Optimal Energy Taxation for Environment and Efficiency: Focusing on The Double Dividend Hypothesis

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ABSTRACT

During the initial economic development period, energy consumption had been promoted through the low price policy since sufficient and secure energy supply is considered as primary factor to economic expansion. However, since more energy consumption for economic growth can induce the harmful side-impacts, it is believed that the control of energy consumption is desperately necessary through pertinent mechanisms for the sustainable economic development.

Despite of the need for energy control, energy pricing based on its own cost and externalities will produce a huge and languid impact on industrial production. Because energy is main production factor in every industry sector, the induced cost increase tends to cause less production and more unemployment. This trade-off between environment and growth makes every government hesitate to establish relevant energy pricing system which reflects pertinent social cost including externality cost.

From this point of view the double dividend hypothesis is suggesting how environment and 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. In addition, the hypothesis provides a rationale for those energy taxes or subsidies to encourage a greater energy conservation or increased supply of alternative fuels.

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 the actual dominant measures have been environmental regulatory standards, most economists have insisted the superiority of the pollution taxes over the regulations because the tax system induces the polluter to internalize all external pollution costs and provides a continuing incentive for polluter to develop cheaper forms of 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. As preliminary work to attain this target, in this limited study I will investigate the specific conditions under which double dividend hypothesis can be valid, and set up the model for optimal energy taxation. The model will be used in the simulation process in the next project.

As the beginning part in this research, I provide a brief review about energy taxation policies in Sweden, Netherlands, and the United States. From this review it can be asserted that European countries are more aggressive in the application of environmental taxes like energy taxes for a cleaner environment than the United States.

In next part I examined the rationale for optimal environmental taxation in the first-best and the second-best setting. Then I investigated energy taxation how it can provoke various distortions in markets and be connected to the marginal environmental damages and environmental taxation. In the next chapter, I examined the environmentally motivated taxation in the point of optimal commodity taxation view. Also I identified the impacts of environmental taxation in various circumstances intensively to find out when the environment tax can yield double dividend after taking into account of even tax-interaction effects. Then it can be found that even though in general the environmental tax exacerbates the distortion in the market rather than alleviates, it can also improve the welfare and the employment under several specific circumstances which are classified as various inefficiencies in the existing tax system.

As pre-existing inefficiencies in the tax system which promote double dividend from environmental taxes, there are following market characteristics. When clean good consumption as a better substitute for leisure and environment as a substitute for leisure are the cases, environmental taxes are likely to yield double dividend. Also when environment is used as a public input into production, and there are pre-existing subsidies on polluting activities, we can find another sources for yielding double dividend. If environmental tax plays a role of optimal tariff and rent tax, the environmental taxation can induce double dividend. Inefficient factor taxation and inefficient commodity taxation are another cases which can yield double dividend from the environmental taxation. When environmental tax is used as a spur to energy-saving technology improvement, and the transfer program enhancing equity is implemented, we can find another sources for yielding double dividend from environmental taxation.

In the next part, I provide a detailed description of the model which can explain in analytical way the conditions under which double dividend of the environmentally motivated taxation is possible. In this model there are two sectors like non-energy good and energy good sector. While non-energy good sector consists of non-energy-intensive manufacturing goods which use fossil fuel not intensively, energy good sector represent the industry which produces energy-intensive manufacturing goods. This model also assume two kinds of consumption goods such as energy-goods and non-energy goods. While energy goods represent the final output from industries that use fossil fuel intensively, non-energy goods are ordinary goods from industries that use fossil fuel not intensively. After using many optimization processes through utility maximization and cost minimization and various market equilibrium conditions, finally we can identify the partial derivatives' conditions under which double dividend from the environmental taxation is possible.

After these findings, in the next project I will expand this investigation into more essential field such as finding the appropriate energy-related tax system for sustainable development. The one of the ultimate targets of further study will be a finding the applicability of the double dividend hypothesis to Korean economy.

국문요약

경제성장 초기에는 에너지의 소비가 저에너지가격정책 등을 통해 촉진되지만 경제성장이 어느 정도 성숙한 연후 에는 에너지소비로 인한 경제 전반에 걸친 부정적 효과에 대한 적절한 관리가 시급히 요청된다. 그러나 이러한 에너지 소비에 대한 적절한 관리의 필요성에도 불구하고 진정한 사회비용을 감안한 에너지가격의 현실화는 경제성장에 부정적 영향을 줄 수 있기에 그 실현이 지연되고 있다. 이러한 현실에서 환경보호와 경제성장 문제가 대체적 관계가 아닌 보완적 관계를 형성할 수 있다는 이중배당이론은 지속가능한 경제발전에 적절한 에너지가격 체계를 구축하는데 있어서 유용한 이론으로 인정되고 있다. 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.

에너지소비의 적절한 관리의 필요성에 의해 시작된 본 과제의 장기적 목표는 환경과 효율성 측면에서 가장 바람직한 에너지세제가 무엇인가 하는 것을 이중배당이론을 중심으로 밝히고자 하는 것이다. 그러한 장기적 목표의 효과적 달성을 위해 본 과제는 그 준비 작업을 수행함을 목적으로 하고 있는데, 이를 위해 이중배당이 가능한 경제적 상황 및 여건을 파악하고 적정 에너지조세의 경제적 효과분석을 위한 기본모형의 수립에 그 구체적 목적을 두고 있다.

적정물품세이론을 중심으로 검토한 적정에너지세제의 특

성을 중심으로 이중배당현상을 검토해본 결과 이중배당이 나타나는 특이한 시장상황의 경우를 살펴보면 다음과 같다. 일반재가 여가와 강한 대체성을 가지고 있거나 환경수준이 여가와 대체관계를 가지고 있는 경우 이중배당이 가능하게 된다. 또한 환경이라는 변수가 주요한 생산요소가 되는 경우와 오염행위에 대한 보조금지급이 행해진 경우도 이중배당 현상이 나타나게 된다. 국제교역조건개선에 환경세가 기여하는 경우도 이중배당이 가능하게 된다. 생산요소나 재화에 대한 비효율적인 과세도 이중배당의 가능성을 높여준다. 이밖에도 환경세가 에너지 절약기술 향상에 기여하거나 형평성 향상을 위한 높은 이전소득지출이 이루어지면 이중배당현상이 가능하게 됨을 알 수 있다.

본 연구에서 수립된 모형은 2개의 소비재화와 2개의 생산부문을 가정한 일반균형모형으로서 각종 최적화과정을 거쳐 도출된 편도함수 형태를 통해 환경세의 이중배당 가능성을 앞부분에 열거된 여러 상황 하에서 검토할 수 있도록 구성되어 있다.

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Chapter 1
Introduction

One of the most depressing problems which the human face today is the continuous deterioration of natural environment. Environmental protection has been an intriguing, but tough issue to most economists. Since in economic theoretical progress the environmental issues have been viewed as the problems of market failure due to missing markets, it needs public intervention, which requires government's specific activities. Among many environmental issues, air pollution has been main target from the starting point when people becomes more concerned about environment. Greenhouse gases and ozone-depleting chemicals have been incessantly injected into atmosphere since Industrial Revolution started at the eighteenth century in Europe. Energy consumption is directly related to these types of air pollution. Originally energy consumption is considered as the major input of production process. While at the first stage in Industrial Revolution coal consumption had the role of main energy source, since the last century oil consumption have been main contributor to the industrial development. However, the more developed the industry structure becomes, the more harmful externality energy consumption produces.

During the initial development period, energy consumption had been promoted through the low price policy since sufficient and secure energy supply is thought as primary factor to economic expansion. However, since the rapid growth of economic size can accelerate the harmful impact of energy consumption, it is believed that the control of energy consumption is desperately necessary through pertinent mechanisms for the sustainable economic development. Since energy consumption is intrinsically contributing to not only production but also pollution, it is believed that energy consumers must pay both energy market price and the externality cost due to energy consumption for the improvement of environmental quality. However, energy pricing based on its own cost and externality cost will produce a huge and languid impact on industrial production. Because energy is main production factor in every industry sector, the induced cost increase induces less production and less employment. This trade-off between environment and growth makes every government hesitate to implement relevant energy pricing system which reflects pertinent social cost including externality cost.

From this point of view the double dividend hypothesis is suggesting how environment and 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. But it provides policy remedies for the market failure in energy sector. Double dividend hypothesis provides a rationale for those energy taxes or subsidies to encourage a greater energy conservation or increased supply of alternative fuels.

Energy policy can make some economic effects such as allocation efficiency, income distribution, effect on energy demand and import. Because of these broad impacts of energy policy, in the real world there are many constraints which restrain 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 the new energy policy 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 the actual dominant measure has been the establishing of 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 a continuing incentive for polluter to develop cheaper forms of 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. As preliminary work to attain this target, this limited study will investigate the specific conditions under which double dividend hypothesis can be valid, and set up the basic model for optimal energy taxation. The model will be used in the simulation process in the next project.

Therefore, this research will focus finding the specific conditions where double dividend hypothesis can be possible and find out when environmental taxes can provide efficiency gains besides environmental improvement in the economy. To explore this issue, in the first part, the current situation about energy taxation in other countries will be reviewed. Among the developed countries, there are chosen three countries such as Sweden, Netherlands and the United States because European countries and America have contrasting energy taxation systems due to the deep policy difference toward the taxation scheme. In chapter 3, the analysis will be focused on the 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 4, there will be a investigation about the energy taxation in terms of the tax distortions in labor, capital, intermediate input and commodity markets and describe how marginal environmental damages need to be controlled through energy taxation. In chapter 5, the environmentally motivated tax reform will be examined in terms of welfare improvement with the emphasis on double dividend hypothesis. In chapter 6, there will be theoretical analyses on how pre-existing inefficiencies in the tax system can induce the circumstances under which double dividend can be realized.

After all these theoretical analyses about optimal energy taxation and the related issues, in chapter 7, 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 final chapter, first of all, there will be a summary of all the findings from the previous chapters, and then suggestions of the topics for further studies and the detailed explanations about what is main purposes in the next study and how to proceed the research with the descriptions about the preparatory works and the alternative policy instruments for the optimal energy taxation.

Chapter 2
Environment, Energy and Taxation:
The Cases of Sweden, Netherlands, and the United States

1. Sweden

1.1 Overview

The incorporating of environmental taxes into the tax system had been a purely academic issue in Sweden until the end of 1980's. Since 1960s, Swedish economists had recommended several economic instruments for efficient environmental policy and illustrated the beneficial secondary effects in the partial substitution of environmental taxes for the distortive income taxes and the possibility of less excess burden of government revenue. This suggestion significantly influenced practical policy in Sweden, and finally produced the Swedish tax reform of 1991, where a significant role was given to the set of environmentally motivated taxes and simultaneously the burden of indirect taxes was increased to allow for the reduction of direct taxes. It was believed that if there was not the reduction of direct taxes like personal and corporate income taxes, environmental taxes could not have been introduced to the extent of 1991 tax reform.

The 1991 tax reform proponents intended to create a simpler and less distortionary tax system which provided less disincentives due to the imposition of very high marginal income tax rates. To attain the less ditortionary tax system, first of all Swedish tax system needed to reduce significantly the marginal income tax rates, whose top rate was dropped to 73 percent from 85 percent in 1989. The 1991 tax reform reduced the marginal income tax rate to 30 percent for most income earners and 50 percent for the remaining high income earners. To finance the compensation for the reductions in income tax revenue, the 1991 tax system sought to broaden the Value-added tax(VAT) base and increase the VAT tax rates, emphasizing the relevance of raising indirect tax revenues. Also the more uniform capital income tax rates are imposed to rectify the distortion between saving and borrowing. More environmental protection induced the 1991 tax reform to focus more on the restructuring of energy tax system.

1.2 Main features in Swedish energy taxes

Total taxes in Sweden in 1991 amount to 56 percent of GDP. Three categories like income taxes, indirect taxes and social security contributions make all the government revenue. While the proportions of income taxes and social security contributions are 21.3 percent and 17.8 percent separately, indirect taxes has a proportion of 16.9 percent. Among indirect taxes, while VAT has a primary role of 9.8 percent of GDP, all excise taxes have a share of 7.1 percent and customs has remaining small portion.

Before the 1991 tax reform, the Swedish instruments used for environmental policy were heavily dominated by the command-and-control type. Prior to 1991 there were a number of indirect taxes which originally had a purely revenue-raising purpose. However, as there have been more debates over the environmental protection and the mitigating inefficiency in Swedish tax system with too high marginal income tax rate, those indirect taxes has been given the additional role of instruments for environmental policy as well as for reducing tax distortions. Several taxes on energy consumption, in particular the general energy tax and the gasoline tax, can be referred to this category.

The new primary environmental taxes introduced in the 1991 tax reform include a carbon dioxide tax on fossil fuel and a sulfur tax on coal and oil. In addition, VAT has been extended to all fuels and a nitrogen oxide taxes are charged on emissions from large combustion plants. Energy taxes dominate among the taxes related to the environment even though they are far from being designed to comply with the environmental effects of different energy uses. To make more efficient Swedish energy tax system, many economists insist that the elimination of tax on clean energy like hydropower electricity and the increase of taxes related to carbon dioxide, sulfur, and nitrogen oxide emissions, and no more deduction of fuel taxes in electricity production.

Comparing with energy taxes on fossil fuels, the energy tax on electricity has a different structure. While the general electricity tax rate is lower in industrial uses than in non-industrial uses, some regions have the opposite tax structure because of the regional policy. The general energy tax and CO_2 tax are deductible from electricity taxation. On nuclear power there is an additional electricity tax. Another feature in the restructuring of Swedish energy tax system is that the relative prices of coal, LPG, and natural gas to oil become higher because Swedish government want to give more incentive effect for environmental protection. The increased energy tax revenue is likely to promote energy saving in industry as well as in the household sector.

When we estimate the emission reductions resulting from the restructuring of energy tax system, the estimation of result is appealing to us. After the introducing of sulfur tax, the sulfur tax induced a significant reduction in the sulfur content of fuels and stimulated power plants to invest in abatement technology.

There has been considerable concern in Swedish economy over the effect of the high energy taxes on energy-intensive industry. Reflecting this concern, it has been proposed that energy taxes for industry should be reduced to prevent Swedish energy-intensive industry from fleeing into foreign countries which have advantages in terms of tax burden. Therefore there is a limit to energy taxes on energy-intensive industry which shows a sharp conflict with efficient environmental policy. The limit implies that, if energy taxes exceed 1.7 percent of the sales value of a firm, the firm can increase its use of fuels without paying any additional energy taxes. Moreover, it means that the incentive for energy saving is much less significant for energy-intensive industry than for small energy users.

A significant part of environmental taxation in Sweden is related to the use of energy for transportation. An efficient taxation on the transportation energy use request us that tax rate should reflect social cost of energy use including environmental damages. However, since the effective differentiation of transportation energy uses is practically impossible, Swedish tax system is designed as multi-part scheme including sales taxes on new cars, annual vehicle tax on ownership of cars, and kilometer taxes according to use. However, the higher sales tax on new cars, the higher the incentive to keep old cars longer becomes. Since this tendency induces more emissions which are harmful to environment, Swedish environmental tax system tends to do poor performances in terms of environmental quality. Therefore sales tax on new cars needs to be reduced and annual vehicle taxes must be increased to compensate for the tax revenue loss due to the reduced sales tax on new cars.

Most of environmental taxes in Sweden is earmarked for specific uses of the revenue obtained. This earmarking is defended even from efficiency point because those taxes cannot be politically acceptable if not earmarked. After the reform, total environmental tax revenues are expected to increase up to additional 2 percent of total government revenue. However, when environmental taxes have been introduced in such a large scale, earmarking would be more likely to cause efficiency problems. Therefore it is suggested that a significant portion of the newly introduced environmental tax revenue can be spent without earmarking.

Even though Swedish environmental tax system has the comprehensive and efficient features, the design of non-compliance charge is significantly inefficient and has many incentives for violation because the burden of proof is heavily placed on the prosecutor and the charge is limited only to the amount of gain of the company.

Since main result of 1991 tax reform is to increase the amount of indirect taxes, the reduction of direct taxes like personal income tax is necessary to provide the rationale for expanded environmental taxation. The background of this drastic shift of Swedish tax policy seems to be based on the double dividend claim that tax-recycling effect can dominate the tax-interaction effect in the economy with highly distorted labor market due to too-high personal income tax rates.

2. Netherlands

2.1 Overview

Since 1970s the environmental policy of Netherlands has steadily evolved into the integrated system dealing with air, water, soil, and waste removal separately. Specially in 1989 Dutch government intensified National Environmental Policy Plan with a plan of drastic increase in environmental expenditure, resulting in double expenditure size until 1994. Dutch environmental policy primarily consists of direct regulation and voluntary agreements with producers. The role of economic instruments had been rather limited, but in 1992 energy taxation focusing carbon emission and energy content was introduced. Also in 1996 the regulatory energy tax was introduced for the promoting the consumption of environmentally-friendly energy.

In Netherlands environmental taxes and charges are main financial resources for environmental expenditure and has a broad tax base and a little tax preferences. Only the preferable tax treatment is applied toward non-leaded gasoline and cars with low-emission converter for an incentive purpose.

Also subsidies are applied in energy tax system to promote energy conservation, low emission and more R&D for clean energy. In environmental policy these subsidies has been used to fulfill complementary roles in reconciling direct regulation with voluntary agreements in environmental protection. While major subsidies are applied energy conservation, CHP (= combined heat and power), renewable energy sources, low emission vehicles, and low emission heating, minor subsidies are provided to R&D for clean technology, compliance cost, and environmental management system.

Dutch energy tax system can be described as a compromise between the ability-to-pay principle and direct benefit principle because it consists of consumption taxes for revenue increase and energy taxes for environmental conservation. The direct benefit principle implies that those who provide harmful effects to society must pay for the pain. While consumption taxes are based on the ability-to-pay principle, the direct benefit principle is applied to energy taxes because those taxes are collected from the polluters who provide environmentally harmful effects.

2.2 Main features in the Netherlands' environmental and energy tax

In Netherlands there are two energy-related taxes, which are the general fuel tax for revenue raising and the regulatory energy tax for energy conservation and carbon dioxide reduction. While two taxes has similarity in terms of taxation criteria, tax bases and tax rate structure are different. Both taxes are imposed on carbon dioxide content and energy content of each fuel. However, while the general fuel tax system is based on the all kinds of energy consumption and has a relatively lower tax rate structure, the regulatory energy tax is imposed mainly on the consumption of diesel, natural gas, electricity and has a higher tax rate structure than general fuel tax.

Since 1988, the main resource for Dutch environmental policy is the general fuel taxes whose primary goal is originally revenue raising. Those taxes replace the previous charges on air pollution, noise, lubricant oils and chemical waste. As one of those taxes, excise taxes on gasoline and diesel has been strengthened through 1990s like average annual increase rate of 4.2% on unleaded gasoline and 6.3% on diesel fuel. Furthermore the preferable tax treatment on unleaded gasoline comparing with leaded gasoline has provided a strong incentive for rapid switch to unleaded gasoline.

In 1990s main targets of Netherlands' energy tax policy has been both a sustainable development and environmental improvement. To make those targets more easily implemented, in 1992 the new energy tax system was introduced through recommendations of EC. This new energy tax system provided new environmentally motivated tax bases so that the half of general fuel tax revenue comes from taxation on carbon content and the remaining half revenue is based on energy content of the fuel. In 1996 current regulatory energy tax was introduced for increase in supply of cleaner energy. The regulatory energy tax provides several tax exemptions toward the consumptions of heating energy provided regional heating system, natural gas for electricity and farming, green electricity.

Users of oil and coal who reduce sulfur dioxide emission and implement a higher rate of desulfurization can get a partial tax refund. This refund scheme is a kind of concession to the power plants which have invested in gas desulfurization. The tax preference toward gas oil for road traffic and large user of natural gas has been introduced for distributional improvement. More generally the energy tax system is dependent on the distributional and political reckonings rather than the concern about environmental impacts of various fuel consumptions.

Since 1998 Netherlands government started tax recycling to household and corporations through the reductions of personal and corporate income tax rate and the increases of household's and corporation's standard deduction amount. This tax recycling has a target to compensate the reduction of overall disposal income in households and corporations due to new regulatory energy tax introduced in 1996. This tax policy is likely to mitigate the resistance against the environmental taxation. Even though the taxation is believed to provide the efficient environmental protection scheme at lower cost, the main reason for the unpopularity of environmental taxation comes from the preferences of industry and environmental bureaucrats toward prevailing command-and-control policy. To mitigate these preferences, the environmental taxation needs to complemented through various schemes generating more benefits besides environmental improvement. The tax recycling is considered as one of these methods. However, the validity of double dividend hypothesis in Netherlands is early to make assessment because tax recycling related environmental taxation just started..

3. The United States

3.1 Overview

Describing the structure of environmental taxes in the United States is not easy task. The U.S. has a federal system of government with central government, fifty states, and many thousands of local governments. Moreover, the fiscal system in the U.S. is a relatively decentralized one in which lower levels of government play the important roles both in the raising and spending of revenues.

Even though actual fiscal structures are very diversified and even confusing, general atmosphere in environmental policy has been more opt to the specific form of quantity instruments like tradable emission permit rather than price instruments such as fees or taxes. The rationale for this preference can be explained as following.

First, the quantity approach gives the environmental authority direct control over the level of pollution. Under the tax approach, the regulator must determine the level of tax, and if it is too low, the target level of pollution cannot be achieved. Since environmental standards are often stated in quantity terms, the environmental agency finds itself in a better position to achieve its regulatory objectives if it has direct control over the quantities of pollution.

A second issue has probably been of even greater importance in the United States. The introduction of any new tax has been fiercely opposed in the U.S. The proposal for the nationwide energy tax system based on BTU during the Clinton administration induced an immediate hostility and suspicion from public and industry. In contrast, a system of tradable permits can avoid this source of opposition when the environmental authority distributes these permits freely among existing sources based on historical performances.

Third, permits have the importance advantage of familiarity because environmental regulators have had long experience with permits. Therefore, even though price instruments have a number of advantages like the flexibility about the setting of uncertainty, generating public revenue, and avoiding the problems in actual operation of permit markets, the United States government still prefers the quantity instruments rather than environmental taxes.

However, current environmental policy reveals some kind of change from previous atmosphere. First of all, prevailing sentiments becomes stronger toward market mechanism for the better solution of social problems, under which atmosphere environmental taxes becomes more receptive than in past periods. There is a broad consensus that incentive-based market solution for environmental protection can provide more effective signals to individuals to find more beneficial ways to society than just command-and-control approach can do. Another reason for the favor to environmental taxation is that it can provide new revenue source with politically feasible targets because of U.S. budgetary stringency condition.

The current U.S. environmental policy, however, still has a tendency tilted to command-and-control approach even tough market incentive mechanism for environmental protection becomes more receptive because historically environmental protection mechanisms have been developed with more emphasis of standards checking.

3.2 Main features in the United States environmental and energy tax

Energy-related excise taxes and associated trust have become more common as a mechanism for internalizing externalities due to energy production and consumption. The primary energy tax in the United States is gasoline taxes which are levied by the federal and state governments and whose total level is lower than most European standards. The primary objective of gasoline taxes has not been an environmental one. These taxes have in large part been seen as an equitable way for financing the construction and maintenance of roads and highways. Highway Trust Fund established by Highway Revenue Act of 1956 has been financed mostly by federal gasoline taxes. Most of the revenue from these taxes are earmarked for transportation programs. Therefore, the construction of an Interstate System, and maintenances of state and local highways and urban routes are financed through the Highway Trust Fund. Even though the gasoline tax is not primarily an instrument for environmental management , it clearly has some side effects on environment, specially air quality.

The efficiency concerns has been implemented through various programs like energy efficiency programs for home appliances and commercial electrical equipments. Other programs are the energy efficiency enhancing programs for low income district and the power-generating equipments' efficiency enhancing program.

The tax incentives related to energy have mainly focused on the attainment of secure supply of energy. First, the preferential tax rates are applied to the capital gains treatment of royalties on coal. Second, the various tax deferrals have an intention to mitigate expenses of energy exploration and development. Third, the various tax credits are provided to oil industry, alternative fuel industry, new energy-related technology investment, and the use of alcohol fuel. As another tax incentive, the Percentage Depletion Allowance provides the measure which reduces taxable income in oil and other natural resources industry by permitting the company owners percentage depletion deductions rather than cost depletions to recover their investment.

Another energy tax in the United States is severance taxes, which are excise taxes levied on the extraction of mineral resources. These taxes are employed primarily at the state level and both the level of rates and the definition of the tax base vary widely among the states. Severance taxes can affect the environment through the impact that they have on the rates and timing of extraction of mineral resources. First they can discourage both exploration and extraction activities because taxation can render those operation unprofitable. Second severance taxes alter the time profile of extraction toward to the future. It can be said that lower levels of exploration, development, and extraction activities by these taxes may result in somewhat less environmental disruption.

Most of major tax and other fiscal programs with effects on the environment are state and local programs in the United States. Also they are vary widely in character and from state to state. Above gasoline taxes and severance taxes have a complicated structure across the states. A number of states employ environmental permit fees whose levels are flat or dependent on the level of discharges.

Some states initiated specific energy program besides tax incentives. Those programs have two broad goals like the promotion of competitive markets for energy efficiency services and the provision of more environmental benefits. Specifically, the energy program are categorized as energy efficiency enhancing services, low-income energy affordability expansion, and research and development investments.

Chapter 3
Environmental Taxation

1. Optimal Environmental Taxation in the First-best Setting

The deterioration of the natural environment becomes one of major challenges which current public policy of each government faces because of conflicting interests among many groups in each society. Energy-intensive industries are concerned that a more burdensome environmental protection is likely to induces both serious capital flight and income losses in the overall economy. In contrast, environmental groups insist that a more ambitious environmental policy may not need large economic cost, but induce higher environmental quality which provides various economic benefits. For example, the influence of the Clean Air Act of 1970 in the United States has provided two conflicting economic effects such as the costly relocation of polluting industries and the fewer environmental victims. Becker and Henderson (2000) analyzed these contrasting impacts with examining unintended effects of the Clean Air Act. Facing with these contradicting arguments and evidences, we need to investigate the interactions between the environmental externalities and the optimal level and structure of environment-related taxes and public spending.

Natural environment has many aspects of public goods since environmental resources like air and water are shared among people with non-rivality 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. Many important environmental qualities are the cases. Even though many environmental qualities have been quintessential to economic life, the production and consumption of those goods have not been implemented according to the principle attaining optimality. The non-existence or quasi-existence of market for environmental goods induces inefficient use of the environment, which often leads to excess demand for environmental goods. The decentralized market economy is inclined to provide imbalance between the demands for ordinary goods and environmental goods if there is no government intervention.

Inefficient use of environmental goods implies the need of government policy for the improving existing distortionary market functions which can be described as market failure caused by the absence of appropriate ownership. As the response to the problem of the absence of appropriate connecting agent between demand and supply, government environmental policies can provide the missing market, which is caused by missing ownership, for environmental goods. 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. It is true that the command-and-control policies have contributed to establish the significant environmental gains because by most measures the qualities of air and water in the developed countries have been improved than they were three decades ago.

However, even though the actual air has become cleaner, the command-and-control approach has encountered too many unnecessary litigations and frustrated so many innovations for environmental protection. Also for decades, government's environmental agency has kept the hostile attitudes toward industries since the agency considered the industries as main contributors. Therefore many economists have realized that the command-and-control approach become more expensive instrument in terms of welfare. Even the recognized environmental gains can be considered as attained at a needlessly high price. In particular, since environmental laws have specified particular technological standards for only achieving pre-targeted goals, they didn't consider the differences of local environmental conditions and marginal cost of pollution abatements among individual companies. The lack of appropriate cost-benefit analysis is another defect because in actual environmental policymaking like standard setting, the cost-benefit analysis has been ignored.

With the growing concerns about serious environmental problems and environmental protection cost, environmental taxes have attracted increasing attention because intensive-based and market-oriented environmental policy could result in improvement of environment at much less cost than the command-and-control approach.. Many economists have argued that pollution taxes, which reflect real social cost of polluting goods, are the efficient instrument for achieving environmental objectives. Theoretically pollution levies are used to improve economic efficiency by charging a polluter for the true opportunity cost of the resources being polluted because polluting input prices of polluter are priced too low. Pigou's classic theory on externalities showed us that the pollution tax employed to correct environmental problems could induce the efficient level of output.

However, there are many practical problems in implementing the Pigovian taxation scheme. Since the estimating of marginal damage in each pollution level is difficult, locating 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.

2. Optimal Environmental Taxation in Second Best Setting

Many studies on optimal taxation for environmental externalities have derived and illustrated the first-order conditions for optimal public policy. However, because in actual policy settings the pre-existing tax distortions, the incomplete information about the costs and benefits of the policy, and the contradicting interests between distributional concerns and economic efficiency are intermingled, the appropriate instrument for environmental protection is hard to find. Under these circumstances, the pollution taxation following Pigovian rule becomes no longer the optimal instrument because economists traditionally have analyzed environmental taxes without taking into account the presence of other distortionary taxes. This omission causes significant result because net effect of environmental taxes depends on the level of other pre-existing taxes like income 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.

While in earlier study on the effect of pollution tax Lee and Misiolek (1986) analyzed how the efficient pollution tax is altered by taking into consideration the efficiency gains generated by tax substitution in terms of partial equilibrium framework, Goulder(1995b) evaluated the net effects of pollution taxes in a dynamic general equilibrium framework which recognizes the interaction between the carbon tax and pre-existing taxes. In this framework, welfare impacts of carbon tax is deeply dependent on the initial conditions of pre-existing tax structure. Goulder showed us that the higher marginal rates of pre-existing taxes, the positive effect of carbon tax on welfare becomes weakened. Therefore the model disregarding the pre-existing taxes tends to underestimate negative welfare costs of environmental tax initiatives.

When emissions has impact on production side, the implications of optimal pollution tax structure can be altered because the relationship between emission and production has a significant effect on pollution tax base. Cremer and Gahvari (2001) investigated the optimal design of second-best pollution tax when production costs have negative relationship with pollution. They claimed that the first-best 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 comparability constraints. Also the adjustment term reflects the revenue effect of marginal emissions when there exists complementary or substitutable relationship between emission and goods levels.

Also Bovenberg and Goulder (2001) explained why the optimal environmental tax is inversely related to the marginal cost of public fund (MCPF) under this second-best setting. Since the government employs the tax system to accomplish both raising revenues and internalizing environmental externalities at the same time, environmental taxes directly affect both objectives. If raising public revenues becomes more costly, the balance between the revenue and environmental-quality objectives is accomplished well at a lower rate for the environmental tax. Specifically, the optimal pollution tax can equate the marginal social benefit from one unit of pollution reduction against the marginal social cost of a one-unit pollution reduction. 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. Before this study, Parry (1997) examined the difference in environmental taxes and non-auctioned environmental quotas in terms of welfare effects under the framework of analytical model. 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) examined the choice issue between environmental tax and environmental quota in second-best setting with pre-existing factor taxes with analytical and numerical general equilibrium model. It 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. Previous studies claims that the second-best setting with pre-existing taxes tends to raise the costs of pollution taxes, and therefore the optimal pollution tax is typically lower than the first-best setting. 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. Alternative Natures of Environment

3.1 Environmental quality in utility function

In general we have assumed that environmental quality is separable in utility function from consumption and leisure. If it is not the case, environmental quality directly affects energy consumption and leisure. In particular, 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. However, if environmental quality is a substitute for leisure, improvements in environmental quality mitigate the adverse employment effects as previously seen in the case of health effect in the second-best setting.

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 environmental improvement results in the reduction of energy demand. 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 Environmental quality in production function

In previous sections we treat environment quality 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. Furthermore employment may rise rather than fall after environmental taxation as a cleaner environment boosts wage due to increased 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 implications. Even though public funds become more costly to raise, the government's ability to adjust tax rates for environmental purposes is not necessarily affected and thereby the tax rate on energy consumption need not be decreased.

3.3 Uncertainties in environmental quality

So far we have associated environmental quality with current level of energy consumption. 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 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.

Besides the uncertainty related to the effect of carbon dioxide accumulation, there is another uncertainty related to the conditions under which the environmental improvement is realized through the environmental taxation. Because the inability of the lawmakers and the general public to appreciate the efficiency advantages of environmental taxes, the environmental taxation is likely to be considered as uncertain and ineffective policy instrument. This reluctance to adopt environmental tax partly reflects the tendency of the political process to avoid the negative distributional impacts which stem from the emission taxes even though the efficiency advantages are acknowledged. The presence of uncertainty tends to add more reluctance for adopting environmental taxation as a device for environment protection. Moreover, uncertainty and associated costs of monitoring and enforcement induce output taxation to be more preferable to environmental taxation because output can be monitored more easily than emission.

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. For 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. The reason for the superiority is that while emission tax generates the efficient level of actual pollution, emission quota cannot induce an efficient pollution level in a simple way.

Chapter 4

Energy Taxation

1. Overview

The main role of energy taxes has historically focused on those tax incentives like expensing of dry holes and percentage depletion allowance that specifically affect the petroleum industry in the United States. Early discussion about the effect of energy tax concentrated on the oil industry profits in 1950s. Since profits in oil industry were considered high, tax preferences toward oil industry were criticized. These favorable tax treatments had applied to depreciation and resource depletion in the oil and gas extraction industries, but these tax preferences were eliminated under the Tax Reform Act of 1986 in U.S. Moreover, a specific form of energy like gasoline faces relatively heavier excise taxes, which means there is no more argument about the tax preferences to oil industry.

Currently there are many reasons for the new focus on energy taxes. To many policy makers, certain type of energy taxes seem more acceptable to the public opinion than traditional tax increases such as increases in personal or corporate income tax rates. 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.

Efficiency concerns becomes another reason for energy taxation.

Some economists consider that energy taxes are relatively 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. One of the basic rules in public finance is that other things being equal, for a given tax rate the excess burden or efficiency cost becomes smaller when the demand and supply of goods upon which a tax is applied are more inelastic. This principle can be related to the intercommodity efficiency effect. If energy is supplied more inelastically than other commodities, then a given taxation can potentially lead to a smaller efficiency cost when applied to energy than when applied to other commodities. 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.

However, even though some economists claim that the supply of energy is relatively inelastic, it seems that the quantity of economically recoverable reserves is elastic. Thus it remains an open question whether supplies of energy are more or less elastic than other commodities in general. Therefore the energy taxation for lower excess burden has positive impact in term of demand elasticity, but ambiguous one with respect to supply side.

2. The Theory of Optimal Commodity Taxation

Current trend of government expenditure makes it important to collect more taxes efficiently because there has been the increased demand for public spending in diverse economic areas which have been traditionally considered as the competitive and private sectors which have needed not government intervention. This trend, of course, induces each government to find more broadened tax bases which has been ignored as ambiguous base. From the efficiency point of view lump-sum tax is an ideal tax because it has characteristic of being nondistortionary because lump-sum tax can be defined as a certain amount that must be paid regardless of the taxpayer's behavior. However, lump-sum taxation is an unattractive policy tool fro several reasons. Under the lump-sum taxation system, government announces that every person's tax liability is same. Most people would consider it unfair for everyone to pay the same tax regardless of their economic circumstances. The types of lump-sum taxes which are feasible may not be very satisfactory from the equity point of view. In particular, if one of the roles of taxation is to redistribute income, lump-sum taxes may not be desirable since they are regressive. For this reason, because it is generally impossible to fulfill such public needs through only lump-sum tax, the taxes for raising revenue are prone to distort relative commodity prices in the economy. An income tax distorts the labor-leisure choice and the alternatives between present and future consumption because income tax induce people to prefer leisure and present income. An excise taxes distort the prices of the goods to which they apply because the relative price of taxed goods becomes higher. Even though these distortions are not avoidable, we need to ask which distortions do the least damage to the economy. That is, we need to find an answer about how can we minimize the efficiency cost of such distortions while raising a given revenue to finance a necessary spending.

When there is a full set of differential taxes on commodities and factors, and no pure rent in the economy, production efficiency is necessary for optimal taxation. Production efficiency is a concept derived from Pareto efficiency. Its conditions abstract the demand side of the economy and concentrate solely on production or supply side. It holds if it is not possible to reallocate factors of production among various uses in such a way as to increase the output of one good without at the same time reducing the output of some other good. The derivation of production efficiency is analogous to that of the exchange efficiency conditions. In general case, production efficiency requires the marginal rate of technical substitution between any two factors of production to be the same in all industries. Different factor taxes distort production efficiency because those factor taxes induce different marginal rate of substitution of capital for labor in different sectors. Therefore only differential excise taxes and uniform factor taxes should be used.

Under these conditions, we need to find the optimal set of excises. 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 is the same. This result is called the Ramsey rule. To implement this condition, optimality requires the marginal deadweight loss per dollar of revenue raised by an excise on any commodity to be equal for all commodities.

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.

If we look at the relationship between Ramsey rule and demand elasticities, we can find another useful implication. Suppose there are two commodities like X and Y. Let h_X, h_Y be the compensated elasticities of demand for X and Y separately and t_X, t_Y be the tax rates on X and Y. The tax rate is expressed as an ad valorem rate rather than a unit tax, so that t_X, t_Y are the percentage increase in the price by those taxes. The Ramsey rule implies that to minimize excess burden, the percentage reductions in quantity demanded must be equal. Finally this condition can be expressed like following.

$$\frac{t_X}{t_Y} = \frac{h_Y}{h_X}$$

Above equation is called the inverse elasticity rule, which implies that as long as goods are unrelated in consumption, commodity tax rates should be inversely proportional to elasticities to minimize excess burden after imposing of excise taxes. That is, the higher is h_Y relative to h_X, the lower should be t_Y relative to t_X.

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.

3. Energy Tax Distortions in Labor, Capital, Intermediate Input and Commodity Markets

There are four main economic choices in which principal distortions with welfare effect occur: the labor-leisure choice, the intertemporal choice, the efficient intermediate good choice, and the efficient consumer good choice. The labor market is the place in which the choice between working and enjoying leisure is made. The capital market is the domain for intertemporal choice between present and future. Input and consumer good markets determine the allocation of producers' expenditures on inputs and of households' expenditures on consumer goods.

Energy taxes have different effects along these choices. For the energy taxes, there are direct impact on input choice and consumer good choice. General fuel tax raises the average cost of energy input relative to other inputs, and in so doing affects firm's input choice. Specific tax like gasoline tax similarly alters the relative prices of gasoline and other consumer goods against the consumption of gasoline. 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.

The outstanding feature of energy taxes is that they introduced distortions in factors market like labor and capital markets as well as product markets. 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. Since higher tax rates tend to imply larger efficiency cost, a narrow-based tax induces greater efficiency loss. Hence, a narrower tax base serves to enlarge the gross efficiency costs of energy taxes relative to equal-revenue income taxes.

4. Environmental Impacts of Energy Taxes

Environmental concerns might seem to favor energy taxes. 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.

The previous discussion suggested that energy taxes are likely to be more costly than the alternative commodity taxes in terms of efficiency loss because energy taxes have relatively narrower tax base. The narrower tax base makes the energy taxation to bear more excess burden because a given revenue can be attained with higher energy tax rates than the alternative commodity taxes. The more excess burden induced by a specific tax implies the reduction of efficiency in overall economy. Thus even if energy taxes are more environmentally beneficial than the other commodity taxes, the question remains as to whether energy taxes are efficient overall.

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.

5. Marginal Environmental Damages and Energy Taxation

The previous discussions do not reveal explicitly the complex connections between the use of energy associated with pollution and the ultimate damages to the environment. In general three-stage connections are involved. 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. Monitoring cost can be defined as management cost for scrutinizing firms' polluting behaviors because the firm tends to violate any regulation related to environmental protection if there is no measuring instrument. 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 and third connections above imply that the marginal damages may not be a simple function of emissions. 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 this case the impact of an additional unit of emissions of a given pollutant depends on basically the concentration of the pollutant. Moreover, in some cases pollutants interact, so that environmental damages depend on the mix of pollutants rather than individual concentrations. In addition, the second connection between emissions and concentrations can depend on geographical conditions and climatic factors. This dependence make the emission-concentration relationship to reveal more nonlinear characteristic. 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 5
Environmentally Motivated Tax Reform

The realization of the negative health and social effects of environmental damage has led many studies to focus on the policy options to limit emissions of greenhouse-related gases and to handle the consequence of climate changes. Therefore, there has been much discussions in the public economics over the best policy instrument for controlling environmental pollution. This discussion has mainly focused on two alternative policies such as regulation and market-based incentives. Among the incentives pollution tax has been considered as one of efficient measures for solving the pollution problem. However, the rise of production cost due to the environmental taxation induced policymakers to consider environmental taxes as unattractive or even harmful measure for environmental protection.

Against this tendency of government reluctances, environmental tax reforms have recently received increasing attention. One reason for this attention seems to be an increasing concern about environmental quality. Another reason is a growing recognition of tax collecting benefits for substituting environmental taxes for other taxes because environmental taxes are more acceptable and enormous revenue potential sources for rapid growing government expenditure. In 1995, revenues from environmental taxes represent on average two percent of GDP and six percent of aggregate tax revenue in OECD countries. Petroleum, diesel fuel, and motor vehicle taxes account for most of these revenues.

In examining environmental tax reforms, it is useful to divide the welfare impacts into gross benefits and gross costs. The gross benefits are the gross welfare gains associated with environmental improvement or the avoidance of environmental deterioration. The gross costs are the gross welfare losses associated with various economic opportunity costs necessary to achieve reduction in pollution. A tax reform is efficiency-improving if it produces more gross benefits than gross costs.

1. Double Dividend Hypothesis

Some economists have suggested even more benefits from the environmental taxes above a cleaner environment. They insisted that replacing distortionary taxes by environmental taxes involves zero or negative gross costs. Even though the taxes are designed to improve the allocation of resources by intentionally influencing economic behavior, they have additional benefit of generating revenues. Financing all the public expenditure has always asked each government to find the various and reliable tax revenue sources from the interrelated private economic activities to the extent which people can recognize and accept real benefits of the specific taxation and the related expenditure. Taxation on the polluting sources can be widely accepted as beneficial government activity. In particular, when government can use the revenues from pollution taxes to decrease other distortionary taxes, the recognition of the benefits will be strengthened.

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. In contrast, a tax on pollution can increase the efficiency of the private sector by inducing the producer pay the full social cost of each polluting activity. 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. Furthermore if government revenue becomes lower, ambitious environmental policies may seem more attractive in terms of the broadened tax bases because the early work of Pigovian taxes essentially ignored the revenue side. 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.

Besides the efficiency gain 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. Gross Costs and Benefits from Revenue-Neutral Environmental Tax Reforms

The economics of the environment has traditionally focused on the effectiveness of environmental taxation in reducing pollutants, which results in the less costly pollution abatement, without paying sufficient attention to several side-effects of the pollution tax. For this insufficient attention, recent discussions about environmental taxation have focused more on the significances of costs which government need to pay for environmental protection. Therefore the balanced cost-benefit analysis is important in the reliable assessments of the impacts from different tax recycling methods in terms of welfare level.

When we divide the welfare impacts of the revenue-neutral environmental tax reform, there are two impacts associated with the changes in labor supply and energy consumption. The non-environmental impact is derived from the distortionary effect in the labor market due to the pre-existing labor income tax. The environmental impact is associated with the change in the demand for the indirect energy consumption and the energy input. 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.

These two impacts are rearranged into the welfare effects of changes in environmental quality and the impact on the tax base. 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

Comparing with United States, 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 of the European plans to reduce unemployment is the tax system change in which removed 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.

When we impose small environmental tax in the case where the initial equilibrium involves no such taxes, the introduction of pollution tax does not affect employment even though the revenue from pollution taxes allow lower taxes on labor. 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 is not applicable to 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.

This additional tax burden depends on two elements such as the initial levels of pollution taxes and the substitution elasticities between ordinary commodities and energy-related commodities. 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.

Even though the employment double dividend hypothesis cannot provide ambiguous answer for the effectiveness of environmental taxation to the employment, the societies concerned more about unemployment are likely to pay more attention from the environmental issues to the unemployment problem. 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 analytical results from the academic trend of favorable treatments for the employment 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 the 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, the more ambitious environmental policy means that a higher pollution tax on natural resources generates more tax revenue with which a lower tax rate on labor can be applied. 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.

The conditions for the validity of the employment double dividend hypothesis become more restrictive. The conditions can be summarized that if the environmental taxation is effective in reducing the tax burden on labor, environmental tax reform can boost employment. 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. However, the option of shifting the tax burden to the recipient of income transfer creates a serious distributional issues. The more tax burden to the recipients will result in less equitable tax system.

Even though the given these theoretical results are very disappointing, we have several reasons to proceed an empirical analysis of the employment double dividend hypothesis. First, there are some empirical evidence in favor of the double dividend hypothesis. 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. As another 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.

Also Bovenberg and van der Ploeg (1998) formulated a competitive model of labor market with structural unemployment caused by hiring costs. Under the framework, they found the environmental tax reform of swapping pollution tax with labor income tax may boost employment if it shifts the tax burden away from workers towards the unemployed in the formal sector. The shift can be successful only if higher energy taxes reduce earnings in the outside formal sector by reducing labor productivity.

4. Environmental Tax Reform and Welfare

By harming employment, higher pollution taxes narrow the tax base, which means that the gross distortionary costs of substituting pollution tax for labor income tax is positive. Moreover, by eroding the base of labor tax, environmental taxes exacerbate pre-existing tax distortions. Therefore, the larger the magnitude of pre-existing tax distortions, the higher become the gross distortionary costs of revenue-neutral pollution taxes. In particular, in the presence of a distortionary tax on labor, welfare will rise if the government marginally reduce the environmental tax below its Pigovian level. The analytical simulation models in Bovenberg and Goulder (1996) indicate that interactions between pre-existing distortionary taxes and newly imposed environmental tax augment the welfare costs and imply that the optimal environmental tax rate will be below Pigovian level.

Therefore the environmental tax appears to be less efficient instrument to finance public spending than a broad-based labor tax in terms of efficiency cost to after-tax wages. The pollution tax on energy consumption distorts the composition of the consumption basket. These distortions enhance environmental quality, but at the same time reduce the real after-tax income from work. Moreover, by enhancing environmental quality, the pollution tax expands the provision of public goods, thereby raising the overall tax burden as measured by the burden of the provision of public goods on private incomes. This additional tax burden corresponds to the abatement costs.

With consideration of 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 first 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.

Emphasizing the increase of production cost, Oates(1995) explained this result through the interaction between labor income tax and pollution tax on waste emission. Suppose a case where there exist taxes on labor income and a introduction of pollution tax. A tax on polluting waste emissions in the production of various goods will raise the price of these goods, thereby reducing the rate of return to work effort and inducing a substitution of additional leisure for consumption. This effect will induce more excess burden due to undersupply of work effort. These incremental distortions can be offset to some extent by using the revenue from the pollution taxes to reduce the rate of taxation of labor income. However, the conditions required for revenue-recycling effect to offset fully the tax-interaction effect are stringent.

Exploring 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.

Chapter 6
Inefficiencies in the Tax System and Possibility of the Double Dividend

If the initial tax system is inefficient in terms of non-environmental taxes, an environmental tax reform may be able to reduce the overall burden of taxation and achieve the double dividend after all. The key requirement is that the revenue-neutral reform can implement the alleviating these prior inefficiencies and transfer the rest of tax system closer into its non-environmental taxation optimum. Several cases can illustrate the conditions under which double dividend hypothesis is valid.

1. The Optimal tax on energy consumption

The optimal tax on energy consumption consists of two parts. The first part is the distortionary or revenue-raising component of the tax on polluting consumption. Together with the optimal labor tax, the optimal level of this distortionary component is determined on the basis of the Ramsey formulas for raising revenues with the lowest efficiency costs to individual private incomes. Uniform taxation of ordinary and energy goods is optimal from the point of raising revenues with smallest excess burden on individual private incomes. These uniform distortionary components are equivalent to labor income tax because uniform commodity taxation results in the proportionate reduction of labor income.

The second part of the optimal tax on energy consumption is the correcting of the environmental externality. The optimal environmental tax has an inverse relationship with the marginal cost of public finds. The government employs the tax system to simultaneously accomplish raising revenue and internalizing environmental externalities. The conflict between raising revenues and protecting the environment exists because an environmental tax reduces pollution by encouraging taxpayers avoid the tax. Tax avoidance not only reduces pollution but also makes it necessary to impose a higher distortionary taxes to finance public spending. Therefore, the higher the need of government revenue, the less the government can afford tax differentiation aimed at environmental protection because energy taxation tends to emphasize the role of raising revenue with sacrifice of environmental protection role.

When people can afford more leisure time, their energy consumptions are likely to increase because a typical leisure like a travel needs more energy consumption. Thus the relationship between energy consumption and leisure can be considered to be complementary. From this relationship we can derive another optimal energy taxation rule like Corlett-Hague rule which is derived from Ramsey rule. According to the Corlett-Hague rule, when there are two commodities, efficient taxation requires taxing the commodity which is complementary to leisure at a relatively high rate. In the optimal commodity taxation theory, the first-best result like revenue-raising with no excess burden can be obtained if it were possible to tax leisure. Even though the tax authorities cannot tax leisure, they can tax goods which tend to be consumed jointly with leisure. In effect, taxing complements to leisure at high rates provides an indirect way to reduce the demand for leisure, and thus induce the tax system to move closer to the perfectly efficient outcome that would be possible if leisure were taxable. Since the consumer would be better off if the marginal change induced him to take less leisure, the optimal commodity tax structure can be attained through taxing the complementary goods to leisure. In this context, the energy consumption needs to be taxed at higher rate than other commodity consumption. Therefore the complementary nature of energy consumption to leisure consumption need to be considered in the determination of optimal energy tax rate.

2.Clean consumption as a better substitute for leisure

In above arguments we assume that leisure is equally good substitute for the consumption of ordinary goods and energy goods. However, if ordinary goods consumption defined as clean consumption is a better substitute for leisure than energy consumption which determines the level of environmental quality, the optimal tax on energy consumption exceeds the optimal tax on ordinary consumption according to Corlett-Hague rule. Intuitively, by shifting the tax burden from clean consumption, which is a relatively good substitute for leisure, to energy consumption, the government implicitly impose a tax on leisure consumption. Since taxing leisure implies the increase in the price of leisure, the resulting higher level of labor supply alleviates the initial tax distortions. In particular, the raising of the tax on energy consumption and the using of the revenues to cut the labor tax make the tax system closer to its optimal structure. In this case, the reform boosts employment, thereby alleviating the distortion imposed by the labor tax.

Analyzing environmental taxes on final goods , Parry (1995) showed us that when polluting commodity like energy is sufficiently weaker substitute for leisure, revenue-recycling effect can outweigh tax-interaction effect, thereby double dividend hypothesis can be valid. However, if energy consumption is a better substitute for leisure than ordinary consumption, the environmental tax exacerbate the distortion induced by labor income tax. Thereby, the double dividend is even less likely to happen in this case.

When the utility function is assumed to be separable between goods and leisure, but non-homothetic because of the minimum consumption requirement, another possibility of double dividend from tax recycling becomes significant. Ballard, Goddeeris, and Kim (2000) found that the cases for parameter combination causing double dividend become equivalent to the situations under which the optimal environmental tax rate is greater than the Pigovian tax rate. Using generalized CES utility form in which utility is generated only if each consumption is greater than the pre-specified level, they revealed that the optimal environmental tax rate lies above significantly above than the Pigovian tax rate. Therefore the non-homothetic utility function represented by minimum consumption requirement will lead the situation under which the double dividend can be realized.

3. Environment as a substitute for leisure

If leisure can be defined as unoccupied time free from demands of work, it has a main role of providing an economic agent preparing time for optimal economic behavior in future. Comparing with leisure, environmental quality has several roles related to economic behavior. One of the roles is the provision of rest from working. In general, the model focusing on the effect of environmental quality has a proxy variable for environment which provides a positive utility to a representative agent.

Thus since leisure provides a positive impact on the utility level, an economic agent tend to purchase environment or leisure to enhance his utility level. Therefore it can be said that leisure and environment are substitutes each other.

When environment is a substitute for leisure, the increase in demand for environment means the reduction of leisure, which causes the increase of labor supply. The more consumption of environmental quality, the higher supply of labor is given in the economy. If environmental quality is a close substitute for leisure, a higher level of environmental quality boosts labor supply , thereby alleviating the labor market distortions on account of the distortionary labor tax. In this case, the introduction of an environmental tax can yield a double dividend.

4. Environment as a public input into production

So far, we assume that the natural environment is a public consumption good. However, a cleaner environment could act not only as a public consumption good but also as a public input into production. According to Ballard and Medema (1993), the environmental factor is incorporated into the production function using the concept of producer-producer externalities which is a typical production externality and the damage done to the structure of production as a result of industrial pollution. They introduced a new parameter that represents the amount by which a unit of output of the polluting sector induces higher production cost in the polluted sector by making it necessary for the polluted sector to use more input of the third-party sector to produce its own output. For example, the laundry, which is negatively affected by the nearby chemical plant, has to use more detergent when washing shirts in order to get them clean.

If the environmental quality enters the economy in this way, environmental benefits are provided as part of the non-environmental dividend. For example, in agriculture the production benefits from a better quality of the soil and the air provide farmers more crop output with same amount of input. Also, since the less air pollution is likely to improve health and morale, the improved environmental quality is boosting labor productivity. Therefore, introducing a pollution tax for environmental quality improvement yields the double dividend in terms of non-environmental benefits, which are environmental benefits and more output.

As a direct consequence of raising labor productivity by environmental quality improvement, both the costs and the benefits of a cleaner environment rise with the amount of labor supplied. Thus the households with the highest supply of labor will receive most benefits from the cleaner environment. Therefore the internalizing environmental externalities becomes less costly in terms of exacerbating labor-market distortions.

Moreover, if the environmental enters into production function as a public production factor, but does not enter the utility function, Bovenberg and van der Ploeg (1994a) demonstrate that the optimal environmental tax equals the Pigovian tax, even in a second-best with distortionary labor tax.

5. Pre-existing subsidies on polluting activities

If the polluting activities receive substantial subsidies in the initial stage, the overall burden on polluting activities becomes too low initially. If the polluting intermediate input was subsidized in the initial equilibrium, the reduction of subsidies leads the employment expansion because more labor, a typical substitute factor of intermediate input, is demanded through the production process. This expansion of labor supply will enlarge private income. Since the environmental tax like energy tax has a real effect of reducing those pre-existing subsidies in polluting input, the environmental tax can yield double dividend in terms of non-environmental benefits.

The reduction of environmentally harmful subsidies is more essential than ever. Such subsidies lavished on many intermediate inputs. To increase agricultural output we needed to make cheap pesticides using subsidy. In the utilities industry, we have subsidized water supply companies for low price to farmers and city-dwellers, and have underpriced electricity for cost reduction in every industry. The OECD calculates that if its members integrate a carbon-based fuel tax with a tax on chemical use, and eliminate the environmentally harmful subsidies, OECD can improve their environments dramatically with a very modest cost like less than 1% of one year's GDP. Poor countries would benefit even more from reduction of subsidies through environmental taxation since they typically waste even more financial resources on damaging subsidies.

6. Environmental taxes as optimal tariff

In an open economy, government can employ pollution taxes as a means of improving the terms of trade. For example, a large oil-importing country may improve its term of trade if it reduces the demand for oil by raising the tax burden on fossil fuels because the higher oil price due to higher tax burden induces smaller oil import. Similarly a large exporting country can boost the prices of its exports by imposing pollution taxes that reduce the supply of exporting goods and raises oil production cost, thereby it can improve its own terms of trade because exporting price becomes higher with a fixed import price. These terms of trade gains shift some of the cost for environmental improvement onto foreigners because foreign consumers must pay relatively higher price than domestic consumers, and thus this price advantage lower the domestic welfare cost which environmental policy should bear. If the terms of trade gains is sufficiently large, the reduction of domestic welfare cost can compensate for the efficiency loss which comes from the environmental taxation. Since output efficiency loss can be offset by the domestic welfare increase due to improved terms of trade, the domestic non-environmental welfare may rise. Therefore when the environmental taxation can provide enough improvement in terms of trade, it can yield double dividend in the view point of non-environmental benefits.

This terms of trade effect on the economy can be applied in Korean economy. It is expected that pollution taxes induce the price increase of energy because of the externalities of energy consumption. The energy price increase causes the reduction of energy demand, which implies the oil import demand decrease in Korea. Thus the pollution taxes eventually tend to improve the terms of trade because of the reduced oil demand in Korea. The improvement of terms of trade can finally induce a significant welfare increase in Korea because there will be enough terms of trade effect. The main reason for the strong terms of trade effect is that Korean industries are heavily dependent on oil whose demands are sufficed through the import only. In this way the environmental taxation in

Korea can induce the situation under which double dividend can be realized.

7. Environmental taxes as rent taxes

Environmental taxes may be an implicit way to tax the scarcity rents associated with natural resources. For example, taxes on the demands for fossil fuels may be borne largely by the owners of reserves of fossil fuels because these taxes may reduce significantly after-tax price of these fuels. As long as the burden of environmental taxes falls on the owners of inelastically supplied reserves, the environmental tax plays a function as a rent tax and produces no efficiency cost. Fullerton and Metcalf (1997) insist that environmental policies creating privately-held scarcity rents tends to raise costs of production more than the necessary level for the mitigating environmental problems. According to them, the shifting of environmental tax burden to the suppliers of fossil fuels results in the non-environmental costs because taxing rents involve no efficiency cost.

Environmental taxation as rent tax improves the prospects for the second dividend because the taxation produces no efficiency cost even after the fuel production costs are raised . However, at the same time this shifting the efficiency loss to the supply side is likely to limit the environmental improvement. The more the tax is borne by owners of reserves, the smaller the increase in the before-tax price to demanders of these fuels. This smaller increases in before-tax fuel prices produce higher demand for the fuel, and thus induce the deterioration of environment. Therefore rent tax improve the prospects for the non-environmental dividend while reducing the environmental quality improvement for induced lower fuel price.

8. Inefficient factor taxation

If the initial tax system involves differences in the marginal excess burdens of various taxes, 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.

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 portion of corporate income tax in Korea is relatively higher than the developed countries, Korean corporate income seems to be relatively overtaxed. 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.

9. Inefficient commodity taxation

Some tax policies favor certain forms of consumption over others. Such policies may be desirable on equity or other grounds, but at the same time they may imply inefficiencies in the allocation of consumer expenditure. In many countries, the tax system has provisions of tax deductions for housing spending or health care since housing and healthcare services have properties of merit goods. To the extent that revenue-neutral environmental tax policies lead to the reduction of labor income tax rates, the values of these tax deductions are reduced because the value of deductions is dependent on the income tax rate in each income range. When this reduction is taken account, the predicted costs of a revenue-neutral environmental tax reform are lower significantly. Therefore the double dividend from the environmental tax can be more materialized.

In Korea, there are the provisions of tax deductions for housing mortgage interest payments and healthcare payments in overall income taxation. These deductions can provide more possibility of double dividend from the revenue-neutral environmental taxation in Korea.

10. Environmental tax and employment dividend

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.

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

11. Environmental tax as a spur to energy-saving technology improvement

Climate change policies are likely to raise the prices of conventional fuels which are carbon-based energy sources. 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.

In general, since a carbon tax raises fossil fuel cost, 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.

Even though the presence of induced technological change usually implies higher gross costs from a carbon tax, the potential net benefits from a carbon tax tend to rise with the technological progress. 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.

Theoretically, 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 presence 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.

Since 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.

In Korea, 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.

12. 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.

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.

Chapter 7
The Model

1. Overview

This model will provide the evaluation for each energy taxation policy using general equilibrium model which generates paths of equilibrium prices, output, and income under specified policy scenarios. The model will be a unique basis in combining a detailed treatment of the Korean tax system with a close investigation of energy demand. This section employs a simple general equilibrium model to examine the optimal rate of tax on environmentally damaging activities.

In this model there will be two industry sectors like non-energy good sector and energy good sector. While non-energy good sector consists of various non-energy-intensive manufacturing goods which are final outputs that use fossil fuel not intensively, energy good sector represent the industry which produces energy-intensive manufacturing goods like steel, pulp, and cement. In this economy energy includes crude petroleum and natural gas, coal mining, synthetic fuels, petroleum refining, electric utilities, and gas utilities.

This model also assume two kinds of consumption goods such as energy-goods and non-energy goods. Energy goods represent the final output 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

The representative household maximizes the utility from consumption of non-energy goods, energy goods and leisure. 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. Also the environmental quality can be assumed as another utility source and to be inversely dependent of consumption of energy such as fossil fuels ($= y(F)$). Therefore, 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 consumptions of non-energy goods and energy goods response significantly to the change of relative price of two goods, it can be assumed CES utility functional form with respect to two goods. With incorporating leisure into the model, the utility function will be a nested CES function. The environmental quality can be assumed to influence the utility level separately and to be negatively dependent on the consumption of fossil fuels..

In this setting 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 $y(F)$, and l is a leisure amount, we can define following utility function of a representative household.

$$U = [d_1 \cdot C^{-r_1} + (1-d_1) \cdot l^{-r_1}]^{-\frac{1}{r_1}} - y(F) \qquad (1)$$

where $C = [d_2 \cdot C_N^{-r_2} + (1-d_2) \cdot C_E^{-r_2}]^{-\frac{1}{r_2}}$ (2)

In general form $U = U(C_N, C_F, l) - y(F)$, where U(.) is continuous and quasi-concave, y is 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 consumption goods and leisure.

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,

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

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

Therefore household choose C_N , $C_{F,}$ and *L* to maximize utility (1) subject to (3)and time endowment ($\bar{L}$). 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.

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

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

Another first order condition for optimal quantity of leisure enables us to find labor supply function like following because $L = \overline{L} - l$.

$$L = L (p_N , p_E , t_L) \qquad (6)$$

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.

$$V = V (p_N , p_E, t_L) - y (F) \qquad (7)$$

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

$$\frac{\partial V}{\partial p_N} = -l \cdot C_N \qquad (8)$$

$$\frac{\partial V}{\partial p_E} = -l \cdot C_E \qquad (9)$$

$$\frac{\partial V}{\partial t_L} = -l \cdot L \qquad (10)$$

where l 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.

$$C_N = f(L_N, R_N, F_N) \qquad (11)$$

$$C_E = g(L_E, R_E, F_E) \qquad (12)$$

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 nested 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.

$$C_N = f(L_N, R_N, F_N) \ = \ f\{N(L_N, R_N), F_N\} \quad (13)$$

where $N(L_N, R_N) = [d_3 \cdot L_N^{-r_3} + (1-d_3) \cdot R_N^{-r_3}]^{-\frac{1}{r_{31}}}$ (14)

Therefore,

$$C_N = [d_4 \cdot N(L_N, R_N)^{-r_4} + (1-d_4) \cdot F_N^{-r_4}]^{-\frac{1}{r_4}} \quad (15)$$

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.

$$\begin{aligned} TC_N &= w_N \cdot L_N + r_N \cdot R_N + p_F \cdot F_N \\ &= 1 \cdot L_N + r_N \cdot R_N + p_F \cdot F_N \end{aligned} \quad (16)$$

where w_N is wage rate in non-energy sector, which is 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.

In energy good sector, we can also assume that production function has another nested 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 followings.

$$C_E = g(L_E, R_E, F_E) = g\{E(L_E, R_E), F_E\} \qquad (17)$$

where $E(L_E, R_E) = [d_5 \cdot L_E^{-r_5} + (1-d_5) \cdot R_E^{-r_5}]^{-\frac{1}{r_5}}$ (18)

Therefore,

$$C_E = [d_6 \cdot E(L_E, R_E)^{-r_6} + (1-d_6) \cdot F_E^{-r_6}]^{-\frac{1}{r_6}} \qquad (19)$$

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

$$\begin{aligned} TC_E &= w_E \cdot L_E + r_E \cdot R_E + p_F \cdot F_E \\ &= 1 \cdot L_E + r_E \cdot R_E + p_F \cdot F_E \end{aligned} \qquad (20)$$

where w_E is wage rate in energy sector, which is 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 supply curve in energy sector can be derived through cost minimization condition.

The cost minimization process in each sector can induce the derivation of factor demand functions such as F_N and F_E . 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.

The use of fossil fuels in non-energy and energy good industries results in a proportional amount of carbon emissions. Also aggregate fossil fuel use is a summation of the use in each sector, which is defined as following.

$$F = F_N + F_E \qquad (21)$$

4. Government behavior

The government collects taxes, distributes transfers, and purchases goods and services. In the further study, the above model will incorporates a wide range of tax instruments including energy taxes, consumption taxes, corporate income tax, and taxes on individual labor and capital income.

In this paper, I assume that the government has an exogenous spending requirement of GE, which is returned to households as a lump sum transfer. The government imposes a proportional tax of t_L on labor income, and regulate carbon emission using environmental tax like carbon tax. Also government budget is assumed to be in a balance.

When government impose carbon tax, it is assumed that the environmental tax revenue is transferred to the public at the initial case. However, to check if double dividend hypothesis is valid, the environmental tax revenue will be recycled through the reduction of pre-existing taxes.

5. Environmental Taxation

Suppose a environmental policy like carbon tax, which creates additional burden of t_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.

$$p_E \cdot C_E = L_E + r_E \cdot R_E + (p_F + t_E) \cdot F_E \qquad (22)$$

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 t_E is followings.

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

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

That is, the ratio of fossil fuel input to final output determines the increase rate in final product prices from increase of t_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_N , r_N , p_F can be influenced by t_E , and the changes in product prices are determined by changes in t_E , the conditional demands for fossil fuel in each sector are followings.

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

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

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

$$F(t_E, t_L) = F_N(t_E, t_L) + F_E(t_E, t_L) \qquad (27)$$

where $\frac{dF}{dt_E} < 0$.

The effect of changes in t_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.

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

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

$$\frac{dt_L}{dt_E} = -\frac{F + t_E \cdot \frac{dF}{dt_E} + t_L \cdot \frac{\partial L}{\partial t_E}}{L + t_L \cdot \frac{\partial L}{\partial t_L}} \qquad (29)$$

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

$$\frac{dV}{dt_E} = \frac{\partial V}{\partial p_E} \cdot \frac{dp_E}{dt_E} + \frac{\partial V}{\partial p_N} \cdot \frac{dp_N}{dt_E} + \frac{\partial V}{\partial t_L} \cdot \frac{dt_L}{dt_E} - y'(F) \cdot \frac{dF}{dt_E} \qquad (30)$$

Substituting (8), (9), (10), (23),(24),and (29), we can derive the functional form for the welfare effect of environmental tax like following.

$$\frac{dV}{dt_E} = h\left(\frac{dF}{dt_E}, \frac{\partial L}{\partial t_E}, \frac{\partial L}{\partial t_L}; l, t_E, t_L\right) \qquad (31)$$

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 $\frac{dF}{dt_E}$, the tax-interaction welfare effect is dependent on $\frac{\partial L}{\partial t_E}$.

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

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

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

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

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 8
Conclusions and
Suggestions for Further Studies

With the growing concerns about serious environment deterioration, environmental taxes have attracted attention. Many economists have insisted that pollution tax is an efficient instrument for achieving environmental targets. Some have gone even further to suggest that environmental taxes may yield efficiency benefits above a cleaner environment. In particular, if the government uses the environmental tax revenues to reduce other distortionary taxes, environmental taxes yield double dividend such as not only an environmental improvement but also a less distortionary tax system. This argument suggests that environmental taxation need to be promoted to achieve both environmental protection and reduction of tax distortion at the same time.

Through all previous sections we investigated the impact of environmental taxes on the economy in terms of the environmental quality and the efficiency of tax system. Since energy consumption is a primary reason for environmental deterioration, energy taxes need to be examined for the study of environmental taxes in terms of economic efficiency.

From the beginning part in this paper, there was provided a brief review about energy taxation policies in Sweden, Netherlands, and the United States. From this review it can be asserted that European countries are more aggressive in the application of environmental taxes like energy taxes for a cleaner environment than the United States.

The next part examined the rationale for optimal environmental taxation in the first-best and the second-best setting. Then the energy taxation is investigated about how it can provoke various distortions in markets and be connected to the marginal environmental damages and environmental taxation. The environmentally motivated taxation, in the next chapter, is examined in the point of optimal commodity taxation view. Also the impacts of environmental taxation are identified in various circumstances intensively to find out when the environment tax can yield double dividend after taking into account of even tax-interaction effects. Then it can be found that even though in general the environmental tax exacerbates the distortion in the market rather than alleviates, it can also improve the welfare and the employment under several specific circumstances which are classified as various inefficiencies in the existing tax system.

As pre-existing inefficiencies in the tax system which promote double dividend from environmental taxes, there are following market characteristics. When clean good consumption as a better substitute for leisure and environment as a substitute for leisure are the cases, environmental taxes are likely to yield double dividend. Also when environment is used as a public input into production, and there are pre-existing subsidies on polluting activities, we can find another sources for yielding double dividend. If environmental tax plays a role of optimal tariff and rent tax, the environmental taxation can induce double dividend. Inefficient factor taxation and inefficient commodity taxation are another cases which can yield double dividend from the environmental taxation. When environmental tax is used as a spur to energy-saving technology improvement, and the transfer program enhancing equity is implemented, we can find another sources for yielding double dividend from environmental taxation.

In the next part, a detailed description is provided about the model which can explain in analytical way the conditions under which double dividend of the environmentally motivated taxation is possible. In this model there are two sectors like non-energy good and energy good sector. While non-energy good sector consists of non-energy-intensive manufacturing goods which use fossil fuel not intensively, energy good sector represent the industry which produces energy-intensive manufacturing goods. This model also assume two kinds of consumption goods such as energy-goods and non-energy goods. While energy goods represent the final output from industries that use fossil fuel intensively, non-energy goods are ordinary goods from industries that use fossil fuel not intensively. After using many optimization processes through utility maximization and cost minimization and various market equilibrium conditions, finally we can identify the partial derivatives' conditions under which double dividend from the environmental taxation is possible.

After these findings, we can expand this investigation into more essential field such as finding the appropriate energy-related tax system for sustainable development. The one of the ultimate targets of further study is finding the applicability of the double dividend hypothesis to Korean economy. To find the applicability, first of all some modifications are needed to incorporate Korean energy-related tax system into the model. For this incorporation we need to review about the energy-related tax parameters, interdependence between industries, and estimates of the necessary parameters for factor supply elasticities. Also the review and estimate of the pertinent parameters of consumption goods' elasticities of demand are necessary.

With the analyses about the complicating factors in a second-best setting and the inefficiencies in the existing tax system, the numerical assessment will be carried about the impacts of energy-related tax reform on consumption and welfare through many intensive simulation processes.

For the numerical assessment, there will be implemented the preparation process and the programming job which will be used for the simulation study. Those preparatory works involve the classification overall industries into six intermediate goods with three fossil fuels and three non-fuel intermediate goods, the differentiating consumption goods into energy intensive good and non-energy intensive good, and finding appropriate parameters for demand and supply function specifications in each sector. Finding relevant interdependences between production sectors and reliable measures of tax rates and economic variables necessary to simulation process is another important preparatory work. For numerical assessment there will be applied the four different tax modification schemes like lump-sum rebates, the substitution of energy tax for labor income tax, substitution of energy tax for capital income tax, and substitution of energy tax for consumption tax.

After this analysis it is expected that this investigation is contributing to establishing the optimal energy-related tax system for the sustainable development in terms of welfare level, and finding the implications for corresponding optimal income tax system after energy-related tax system reform. Also this study will provide what are the implications for the welfare improving energy-price system and environmental policy and illustrate several cases where environmental quality enhancing tax scheme is effective on welfare improving.

References

Ballard, Charles and Goddeeris, John and Kim, Sang-Kyum (2000), ' Non-Homothetic Preferences and the Non-Environmental Effects of Environmental Taxes' , *Discussion Paper*. Michigan State University.

Ballard, Charles and Medema, Steven (1993), " The Marginal Efficiency Effects of Taxes and Subsidies in the Presence of Externalities: A Computational General Equilibrium Approach", *Journal of Public Economics*, Vol. 52, No.2, pp.199-216.

Becker, Randy and Henderson, Vernon (2000), " Effects of Air Quality Regulations on Polluting Industries", *Journal of Political Economy*, Vol.108, No.2, pp.379-421.

Bohm, P. (1994), " Environment and Taxation: The Case of Sweden", *OECD Documents: Environment and Taxation*, pp.51-101.

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(1996), "Optimal Environmental Taxation in the Presence of Other Taxes: General-Equilibrium Analyses", *American Economic Review*, Vol.86, No.4, pp.985-1000.

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.

Bovenberg, A. Lans and van der Ploeg, Frederick. (1998), “Tax Reform, Structural Unemployment and the Environment”, *Scandinavian Journal of Economics*, Vol.100, No.3, pp.593-610.

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

Fullerton, Don and Metcalf, Gilbert (1997), “ Environmental Taxes and the Double Dividend Hypothesis: Did You Really Expect Something for Nothing?”, *NBER Working Paper No.6199*, pp. 1-36.

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.

Lee, Dwight and Misiolek, Walter (1986), " Substituting Pollution Taxation for the General Taxation: Some Implications for Efficiency in Pollutions Taxation", *Journal of Environmental Economics and Management*, Vol.13, pp. 338-347.

Nordhaus, William (1982), " How fast should we graze the global commons?", American Economic Review, *AEA Papers and Proceedings:*

84^th^ Annual Meeting, Vol.72, No.2, pp.242-246.

Oates, Wallace (1994), " Environment and Taxation: The Case of the United States", *OECD Documents: Environment and Taxation*, pp.103-143.

Oates, Wallace(1995), " Green Taxes: Can We Protect the Environment and Improve the Tax System at the same time?' *Southern Economic Journal*, Vol.61, No.4, pp.915-922.

Oosterhuis, F. and Lohman, S. (1994), "Environment and Taxation: The Case of the Netherlands", *OECD Documents: Environment and Taxation*, pp.7-50.

Parry, Ian (1995), "Pollution Taxes and Revenue Recycling", *Journal of Environmental Economics and Management*, Vol.29, pp. S64-S77.

Parry, Ian (1997), " Environmental Taxes and Quotas in the Presence of Distorting Taxes in Factor Markets", *Resource and Energy Economics*, Vol.19, pp.203-220.

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.