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ECONOMIC EFFECTS OF ENVIRONMENTAL TAXATION ON CHEMICAL FERTILIZERS IN KOREA*

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Keywords
nonpoint pollutants, polluter-pays principle, internalization of negative externality, environmental taxation, yield-response function

Abstract
Environmental taxes as one of market-based instruments forces producers and consumers to consider the cost of negative externality in their economic decision. This paper analyzes the economic effects of environmental taxation on chemical fertilizers which is focused on effects of fertilizer consumption, rice yield, farmer's income, tax revenue from national economy aspect, enhancement of economic welfare through quality improvement of environment. The analytical results show that in order to achieve effective policy objective of the imposition of environment tax on chemical fertilizers very high tax rate is required due to inelastic demand of chemical fertilizer but it requires high cost burden on the part of farmers. This study provides an insight into the application of market-based instrument to achieve sustainable agricultural development.

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I. Introduction

As intensive farming is expanded to increase agricultural productivity, the increase in the use of chemical inputs, such as fertilizers and pesticides, has increased water and soil pollution and accelerated the deterioration of the ecological system due to the leakage and infiltration of non-point pollutants. The principle of holding the sources of pollution responsible (polluter-pays-principle, PPP) was introduced as one of the basic tools for environmental preservation aimed at reducing the emission of environmental pollution by imposing a financial burden on their sources. The PPP was designed to make those causing environmental pollution pay the price of the damages to the environment. The PPP is an economic inducement policy which internalizes a negative externality from environmental pollution through a price mechanism. The PPP has been used by many countries as a guiding principle for preventing environmental pollution since its initial adoption by the OECD in 1972. The environmental policies of most OECD countries utilize environmental taxes, emission charges, product charges, deposits, and emission permit trades as means to implement the PPP, rather than direct command and control methods. Environmental taxation as one of representative market-based instruments changes relative prices to ensure that polluters take account of the effects of their activities on the environment. Compared with command and control measures, environmental taxes are more flexible: polluters are free to adapt market signals in the most effective manner. In practice, in the field of agricultural sector, several EU countries like Norway, Sweden, Austria, and Finland are imposing environment taxes in the form of product imposition against chemical fertilizers and pesticides in order to reduce environmental pollution loads from the excessive use of chemical inputs.

Since joining the OECD in 1996, the Korean government has been building a linkage between the economy and the environment. The concept of “sustainable development” is a key part of the new agricultural policy paradigm for the 21st century. The promotion of an environmentally friendly agriculture is emerging as an important policy task. The Korean government has implemented various policy measures to reduce the environmental pollution loads from agriculture. Restricting agricultural chemicals is one of several options policy makers consider to prevent further damage to water quality. In July of 2005, the Korean government abolished the subsidy for chemical fertilizers. In order to properly manage agricultural production activities and non-point pollution, there is an increasing need to develop more effective and efficient environmental policies for agriculture. The PPP serves as the theoretical and practical basis for environmental policy toward agriculture in addition to previous programs and restrictions

There have been several studies on the theoretical and practical aspects of the PPP in non-agricultural fields. Lee (1994) analyzed the theoretical structure of environmental taxes and the economic effect of carbon tax on the suppression of CO_2 gas emission. Na and Choi (1995) measured the effect of carbon tax as an indirect environmental tax on the national economy in terms of pollution reduction, export, income distribution, and tax revenue by using an industrial relations analysis method.

In a study on the practical application of PPP to the agricultural sector, Choi and Feinerman (1995) investigated the effects of a tax or a quota as the first-best policies in regulating nitrogen pollution under uncertainty at the wheat farm level in Israel. Helming and Brouwer (1999) assessed the effects of putting a tax on fertilizer or a tax on nitrogen surplus using a Dutch Regionalized Agricultural Model based on a partial equilibrium model. Kwon, Kim and Oh (1999) estimated the economic effects of fertilizer taxes on farmers' income and fertilizer use through a rice response function. Kim and Kim (1999) analyzed the economic effects of taxes on chemical fertilizers through a partial equilibrium model and suggested the directions for introducing the PPP in agricultural sector. More recently, Kwon (2005) investigated the impacts of reducing fertilizer subsidy on fertilizer demand using the elasticity approach and the input-output model.

The objective of this paper is to analyze the economic effect of the imposition of environmental taxes on chemical fertilizers by using an elasticity analysis method in a partial equilibrium model. The rest of the paper is organized as follows. Section II outlines the analytical model for environmental taxation. Section III discusses the analytical results from the model and finally Section makes some concluding remarks.

II. Analytical Model for Environmental Taxation

The basic theoretical premise behind environmental taxation to correct environmental damage is the existence of negative externality.[1] Historically, taxes were the first policy instrument proposed to deal with the presence of an externality. Pigou (1932) argued in essence that a farmer, when using polluting agricultural chemicals which result in an externality, does not bear all the costs of producing agricultural products. The imposition of tax on the use of fertilizer has some advantages over other policy approaches dealing with the externality issue. First, because the use of fertilizer has shown to respond to market forces, it is efficient to use the market to control the use of fertilizer. Next, because of many farmers involved, the cost of setting and collecting the tax is lower than it is for, say, monitoring nutrients leaching and runoff. Additionally, a tax provides an incentive for a farmer to reduce the amount of the input used. Finally, a tax is preferred to other approaches to controlling an externality because it provides a continuing incentive to the polluting farmer to cut back on emissions. However, one of the drawbacks to using an environmental tax to adjust for externalities is to determine precisely what the optimal tax rate should be. This requires the knowledge of what are the marginal social cost and the marginal private cost of production (Pearce and Turner, 1990).

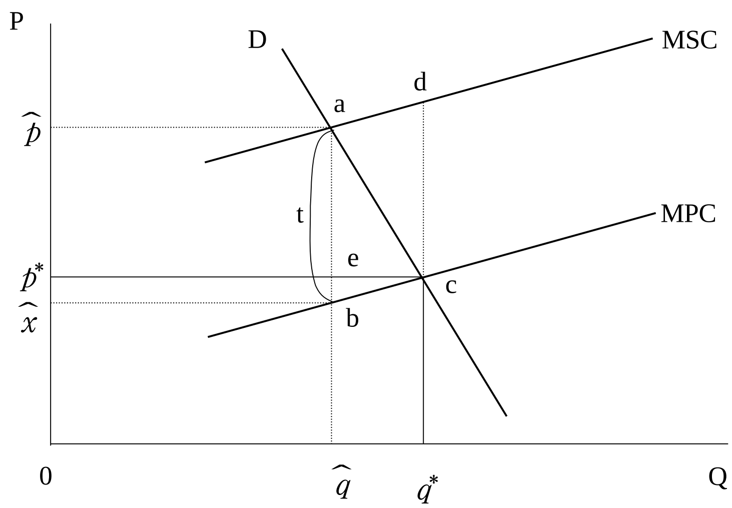
The economic effect of fertilizer taxation on the farmers who cause pollution and manufacturers of chemical fertilizers and social welfare can be explained from a partial equilibrium view in the graph below. In the case where environmental taxes are imposed on chemical fertilizers, production activities are adjusted among pertinent economic subjects such as farmers, fertilizer manufacturers, and consumers. Basic outcomes from the imposition of environmental taxes are different depending on the shape of demand and supply curves for inputs (Just, Hueth, and Schmitz, 2004). The example shown in Figure 1 depicts a highly simplified model to illustrate the economic effect of

[1] A negative externality is a cost that one economic agent imposes on another but does not take into account when making production or consumption decision (Baumol and Oates, 1998)

an environmental tax imposed in a market with a linear demand curve (D) and a linear supply curve (also called marginal private cost, MPC) for chemical fertilizer. As we can see from the illustrated example in the graphs, the more inelastic the demand, the more the burden on farmers increases. The more elastic the supply, the less the tax burden on fertilizer producers.

Suppose that the supply curve when there is no pollution tax on chemical fertilizers is MPC, and that the intersection of demand curve D and MPC is market equilibrium at point c. At the price level (p^*), the quantity demanded of chemical inputs is equal to the quantity (q^*) fertilizer producers want to sell. The addition of an environmental or Pigouvian tax equal to t causes the input supply curve to move upward by the amount of the tax, and the new equilibrium point is at a.[2] Here, environmental tax rate t is exogenously given,

FIGURE 1. Analytical Framework of Environmental Taxation on Fertilizer



2 To make truly "Pigouvian tax" of product, it is necessary to collect information on the relationship between the product and the detrimental emissions, which is not always easily available. In most case, the relationship is not very well known, os the product tax a second or third best solution. The degree to which a tax is really Pigouvian depends essentially on whether it is possible to quantify the marginal social cost of emission (Baumaol and Oates, 1998).

but it should be equal to the marginal external pollution damage cost per unit of fertilizer sold. Thus, the upward shift in the supply curve by t would represent the marginal social cost (MSC) curve. Under the new equilibrium, the price which rice farmers and consumers of chemical fertilizers have to pay increases to $\hat{p}$, while the price which chemical fertilizer producers receive decreases from p^* to $\hat{x}$. The imposed environmental tax $t = \hat{p} - \hat{x}$ is the outcome of the tax transfer to economic subjects. Farmers should cover $p^* \hat{p}$, while producers of chemical fertilizers should cover $\hat{x}p^*$. Consequently, the advantage of environmental tax is that it sends the signals of partial responsibilities for environmental pollution loads to farmers as well as fertilizer manufacturers. The purpose of the tax is to induce the conversion toward the production and consumption of products to where they would be in a market with no uncompensated external pollution damages. This is accomplished with reduced pollution loads by passing the tax for the cost of pollution damages caused by chemical fertilizers to both groups. There are lowered profits and sales by fertilizer producers and increased input prices to farmers. The allocation of the tax burden in the form of environmental taxes to manufacturers and consumers of chemical fertilizers depends on the relative ratio of the price elasticity of demand (ε_i) and the price elasticity of supply (η_i) of chemical fertilizers.

The influence of the imposition of environmental taxes on economic subjects and social welfare effect can be measured as follows using the demand and supply elasticities of chemical fertilizers:

1) When environmental taxes are imposed on chemical fertilizers, farmers who are consumers of the fertilizers have to pay more (up the amount of the $ECOTAX^C$) per unit, while manufacturers of inputs, who are the sellers of fertilizers, have to share a portion of the burden of environmental taxes through decreased sales of fertilizer. The precise allocation of the ECOTAXC and the burden between consumers and producers can be measured by expressions (1) and (2) respectively.

$$ECOTAX^C = \frac{\eta_i t}{\varepsilon_i + \eta_i} \quad (1)$$

$$ECOTAX^P = \frac{\varepsilon_i t}{\varepsilon_i + \eta_i} \quad (2)$$

2) The quantity of fertilizer purchased ($\hat{q}$) after the price increase from the imposition of an environmental tax on chemical fertilizers can be measured by expression (3).

$$\hat{q} = q^{*}\left(1 - \frac{\varepsilon_i \eta_i t}{p^{*}(\varepsilon_i + \eta_i)}\right) \tag{3}$$

3) The tax revenue (*TAXREV*) received by the government from the environmental taxes can be measured by expression (4).

$$TAXREV = t\hat{q} = (ECOTAX^{C} + ECOTAX^{P})\hat{q} \tag{4}$$

4) As shown in Figure 1, the changes in the economic welfare effect of pertinent economic subjects from the imposition of an environmental tax consists of decreases in consumers' surplus ($\triangle CS$), decreases in producers' surplus ($\triangle PS$), and gains from the reduction in uncompensated environmental damages. The consumers' surplus change ($\triangle CS$), which represents the decreased portion of farmers' welfare, is equal to $p^{*}\hat{p}ac$, which can be estimated by expression (5), whereas that for the decreased portion of fertilizer producers' surplus ($\triangle PS$), which represents the decreased fertilizer manufacturers' welfare, corresponds to domain $\hat{x}p^{*}cb$, which can be estimated by expression (6).

$$\Delta CS = ECOTAX^{C}\left(\hat{q} + ECOTAX^{C}\frac{\varepsilon_i q^{*}}{2p^{*}}\right) \tag{5}$$

$$\Delta PS = ECOTAX^{P}\left(\hat{q} + ECOTAX^{P}\frac{\eta_i q^{*}}{2p^{*}}\right) \tag{6}$$

5) When environmental taxes are imposed on chemical fertilizers, environmental pollution loads decrease due to the decreased use of chemical fertilizers, and accordingly Marginal External Cost (MEC) is decreased through the improvement of environment quality. (Environmental damages, though reduced, still occur, but the remaining damages are paid for through the tax). This in turn will increase total social welfare (TSW) which is equivalent to the rectangular area *badc*, as measured by expression (7).

$$TSW = ECOTAX^{C}\left(1 + ECOTAX^{P}\,\frac{\varepsilon_i q^*}{p^*}\right) \qquad (7)$$

6) The triangular area *adc* (the net increase in social welfare) is what is left after deducting the decrease in consumers' surplus and the decrease in manufacturers' surplus associated with tax burdens from total social welfare (TSW) generated by the improved environment due to the imposition of environmental taxes on chemical fertilizers. The NSW increment can be measured by expression (8).

$$NSW = \frac{1}{2}TSW \qquad (8)$$

In the case where there is no negative externality, an increase in taxes reduces NSW. That is taxes on certain goods decrease both manufacturers' surplus and consumers' surplus and increase tax revenue of the government. However, in the absence of a negative externality, the decrease in welfare of manufacturers and consumers due to the imposition of taxes exceeds the amount of tax revenue collected by the government. As such, the decrease in total social surplus due to the imposition of taxes will result in net economic losses. That is to say, in the case where environmental taxes are imposed as in Figure 1, and if we assume that SMC is a new supply curve by the shift of the supply curve of the case, the decreased portion in consumers' surplus becomes area *eac* of the triangle and the decreased portion in manufacturers' surplus is equal to area *bac* of the triangle, while deadweight loss due to tax imposition is equal to area *bac*. However, in case the externality based on environment pollution does exist, the imposition of the correct environmental tax *t* reduces the level of environment pollution from Oq^* to $O\hat{q}$, increases the level of national welfare, and improves the quality of the environment.

III. Model Application and Analytical Results

1. Economic Welfare Effects of Eco-Taxes

Rice farms were selected for an analysis related to chemical fertilizer use, as most rice farms use chemical fertilizers and it is relative easy to obtain data required for positive analysis. In relation to measuring the demand and supply elasticity for chemical fertilizers, we can approach the demand side easily through survey data for the cost of rice production.[3] However, it is difficult to measure supply elasticity as fertilizers are manufactured by different firms and the prices vary by the type of fertilizer. In this research, we applied the supply elasticity of a complex fertilizer which is measurable based on the assumption that such a complex fertilizer is the representative fertilizer supplied for rice farms. The price elasticity of demand for chemical fertilizers was found to be 0.1456 and the supply elasticity was found to be 2.7875.[4]

If eco-taxes were imposed on the sales of chemical fertilizers in the form of an *ad valorem* (or per unit) tax, the farmers' welfare decreases due to the increased fertilizer price and then the quantity of farmers' consumption decreases accordingly. Total fertilizer consumption before the imposition tax was found to be 1,680 thousand tons as shown in Table 1. However, in case

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3 The data for rice production and cost are employed official survey data (Korea National Statistical Office, 1990-2006) and the fertilizer price data by the National Agricultural Cooperative Federation (2006) are used.

4 To measure the price elasticity of rice farm's demand toward chemical inputs such as fertilizer and pesticide, Translog cost function and Shephard's Lemma were applied, and a conditional input demand function was measured as well. For the price elasticity of overall input demands for rice production (applied with average elasticity value during the target period), it was found that chemical fertilizer recorded 0.1256, pesticide 0.2968, and organic fertilizer 0.4103 and, accordingly, that they are non-elastic. Meanwhile, when the supply function for chemical inputs for rice production, such as nitrogen, phosphorous acid, and potash, was inferred, only complex fertilizer showed 67 percent of relevance toward signals and assumed model. Other fertilizers and pesticides could not generate theoretically valid function inference. The price elasticity of complex fertilizer supply was found to be quite high with 2.7875. For more details on the Translog cost function expression and inferred co-efficient, see Kim and Kim (1999).

of imposing 10 percent tax increase, the quantity consumed would decrease to 1,655 thousand tons which represents 1.5 percent decrease. In the case of a 100 percent tax imposition, the consumption would decrease to 1,435 thousand tons, which would be a 14.6 percent decrease. A 200 percent tax would decrease the consumption to 1,191 thousand tons, which would be a 29.1 percent decrease in fertilizer use. On the other hand, the price received by fertilizer producers would decline and the quantity produced would decrease. The decrease in sales is estimated to be 7.6 billion won in the case of a 10 percent tax imposition, 38 billion won in the case of a 50 percent tax imposition, 76 billion won in the case of a 100 percent tax imposition, and 152.1 billion won in the case of a 200 percent tax imposition.

TABLE 1. Economic Effects of Environmental Taxes on Chemical Fertilizers

Category	Environmental tax rate (percent)					
	0	10	30	50	100	200
Fertilizer consumption (1,000 ton)[1]	1,680	1,655	1,607	1,558	1,435	1,191
(Fertilizer consumption reduction rate, %)	0.0	1.5	4.4	7.3	14.6	29.1
Fertilizer sales amount (100 millions, won)	5,223	5,147	4,995	4,843	4,463	3,702
Sales reduction amount of fertilizer producers (100 million won)	0	76	228	380	760	1,521
Government tax revenue (100 million won)	0	515	1,498	2,421	4,463	7,404
- Tax on farmers (100 million won)	0	488	1,420	2,295	4,229	7,017
- Tax on fertilizer producers(100 million won)	0	27	78	126	233	387
Reduced surplus amount of rice farmers (100 million won)	0	500	1,525	2,585	5,413	12,094
Reduced surplus amount of fertilizer producers (100 million won)	0	26	80	135	283	632
TSW from environmental quality improvement (100 million won)	0	8	76	218	946	4,560
NSW from environmental quality improvement (100 million won)	0	4	38	109	473	2,280

Note: 1) The total volume of fertilizer consumption is based on the sales figure of the National Agricultural Cooperative Federation (2006).

With respect to the economic welfare of pertinent economic subjects, the decline in farmers' surplus was estimated to be 50 billion won in the case of a 10 percent environmental tax. The fertilizer manufacturers' surplus would decline by 2.6 billion won.

However, in the case of a 100 percent imposition, farmers' surplus will decrease by 541.3 billion won and manufacturer's surplus will decrease by 28.3 billion won. This means that the loss of economic welfare from the imposition of environmental taxes on the part of consumer farmers is much bigger than that of manufacturers of chemical fertilizers.

Government tax revenue from the imposition of environmental taxes is estimated to reach 51.5 billion won in the case of a 10 percent tax rate and 446.3 billion won in the case of a 100 percent tax rate, respectively. An analysis showed that farmers' burden from taxation reaches approximately 95 percent of total tax amount, whereas fertilizer producers share only about 5 percent of total tax amount.

The quality of the environment will be improved due to the decrease in pollution loads from the imposition of environmental taxes. However, the actual increase in total social welfare is calculated on the assumption that the tax rate is set equal to the marginal externality rate in each case. If the MEC per ton for fertilizer was 30 percent of the current price, then a 30 percent tax would total social welfare by 7.6 billion won. The potential gain in NSW was estimated to be approximately half of TSW generated at each tax rate.

2. Effects of Eco-Taxes on Rice Production Volume and Farm Household Income

In order to identify the influence of environmental taxes on chemical fertilizers on the rice yield, a response function for fertilization and quantity should be measured. To find out rice yield changes according to the fertilization type of rice farm, the data on water field rice farms should be obtained. However, due to constraints in obtaining data, a yield-response function was estimated using the survey conducted by the Rural Development Administration (Kim and Kim, 1999) on the quantity of nitrogen fertilizer used. Functions such as the Spillman function, the Mitcherlich function, a 1.5 power type function, the square root function, and the quadratic function were considered as possible fertilizer-yield response functions for the production of “Nakdong” rice.[5] This is the kind of rice grown in the normal paddy field. The J-test, which is a non-nested hypothesis test to the suitability of various types of functions, revealed that the quadratic response function had the highest goodness-of-fit.[6] As a proxy of chemical fertilizer uses, the quantity of nitrogen use (phosphorous fertilization was assumed constant at 70 kg/ha) per ha with maximum production level pursuant to the estimated fertilizer-yield response function was measured to be 160kg. In this case, the quantity of yield per ha was measured to reach 5.04 tons. In case we set standard nitrogen use as 110kg considering environmental preservation, the quantity of nitrogen used for maximum production level appeared to be in excess by approximately 30 percent.[7]

In the case of imposing a 100 percent eco-tax rate on chemical fertilizers, the quantity of chemical fertilizers used by individual rice farms was estimated to decrease by approximately 15 percent (see Table 2). However, this level of decrease in fertilization had almost no influence on the quantity of yield. The analysis also shows that the cost of fertilization is estimated to be approximately 6 percent of total farm management cost. This means that the decrease in farmer's income would be only 3 percent in the case of a 100 percent tax rate. Even though the quantity of fertilizer use is estimated to decrease to 15 percent from the current level with a 100 percent eco-tax, the

[5] The data for estimating fertilizer-yield response function were drawn from nitrogen application of real rice farming experiment in the paddy field for soil quality improvement designed by the Rural Development Administration (1984).

[6] The choice of appropriate fertilization-quantity response function for the given data is very important to make a decision on optimized fertilization. Among various fertilization-quantity response functions, there is no particular theoretical base to accurately discern right functions. The right choice entirely depends on experience. It is possible to choose the most appropriate model among various function types by applying the non-nested hypothesis test. The details on choosing fertilization-quantity response functions based on the non-nested hypothesis test can be found in Paris (1992) and Kim and Kim (1999).

[7] Nitrogen is an essential plant nutrient required to produce rice and other crops. It becomes a pollutant when excessive amounts enter both surface and ground water. When excess nitrogen enters surface water, it can promote eutrophication of estuaries. Excess nitrogen in groundwater can be a hazard to human health. The application standard of nitrogen fertilization is guidance for minimizing environmental problems in producing paddy rice.

TABLE 2. Effects of Eco-Taxes on Rice Production and Farm Household Income

Category		Environmental tax rate (%)					
		0	10	30	50	100	200
Normal Paddy Field	Nitrogen fertilization per ha (kg)	160	158	153	148	136	112
	(Reduction rate of nitrogen fertilization, %)	(0.0)	(1.3)	(4.6)	(7.5)	(15.0)	(30.0)
	Yield per ha (ton)	5.04	5.04	5.04	5.03	5.01	4.96
	(Reduction rate of yield, %)	(0.0)	(0.0)	(0.0)	(0.2)	(0.4)	(1.6)
	Chemical fertilizer cost per ha (1,000 won)	195	214	254	293	390	585
	Management cost per ha (million won)	3.15	3.17	3.21	3.24	3.34	3.54
	Farm income per ha (million won)	7.16	7.14	7.10	7.04	6.90	6.19
	(Reduction rate of farm income, %)	(0.0)	(0.3)	(0.8)	(1.7)	(3.6)	(7.7)
Ill-drained Paddy Field	Nitrogen fertilization volume per ha (kg)	200	197	191	185	170	140
	(Reduction rate of nitrogen fertilization, %)	(0.0)	(1.5)	(4.5)	(7.5)	(15.0)	(30.0)
	Yield per ha (ton)	4.50	4.50	4.49	4.48	4.45	4.36
	Yield reduction rate (%)	(0.0)	(0.2)	(0.3)	(0.5)	(1.2)	(3.2)
	Chemical fertilizer cost per ha (1,000 won)	195	214	254	293	390	585
	Management cost per ha (million won)	3.15	3.17	3.21	3.24	3.34	3.54
	Farm income per ha (million won)	6.05	6.03	5.97	5.91	5.76	5.38
	(Reduction rate of farm income, %)	(0.0)	(0.3)	(1.3)	(2.3)	(4.9)	(11.7)

Note: Fertilizer expenses include all inorganic fertilizer expenses, including nitrogen input for rice production. The assumption is that the total fertilizer expenses for normal paddy and ill-drained paddy are same.

quantity of rice yield would be nearly unchanged. This means that the estimated fertilization-quantity response function for rice crop is nearly flat at current level of fertilizer use.

Next, when we look at the influence of eco-taxes on farmers' income, fertilizer cost is only 6.2 percent of total management cost for rice production. Thus, the decrease of farmer's income from the normal paddy rice is estimated to not exceed 3.6 percent even when a 100 percent eco-tax is imposed.

3. Effects on Reducing Fertilizer Subsidy

As a result of the implementation of a price subsidy system to compensate the loss from the fertilizer sale, the rate of subsidy to total inorganic fertilizers is approximately at the 20 percent level, and the subsidy significantly contributed to mitigate farmers' burden when purchasing agricultural inputs. However, the subsidy increases the volume of chemical fertilizer used and so is considered as an environmental harmful subsidy.[8] The economic effect of decreasing the subsidy for fertilizer prices is very similar to that of the imposition of environmental taxes since subsidy is by nature a negative tax. If the subsidy were reduced by 20 percent, which means the price subsidy is entirely eliminated, the estimate shows that the total consumption of fertilizers would decrease by 2.9 percent. The farmers' share would be 101.4 billion won, and through decreased sales the fertilizer manufacturers' share would be approximately 15.2 billion won. Even in the case where the quantity of inorganic fertilizer input is reduced according to the reduction of subsidy rate, the estimates show that there would not be a significant influence on the yield of rice per tan and the decrease in rice farmers' income is estimated to be only 0.5 percent (see Table 3).

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8 Korea has one of the most fertilizer-intensive agricultures of the world despite the decrease in chemical fertilizer consumption since 1990. The nitrogen balance of total agricultural land (253kg/ha) is surpassed only by the Netherlands (262kg/ha) (OECD, 2001, p.123). Fertilizer subsidy had contributed to one of the heaviest users of chemical fertilizers in the OECD countries.

TABLE 3. Effects on Reducing Subsidy Rate in Chemical Fertilizer

Category	Subsidy reduction rate (percent)		
	0	10	20
Total fertilizer consumption volume (1,000 ton)	1,680	1,655	1,631
(Reduction rate of consumption, %)	0.0	1.5	2.9
Total fertilizer sales amount (100 million won)	5,223	5,147	5,071
Spending increment of farmers (100 million won)	0	515	1,014
Sales reduction amount of fertilizer producer (100 million won)	0	76	152
Reduction rate in yield per ha (%)	0	0.0	0.0
Reduction rate in farm income (%)	0	0.3	0.5

VI. Summary and Concluding Remarks

Many OECD member countries are introducing the PPP for sustainable agricultural development and hold farmers liable for maintaining a certain level of environment quality. They are continuously reforming agricultural policies to reduce price subsidy and the support for inputs which are in conflict with environmentally-friendly agricultural production. These reform-oriented measures are viewed as an opportunity and a risk at the same time.

In this context, this paper tried to analyze the economic effects of environmental taxation on chemical fertilizers which were focused on effects of fertilizer consumption, rice yield, farmer's income, tax revenue from national economy aspect, enhancement of economic welfare through quality improvement of environment. Our consolidation of the above result of analysis revealed that in order to achieve effective policy objective of the imposition of environment tax on chemical fertilizers very high tax rate is required due to price inelastic demand but it requires high cost burden on the part of farmers. On the other hand, as to the influence of the imposition of 10% environment tax on chemical fertilizers, it is estimated that the quantity of fertilization for rice paddy was decreased by 1.5%, rice yield remained almost unchanged while the ratio of fertilizer cost out of total farm management cost was approximately 6% and the influence to the decrease in farmers' income was insignificant at 0.6% level. In this context, it will be necessary to consider the introduction of environment tax within the range of 10~20% for chemical input materials as mid to long term policy from changing direction point of view. The introduction of market oriented policy means such as environment tax which realizes such PPP can alert both manufacturers of chemical fertilizers and farmers about the environmental pollution and at the same time enhance the recognition for sharing responsibilities together. And also we can emphasize that it enables to provide systematic support for research and development of environmentally friendly agriculture and promotion project for farmers who practice environmentally friendly agriculture while applying advanced market oriented incentive policy externally.

In reality, there may be various practical issues associated with the introduction of environmental taxes in agricultural field for the realization of PPP. The correct tax rate cannot be set without establishing the amount of environmental damage caused per unit of fertilizer used. Furthermore, the major fertilizer elements like nitrogen and phosphorus have differential effects. The environmental damages are caused by the nutrients carried from the soil surface and profile by runoff and leaching. Not all fields are identical in their potential to cause environmental damages. The majority of farmers might raise objections in the process of setting tax rates and the selection of targets for taxation will create a series of debates. There may be political difficulties related to the introduction of environmental taxes on chemical fertilizers. Hence, a thorough review should be done not only to increase positive environment welfare but also to reduce negative influence to the environment for the eventual maximization of agricultural multifunctionality. The introduction of environmental taxes as one of policy measures for reducing greenhouse gases is a task which should be implemented on a mid- to long-term basis. Especially the understanding and cooperation among farmers, producers, the industries concerned, and consumers on government policy is essential for the implementation of realistic policies related to environmentally friendly agriculture for the development of agriculture/farm in the 21st century. In this regard, it will be very important to develop a new policy which internalizes the external costs of environmental pollution loads from agricultural production within the system.

In future studies relating to the introduction of environmental taxes in the agricultural field, more systematic and persuasive research on the calculation of environmental pollution cost by type of fertilizer nutrient, as well as in-depth surveys and analyses on farmers' responses to environmental regulations, needs to be conducted before environmental taxes are imposed. In particular, a method of combining agronomic simulation models and multi-objective mathematical programming models should be developed to analyze the effects of environmental taxation on farmers' revenue and the nutrients leaching and run off.

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