycling to reduce corporate income taxes will induce more efficiency gains. Therefore, it can be implied that the tax recycling of environmental taxes to corporate income taxes will raise the possibility of the realization of double dividend.

However, since it is very ambiguous whether labor income is undertaxed or not in Korea, the tax recycling only to reduce corporate income taxes might not be appropriate. The tax recycling to reduce labor income taxes is a typical tax recycling method to investigate the possibility of double dividend in many previous empirical studies about double dividend hypothesis in the developed countries. Therefore, in this study the impact of the tax recycling of environmental taxes to reduce labor income taxes needs to be investigated to find out the possibility of double dividend hypothesis. After the investigation of the impact about tax recycling to reduce corporate income taxes, this study will continue to find out the impact of tax recycling to reduce labor income taxes, investigating whether there is any inefficient production factor taxation in Korea.

2.2 Employment dividend from heavy taxation on energy-intensive industry

In Korea, energy-intensive industries have a relatively low labor-intensity because energy-intensive industries like steel and petrol-chemical industries require a heavy equipment investment, which implies a high capital-intensity. Thus the revenue-neutral heavy environmental taxes on energy-intensive industries can shift tax burden from labor into capital, which can lower the labor income tax rate. Therefore the environmental taxation can induce more possibilities of double dividend.

However, this possibility of double dividend is based on the favorable tax treatment in existing tax system. If this favorable tax treatment is not significant, this possibility of double dividend is drastically reduced.

2.3 Environmental tax recycling to energy-saving technology sector

Still, the amount of Korean energy-saving technology investment seems to have stayed in a relatively primitive phase. If the energy-saving technology progress can raise the possibility of double dividend of environmental taxation, it seems enhancing welfare much more to recycle the environmental tax revenue to the energy-saving R&D sector for the sustainable economic development. Therefore, the tax recycling to energy-saving technology sector implies a higher possibilities of double dividend.

2.4 Transfers enhancing equity

Currently Korean government have provided much more public assistance program than the previous decade. Some economists argue the current public assistance program expenditure can be a main contributor to future government deficit. Reflecting this trend of Korean government spending, the equity enhancing transfer can raise the possibility of double dividend of environmental taxation through the shift to the inactive households. However, the rate of inactive household's income reduction due to the environmental taxes needs to be analyzed first. If the income reduction rate is small, the double dividend can be hardly materialized. Since Korean public assistance program does not have a long tradition, the tax burden shift to transfer recipients seems to be ambiguous

If this transfer can induce more output production, it can be believed that double dividend will be realized through the transfer payment. However, since theoretically the impact of lump-sum transfer on output increase is expected to be relatively weak than the other methods like the reduction of distortionary tax rates, it is difficult to expect that this transfer payment increase method can realize the double dividend hypothesis in the economy.

Chapter 6
Energy Tax Recycling Impact on Korean Economy Through Simulation Process

1. Estimation of Coefficients in Demand and Supply Sides

To solve the above model in chapter 4 numerically, we need to estimate the necessary coefficients of the model through demand and supply functional forms. Each functional specification like CES functional form provides us how to estimate those coefficients. They will be used for the initial parameter values in the simulation process.

For the demand function, we need the estimates of the parameters in utility functional form which include each factor share parameter and elasticity of substitution among consumption demands for each good. Since consumer goods are divided into non-energy goods and energy goods, we need also the estimates of parameters such as each goods' share parameter and elasticity of substitution between non-energy goods and energy goods.

In the production function, the estimates for scale parameter which reflects technological change, the estimates of each factor share parameters, and the estimate of the elasticity of substitution between each factor are necessary. Since each production function has three production factor like labor, clean intermediate input, polluting intermediate input, we need to estimate all the coefficients such as share parameter, elasticity of substitution between production factors. For the convenience of analysis, in the model we assume the scale parameter to be one.

In the above model, since I assume two consumer goods such as non-energy goods and energy goods, and two intermediate goods such as clean intermediate and polluting intermediate, there are three utility variables and three production factors in this economy. In Korean economy, non-energy goods industry includes agriculture and fishery, manufacturing except energy-intensive and energy-related manufacturing, and services including construction, while energy goods industry includes coal mining, crude oil, petroleum refining, natural gas, city-gas, electricity, heat-supply industry. Also while the polluting intermediate goods are oil products, city-gas, and coal, the clean intermediate goods are electricity, LNG, crude oil, and all the capital goods.

For the demand function, we need the information about expenditures to each goods in each household. This information can be found in *The Survey of Urban Household Expenditure*. The Survey has been made by Korea National Statistical Office(KNSO) through the collecting the data about revenue and expenditure of each household. The items of *The Survey* includes the amount of expenditure on food, housing services, electricity and water, furnishings and appliances, clothing, health, education and recreation, and transportation. The detailed items encompass the expenditure information of 600 products. Among them we can find the expenditures on electricity, city-gas, kerosene, diesel, LPG, and motor vehicle fuel. From these data we can find total energy expenditure in each household. In utility function we have two utility variables such as non-energy consumption, and energy consumption. Using the data of *The Survey* we can estimate the primary coefficients in the utility function.

In the production side, we can use *The Input-Output Tables* made by Bank of Korea in 1995. The sectoral classification in the 1995 tables is based on the recently updated Korean Standard Industrial Classification and has been achieved mainly by dividing, incorporating or abolishing the sectors in the 1990 tables, or by establishing new ones to reflect the changes in the domestic industrial structure resulting from technological advances and changes in the structure of relative prices. The 402 resulting basic intermediate sectors are re-aggregated into 168, 77 and 28 sectors for analytical purposes. From this table we can find the intermediate goods consumption and value-added production. Intermediate consumption represents the value of all the goods and services consumed during the production process apart from fixed capital goods. Goods and services produced for own consumption and the imputed output of financial services are also counted as intermediate consumption. The valuation of intermediate consumption is made by comparison of producer's prices in the table of producer's prices, so the transportation cost and trade margin are deducted from purchaser's prices. Using The I-O Table, we can find the amount of each intermediate goods. With the information about the intermediate goods in each sector, we can derive the coefficients of production function I each sector such as non-energy goods and energy goods.

2. Finding the Impact of Energy Tax on the Economy Using the Market Equilibrium Conditions

With these production function estimates, we can derive equilibrium value of each factor’s rate of return. The equilibrium conditions of each goods and each factor market enable us to find equilibrium value of wage, capital return, fossil fuel price in each sector. In the above model, all the equilibrium values of factor return are influenced by τ_E because the effect of energy tax is applied to all the production factors.

Suppose the increase of energy tax rate. Using equilibrium conditions in each market, we can find the new equilibrium rate of return of each production factor. With those new equilibrium return rate, we can find a new equilibrium output level in each goods market. The summation of those output levels will determine the new total output level in the economy. Through this process, we can find how much the output impact of energy tax rate on the economy is.

After getting the equilibrium values of the rates of return of all factors from above simulation process, the next step would be the measuring of benchmarks for deadweight loss or income level change after incorporating actual Korean energy-related tax system into the model. After getting these benchmarks we can be in the position to analyze the impact of different energy-related tax system.

After-tax rates of return on each factor are followings.

$p_F^{'} = p_F + \tau_E$ after-tax fuel price

$r_E^{'} = r_E(1 - t_E)$ after-tax clean intermediate input

rental rate
in energy good sector

$r_N^{'} = r_N(1 - t_N)$ after-tax clean intermediate input

rental rate in non-energy good sector

$w' = w(1 - t_L)$. after-tax real wage rate

where τ_E is fuel tax rate

t_E is tax rate to clean intermediate in energy good sector

t_N is tax rate to clean intermediate in non-energy good sector

t_L is labor income tax rate.

With these formula for after-tax rates of return and the data of Korean tax rates, we can proceed the same simulation procedure based on Newton's method. Then we can find the benchmark after-tax rates of return of each factor and total income.

In Korea the calculation of the economically meaningful fuel tax rate is very difficult because the after-tax prices of most transportation fuels such as gasoline and diesel usually surpasses the before-tax prices of those fuels by more than two times. In this model, the fuel tax rate is incorporated into the fuel sale price. Therefore, since the original fuel tax rate, before fuel tax-increase, is treated as part of commodity price in this study, the fuel tax rate increase can be translated into only fuel price increase.

3. Impact of Energy Tax Recycling through Corporate Income Tax Reduction

Suppose in an economy tax revenue consists of fuel tax (τ_E), clean intermediate input tax (t_E, t_N) and labor income tax (t_L). Initially the government budget is assumed to be in balance, and the balance will be sustained after the taxation system is reformed for the more concerning to the environmental improvement in the future.

Then, raise fuel tax rate for environmental protection and simultaneously reduce the corporate income tax rate to maintain budget neutrality. In this model the reduction of corporate income tax rate can be reflected in the reduction of clean intermediate input tax rate. Since corporate income comes from the overall business and capital has a main role in recent business operation, the capital represented by clean intermediate input can be considered as the source for corporate income.

It is believed that the raising of the fuel tax rate (τ_E) has a broad impact to all the sectors because the fuel is essential input to non-energy good sector as well as energy good sector. With the simultaneous change of clean intermediate input tax rate and the equilibrium conditions in labor market and clean intermediate input market, we can find new equilibrium rate of return of all production factor. With these new equilibrium rate of return and supplied factor amount, we can find a new equilibrium output level after the energy tax recycling. Comparing this output level to the initial ouput level with no increase of fuel tax rate enables us to determine how much impact of energy tax recycling has on the economy in terms of welfare.

If the new output level is increased after the tax recycling, we can say that the double dividend hypothesis is possible in the Korean economy. If not increased, it is doubtful that the double dividend hypothesis can be applied to the economy.

4. Impact of Energy Tax Recycling through Labor Income Tax Reduction

Suggest tax recycling through labor income tax rate reduction. This policy implies that a government raises fuel tax rate for environmental protection and simultaneously reduce the labor income tax rate to maintain budget neutrality.

In this model in each sector the supplied labor is assumed to be independent of wage rate. This assumption implies that the change of wage rate does not have effect on the change of labor supply. In the labor market the equilibrium wage rate is determined through the equating labor demand with labor supply. Since labor supply is fixed, the change of wage rate cannot adjust the discrepancy between labor demand and supply. In this model there might be disequilibrium in labor market after the change of labor income tax rate.

In this case the impact of the reduction of income tax rate through the tax recycling on the output level cannot be significant since the after-tax wage rate increase cannot change the equilibrium level of available labor in the economy. Rather the after-tax wage rate increase can induce each firm substitute labor with other intermediate input which becomes relatively less expensive. This substitution can raise overall output if the productivity of these inputs is relatively higher than labor productivity in each sector. However, because this productivity difference between factors is hard to figure out, this substitution effect from the tax recycling is uncertain.

Therefore, in this model the tax recycling through the reduction of income tax rate can be expected not to make a significant impact on overall output level in each sector. If not significant, it implies that the double dividend hypothesis cannot be realized in this method of tax recycling.

5. Impact of Energy Tax Recycling through Transfer Increase

In this model the government budget constraint is initially

$$\tau_E \cdot F + t_L \cdot (w \cdot L) + t_E \cdot (r_E \cdot R_E) + t_N \cdot (r_N \cdot R_N) = GE \,.$$

where τ_E is energy tax rate

t_L is labor income tax rate

t_E is tax rate imposed on polluting intermediate input in energy sector

t_N is tax rate imposed on polluting intermediate input in non-energy sector

GE is exogenous government spending.

When we consider energy tax recycling through transfer increase, we can modify the government budget constraint like following.

$$\tau_E \cdot F + t_L \cdot (w \cdot L) + t_E \cdot (r_E \cdot R_E) + t_N \cdot (r_N \cdot R_N) = GE^{'} + Tr$$

In the above budget constraint, total government expenditure is divided into the after-transfer government expenditure (*GE'*) and the net transfer payment (*Tr*). The tax recycling through transfer increase implies that the raised energy tax revenue due to the increase of fuel tax rate τ_E will induce the increase in transfer payment (*Tr*).

If this transfer can induce more output production, it can be believed that double dividend will be realized through the transfer payment. However, since theoretically the impact of lump-sum transfer on output increase is expected to be relatively weak than the other methods like the reduction of distortionary tax rates, it is difficult to expect that this transfer payment increase method can realize the double dividend hypothesis in the economy.

Chapter 7
Simulation Results and Evaluation of Energy Tax Recycling Impact on Korean Economy

1. Output Changes through Energy tax Recycling

1.1 Impact of Energy Tax Recycling through Corporate Income Tax Reduction

With those coefficients estimate in the above model and using Gauss program, we can calculate numerical solutions for the target variables. After getting the equilibrium values of the rates of return of all factors from the simulation process, the next step would be the measuring of benchmarks for macro-economic variables after incorporating Korean energy tax system into the model. After getting these benchmarks we can be in position to analyze the impact of different energy tax system.

To investigate the impact of corporate income tax rate reduction, we need to lower tax rates imposed on clean intermediate input such as r_N, r_E to maintain the government budget neutrality when energy tax rate like τ_E is increased. In this simualtion at first we increased τ_E by 10%. Since the proportion of energy tax in Korea is around 8% and the ratio of corporate income tax to total tax is 16%, the tax rates imposed on clean intermediate (r_N , r_E) are appropriately reduced by same proportion to maintain the budget neutrality, using government budget constraint formula like following.

$$\tau_E \cdot F + t_L \cdot (w \cdot L) + t_E \cdot (r_E \cdot R_E) + t_N \cdot (r_N \cdot R_N) = GE$$

Since the after-tax rate of returns of capital imbedded in clean intermediate inputs are followings,

$r_E^{'} = r_E(1-t_E)$ after-tax clean intermediate input rental rate in energy good sector

$r_N^{'} = r_N(1-t_N)$ after-tax clean intermediate input rental rate in non-energy good sector

the reduction of r_N , r_E will induce after-tax rate of returns to be raised.

The first effect from the reduction of r_N , r_E is the increase of after-tax rate of return of clean intermediate good in each sector. This rate of return increase will induce the substitution other inputs with clean input. If the clean input is overtaxed before this tax recycling, this factor substitution will induce the efficiency increase in the sector where the sector-specific input is utilized.

The simulation result from the corporate income tax recycling method implies that the clean intermediate good seems to be a little overtaxed overall because output after the tax recycling is increased by 0.12%. The implication of this output increase is that the lowering of r_N , r_E might induce the efficiency gain through the factor substitution.

1.2 Impact of Energy Tax Recycling through Labor Income Tax Reduction

Instead of lowering the rates of return to clean intermediate input, we can reduce the labor income tax rate to maintain the budget neutrality when we raise the environmental tax rate τ_E . When the labor income tax rate is reduced, it is expected that the lower income tax rate induce the increase of labor supply in the competitive labor market because the augmented after-tax wage rate will induce ordinary worker to reduce his/her lesure for earning higher wage income. However, since in this model labor supply is assumed to be constant due to analytical simplification, the augmented wage rate induces only substitution effect between factors through production process in each sector. Since three factors such as labor, clean intermediate and polluting intermediate good are assumed in this model and the supply of labor is assumed to be fixed, this substitution effects are induced through the effect from the change of the ratio between wage rate and rate of return of each sector-specific clean intermedate input. When the after-tax wage rate is raised through the tax recycling of reduction of labor income tax rate, the derived demand for clean intermediate input in each sector will be increased because the demand for clean input has an inverse relationship with the rate of return of the clean input. Also the demand for the polluting intermediate input might be increased by the increaseof after-tax wage rate because the demand for the polluting input is inversely dependent of the rate of return of the polluitng input.

Since these substitution effects such as two other intermediate inputs are limited in their magnitude, the impact of tax recycling through labor income tax rate reduction is expected to be insiginficant in this model.

To investigate the impact of labor income tax rate reduction, when energy tax rate like τ_E is increased, we need to lower labor income tax rate (t_L) to maintain the government budget neutrality. In this simualtion at first we increased τ_E by 10% which is the same rate in the previous section. As we anticipated, the ouput is increased by 0.01%

overall after the tax recycling through the income tax rate reduction. This insignificant output increase after tax recycling can be explained by many analytical ways. But, the inflexibility of this model in terms of labor supply seems to provide a reasonable explanation.

1.3 Impact of Energy Tax Recycling through Transfer Payment Increase

One of most significant equity enhancing policy is public assistance program like transfer payment. Through transfer payment we can provide another case under which double dividend is possible. When we assume two types of households whose have different income sources, there will be classified as active household and inactive household. While the active household obtains income entirely from labor earnings, the inactive household acquires its income through government's transfer payment. Also it can be assumed that transfers are not subject to labor income tax but to consumption tax price index used to determine real transfers does not include consumption taxes.

Suppose environmental tax to be imposed on dirty good consumption. Even though the active household is affected by higher commodity prices and consequently the active household's real income is reduced for the imposition of the higher environmental tax, government can compensate the active household more than the income loss due to the higher environmental tax because the tax reform for equity shifted the tax burden from labor income earners to transfer beneficiaries. This shift comes from the fact that transfer payments are subject to consumption tax. In this case the incremental environmental tax raises real wages and employment and it seems that the improvement of environmental quality becomes accompanied by a higher level of employment. Therefore the double dividend like higher environmental quality and more efficiency in labor market can be realized. However, this incremental effect of transfer payment needs that there are distinct groups like active and inactive ones who have different income sources. Without distinctive groups, transfer payment can induce the efficiency loss because transfer payment can be considered as lump-sum transfer in the economy. The tax recycling method through lump-sum transfer has been criticized for its raising effect on the deadweight loss.

Suppose the increase in tax rate imposed on polluting intermediate goods as same as previous case and the transfer payment is used as environmental tax recycling method. This implies that we increase both τ_E and *Tr* at the same time to maintain the budget neutrality. When we look at the simulation result, it is found that overall output level is decreased by 0.43%, which is very significant output effect. Therefore it can be said that in Korea there is no obvious two group like active and inactive group in terms of income sources.

2. Utility Changes through Energy tax Recycling

2.1 Impact of Energy Tax Recycling through Corporate Income Tax Reduction

Instead of output change, we can investigate the possibility of double dividend hypothesis through uility level change after the tax recycling of corporate income tax reduction. Even though output level is more frequently used for the measurement of national welfare change, the amount of utility level has been used as the sound measurement for welfare level change. In this model utility faunction has three utility sources such as consumption of energy and non-energy goods and fuel consumption. While the consumption of former two goods provides utiilty, the consumption of fuel make each household to be worse off in terms of utility level. The fuel consumption becomes a variable which provides the positive utilities through consumption of enegy and non-energy goods and the negative utilities for polluting effect on the consumer.

In this case, we can find a consistent simulation result with output change investigation result. Suppose in this simualtion at first increase the fuel tax rate τ_E by 10%. Then lower the corporate income tax rates as the previous section. After this tax-recycling we can fuind the equilibrium level of energy and non-energy goods output production. With these eqilibrium level of each goods and equilibrium level of polluting input demand, we can calculate the corresponding the utility level. After these simulation process, we can find the utility level increase by 0.17% which is consistent result with the previous section of investigation about output level change.

2.2 Impact of Energy Tax Recycling through Labor Income Tax Reduction

Instead of the reduction of the coprporate income tax rate, we can implement environmental tax recycling through the reduction of income tax rate. In this section we can investigate the welfare impact of labor income tax rate reduction in terms of utility level. In untility function, the utiltiy source variable includes only two goods and fuel consumption. Since in this model leisure is not included as utility source in the utility functional form, the reduction of labor income tax rate is expected to raise a little more utility level than otherwise.

Because the reduction of income tax rate is expected to induce more labor supply, the tax recycling through labor income tax rate reduction might result in a less leisure consumption in the labor market under perfect competition, which induces the decrease of utility level since leisure is one of the utility sources. However, since in this model leisure is not included in the utility functional form, the net impact of reduction of labor income tax rate is expected to be dependent only of substitution effect due to the increase of after-tax wage rate. Therefore in this model the utiltity effect of labor income tax rate reduction is expected to be more positive one because the reduction of labor income tax rate induces the utility decrease for the reduction of leisure in the case of utility function with leisure as a utility source.

Suppose we do the same restructuring of taxation system such as increase of the tax rate imposed on polluting intermediate goods and the decrease of the labor income tax rate. To investigate the impact of labor income tax rate reduction, when energy tax rate like τ_E is increased, we need to lower labor income tax rate (t_L) to maintain the government budget neutrality. In this simualtion case at first we increased τ_E by 10% which is the same rate in the previous section. As we anticipated, the ouput is increased by 0.02% in terms of overall utility level after the tax recycling through the income tax rate reduction. Even though this growth rate is very small number, the number seems to be a little higher than the case of the output growth comparison. This insignificant, but a little higher utility increase after tax recycling can be explained by many analytical ways. But, while the inflexibility of this model in terms of labor supply seems to provide the reasonable and primary explanation, the functional form difference between production function and utility function.

2.3 Impact of Energy Tax Recycling through Transfer Payment Increase

As previously explained, the equity enhancing policy such as transfer payment. can provide another possibility of the realization of double dividend hypothesis. With the assumption of two types of households whose incomes have different sources like labor earning and transfer payment, we can classify all the households such as the active and the inactive household. While the active household obtains income entirely from labor earnings, it is assumed that the inactive household acquires its income through government's transfer payment. Also it is possible to assume that transfer payments are not subject to labor income tax but to consumption tax because price index used to determine real transfers does not include consumption taxes.

Suppose environmental tax to be imposed on polluting good consumption. Then, the government can compensate the active household more than the income loss due to the higher environmental tax because the tax reform for equity shifted the tax burden from labor income earners to transfer beneficiaries. In this case the incremental environmental tax raises real wages and employment and it seems that the improvement of environmental quality becomes accompanied by a higher level of employment. However, this incremental effect of transfer payment implies that there are different groups who have different income sources. Without distinctive groups, transfer payment can induce the efficiency loss because transfer payment can be considered as lump-sum transfer in the economy. The tax recycling method through lump-sum transfer has been criticized for its raising effect on the deadweight loss.

When the welfare effect of transfer payment in terms of utility level, in this model we need to consider the effect of lack of leisure variable in the utility functional form. Since the main effect of transfer payment to raise the possibility of double dividend comes from the raised employment level, the lack of leisure can reduce the negative impact of leisure reduction due to the transfer payment increase. Therefore, we can expect the less negative impact of lack of leisure when we calculate the welfare effect of tax recycling through transfer payment increase in terms of utility level.

Suppose the increase in tax rate imposed on polluting intermediate goods as same as previous case and the transfer payment is used as environmental tax recycling method. This implies that we increase both τ_E and Tr at the same time to maintain the budget neutrality. Comparing with the simulation result, it is found that overall utility level is decreased by 0.38%, which is very significant utility effect. As we expected in the magnitude of negative impact of transfer payment, the amount of utility decrease becomes smaller than the simulation result of output change case. This simulation result seems to confirm once more that in Korea there is no obvious two group like active and inactive group in terms of income sources.

3. Evaluations of the Simulation Results

3.1 The Double Dividend Possibility Through Income Tax Reduction

In previous section, we investigate the possibility of double dividend in Korea through environmental tax recycling. At first the reduction of corporate income tax is applied for the tax recycling method to find out the possibility of double dividend such as environmental improvement and less tax distortion in the economy. Since the improvement of environmental quality is taken for granted through the mechanism of higher environmental tax rates, the higher efficiency due to less tax distortion can be considered as the proof of realized double dividend from environmental taxation.

After the simulation, it is found that while corporate income tax rate reduction can raise the possibility of double dividend in Korea, labor income tax rate reduction does not provide enough driving force for the double dividend of environmental taxation. While the output effect of corporate income tax rate reduction is significant like an increase of 0.12% , the labor income tax rate reduction does not deliver the significant impact to the output growth since the output is just increased by 0.01%. This insignificant effect is partially expected because the model in this study assumes the inflexibility of labor supply.

Another simulation to investigate the welfare effect in terms of utility level is implemented. The simulation results are very consistent with the result of the previous simulation for the calculation of output effect from the tax recycling through income tax rate reduction. The reduction of corporate income tax rate induces a higher utility increase than the impact of the labor income tax rate on utility level. Also the magnitude of growth rate is a little higher in terms of utility increasing rate comparing with the output increasing rate.

From above simulation results, we could suggest that the environmental tax recycling through the corporate income tax rate reduction would induce the economic efficiency increase significantly. However, the environmental tax recycling through the labor income tax rate reduction would have ambiguous effect on efficiency gain. Therefore, while the corporate income tax rate reduction could induce the double dividend in Korea, the tax recycling through the labor income tax rate reduction could not provide a definite answer to the existence of double dividend after imposing the higher environmental taxation.

3.2 The Double Dividend Possibility Through Increased Transfer Payments

In previous sections, we investigate the possibility of double dividend in Korea through output and utility effect of transfer payment increase as one of the tax recycling method for environmental protection. In this section we focus how to evaluate those effects as an indicator for the feasibility of double dividend in Korea.

When we check the simulation results, it can be found that while output level is decreased by 0.43% through transfer payments increase, the utility level is reduced by 0.38% through the lump-sum transfer. From these simulation results we can say that there is no double dividend in Korea if the transfer payments increase is used for environmental tax recycling method. Also it can be said that since in Korea there is no obvious two group like active and inactive group in terms of income sources, the transfer payment increase induces only more distortion which lump-sum transfer payment can create in labor market.

Chapter 8
Conclusions and Suggestions for Further Studies

1. Summary and Policy Implications

Up to the previous chapter, we have shown the process about how to test and evaluate if the double dividend hypothesis can be applied to the Korean economy under the simple framework of two production sector and three input factor. The applied recycling methods are the reduction of corporate income tax rate, the reduction of labor income tax rate and the transfer payment increase.

All the first four chapters explains the model structure and the detailed simulation process, following with theoretical concepts of double dividend hypothesis in detail. The next two chapters are about how to the actual Korean energy-related tax structure can be applied to the all the steps in the simulation process. The coefficient estimation using *The Survey of Urban Household Expenditure* and *The Input-Output Tables* must be the first step in finding the actual Korean economic structure. After that stage, the appropriate tax rates in Korean energy-related tax system , which will be applied to simulation process, has been identified before all the tax rates are applied to the finding actual equilibrium rate of return of each production factor. Then we can find the initial equilibrium rate of return of each production factor in Korean economy. With these results we can calculate the benchmark output level in Korean economy before energy tax reform with tax recycling.

After finding benchmarks, we implement the simulation process for three methods of tax recycling such as the tax rate reduction of corporate income and labor income and the transfer payments increase. The simulation process reveals us that the tax rate reduction induce some efficiency gains and the transfer payment increase results in more distortion to the economy. In terms of double dividend hypothesis, the strengthened environmental taxation with other distortionary tax rate reduction can make double dividend to be realized in Korea even though the magnitude of the second dividend is dependent on the tax recycling method. However, since the transfer payment increase could not induce efficiency gain, the double dividend of this case cannot be realized in Korea.

2. Extensions for Further Studies

After this process is confirmed as relevant in the test procedure about the applicability of double dividend hypothesis to Korean economy, we need to extend this analytical testing method of double dividend hypothesis to more complicate economic system. In previous analysis, we considered the interdependence between non-energy goods sector and energy goods sector only in terms of equilibrium condition in each factor market such as labor, clean intermediate, and polluting intermediate market. However, in real world the interdepences between each sector are more complicated. Also when we divide both energy goods sector and non-energy goods sector into more sub-sector, the economic impact of interdepences between sectors becomes more significant.

Besides the more complicated interdependence, another significant extension of this study will be the investigation of welfare impacts of other tax recycling method such as the increased subsidies to energy-saving technology R&D and the heavy taxation on energy-intensive industry. Each recycing method needs more modification of previously suggested analytical model and more data set for the wider scope than previous analysis. However, if those extensions are implemented and find some concrete results about the applicability of the double dividend hypothesis, the conclusion about the validity of double dividend hypothesis to Korean economy becomes more meaningful and significant in determining what is the appropriate direction for the next Korean energy price reform which is scheduled to be started in 2006.

References

Bosquet, Benoit (2000), “Environmental Tax Reform: Does It Work? A Survey of the Empirical Evidence,” *Ecological Economics*, Vol. 34, pp.19-32.

Bovenberg, Lans and De Mooij, Rudd (1994), “Environmental Levies and Distortionary Taxation”, *American Economic Review*, Vol.84, No.4, pp.1085-1089.

Bovenberg, Lans and Goulder, Lawrence (1997), “ Costs of Environmentally Motivated Taxes in the Presence of Other Taxes: General Equilibrium Analyses”, *National Tax Journal*, Vol.50, pp.59-88.

Bovenberg, Lans and Goulder, Lawrence (2001), “ Environmental Taxation and Regulation”, *NBER Working Paper No.8458*, pp.1-65: App. 66-75.

Bovenberg, Lans. and van der Ploeg, F. (1994a), “ Environmental policy, public finance and the labor market in a second-best world”, *Journal of Public Economics*, Vol.55, pp.349-390.

Bovenberg, A. Lans and van der Ploeg, F. (1994b), “ Green Policies and Public Finance in a Small Open Economy”, *Scandinavian Journal of Economics*, Vol.96, No.3, pp.343-363.

Carraro, Carlo and Marzio Galeotti and Massimo Gallo (1996), “Environmental Taxation and Unemployment: Some Evidence on the

'Double Dividend Hypothesis' in Europe," *Journal of Public Economics*, Vol.62, pp.141-181.

Cremer, Helmuth and Gahvari, Firouz (2001), " Second-Best Taxation of Emissions and Polluting Goods", *Journal of Public Economics*, Vol.80, pp.169-197.

Goulder, Lawrence (1995a), "Environmental Taxation and the 'Double Dividend': A Reader's Guide", *International Tax and Public Finance*, Vol.2, pp.157-183.

Goulder, Lawrence (1995b), " Effects of Carbon Taxes in an Economy with Prior Tax Distortions: An Intertemporal General Equilibrium Analysis", *Journal of Environmental Economics and Management*, Vol.29, pp.271-297.

Goulder, Lawrence and Parry, Ian and Burtraw, Dallas (1996), " Revenue-Raising vs. Other Approaches to Environmental Protection: The Critical Significance of Pre-Existing Tax Distortions", *NBER Working Paper No.5641*, pp. 1-27; App.28-44.

Goulder, Lawrence and Parry, Ian and Williams III, Roberton and Burtraw, Dallas (1998), " The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second-Best Setting", *NBER Working Paper No.6464*, pp.1-30, App.31-48.

Goulder, Lawrence and Schneider, Stephen (1999), " Induced Technological Change and the Attractiveness of CO_2 Abatement Polices", *Resource and Energy Economics*, Vol.21, No.3-4, pp.211-253.

Nordhaus, William (1982), " How fast should we graze the global commons?", American Economic Review, *AEA Papers and Proceedings: 84th Annual Meeting*, Vol.72, No.2, pp.242-246.

Parry, Ian and Williams III, Roberton (1999), "A Second-best Evaluation of Eight Policy Instruments to Reduce Carbon Emissions", *Resource and Energy Economics*, Vol.21, No.3-4, pp.347-373

Parry, Ian. and Bento, Antonio. (2000), 'Tax Deductions, Environmental Policy, and the "Double Dividend" Hypothesis, *Journal of Environmental Economics and Management*, Vol.39, No.1, pp67-96 .

Pearce, David (1991) "The Role of Carbon Taxes in Adjusting to Global Warming", *Economic Journal*, Vol.101, pp.938-948.

Terkla, David (1984), " The Efficiency Value of Effluent Tax Revenues", *Journal of Environmental Economics and Management* ,Vol.11, pp.107-123.

Williams III, Roberton (2000), " Health Effects in a Model of Second-Best Environmental Taxation or Reconsidering 'Reconsidering the Tax-Interaction Effect'", *NBER Working Paper No.8048*, pp. 1-13.