

Economic Effects of Environmental Taxation on Chemical Fertilizers

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I. Introduction

As an intensive farming is expanded to increase agricultural productivity, the increased in the use of chemical inputs such as fertilizers and pesticide have increased water and soil pollution and increased the deterioration of ecological system due to the leakage and infiltration of the 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 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 damages to the environment. 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. Environmental policies of most OECD countries utilize emission charges, product charges, deposits, and emission permit trades as a means to implement the PPP, rather than direct command and control methods.

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 of agricultural sector. 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 the PPP in non-agricultural fields. Lee (1993) analyzed the theoretical structure of environmental taxes and the economic effect of the carbon tax on the suppression of CO₂ gas emission. Na and Choi (1995) measured the effect of the carbon tax as 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 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 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.

II. Analytical Model for Environmental Taxation

The economic effect of fertilizer taxation on the farmers, who cause pollution, manufacturers of chemical fertilizers and social welfare can be explained from a partial equilibrium view in the graph below. In 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 explains the economic effect of 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 . Here, environmental tax rate t is exogenously given, 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 marginal social cost (MSC) curve. Under the new equilibrium, the price which rice farmers, 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 tax transfer to economic subjects. Farmers should cover $p^* \hat{p}$, while producers of chemical fertilizers should cover $\hat{x} p^*$. As such, 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

$$ECOTAX^P = \frac{e_i t}{e_i + h_i} \quad (2)$$

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).

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

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

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

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

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

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 though 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).

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

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).

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

In 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 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 become 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 of the level of national welfare, and improves the quality of environment.

III. Analytical Results of Environmental Taxation

1. Economic Welfare Effects of Eco-taxes

Rice farms were selected for analysis related to chemical fertilizer use, as most of 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. 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 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 2.7875.¹

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.

¹ 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 conditional input demand function were 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 so 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 pesticide 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

However, in case of imposing 10 percent tax increase, the quantity consumed would decrease to 1,655 thousand tons which represents 1.5 percent decrease. In case of a 100 percent tax imposition, consumption would decrease to 1,435 thousand tons which would be a 14.6 percent decrease. A 200 percent tax would decrease 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 case of a 10 percent tax imposition, 38 billion won in case of a 50 percent tax imposition, 76 billion won in case of 100 percent tax imposition and 152.1 billion won in case of 200 percent tax imposition. (see Table 1)

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

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	0	27	78	126	233	387

details on the Translog cost function expression and inferred co-efficient, see Kim and Kim (1999).

(100 million won)						
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 fertilizer consumption volume is based on the sales figure of the National Agricultural Cooperative Federation (2005) for entire types of fertilizers.

However, in case of 100 percent imposition, farmers' surplus will decrease by 541.3 billion won and manufacturer surplus will decrease by 28.3 billion won. This means that Government tax revenue from the imposition of environmental taxes is estimated to reach to 51.5 billion won in case of 10 percent tax rate and 446.3 billion won in case of the loss of economic welfare from the imposition of environmental taxes on the part of 100 percent tax rate respectively. Analysis showed that farmers' burden from taxation consumer farmers is much bigger than that of manufacturers of chemical fertilizers. reaches to approximately 95 percent of total tax amount, whereas fertilizer producers share only about 5 percent of total tax amount.

The quality of environment will be improved due to 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 were 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 fertilization type of rice farm, the data on water field rice farms should be obtained. However due to constraints in obtaining data, a quantity-response function was estimated using the survey on the quantity of nitrogen fertilizer used conducted by Rural Development Administration (Kim and Kim, 1999). 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. 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 the quadratic response function had the highest goodness-of-fit.² 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 ton. 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.

In case of imposing 100 percent eco-tax rate on chemical fertilizers, the quantity of chemical fertilizers used by individual rice farm was estimated to decrease by approximately 15 percent. However, this level of decrease in fertilization had almost no influence on the quantity of yield. And also the analysis shows that the cost of

² 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).

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 case of a 100 percent tax rate. However even though the quantity of fertilizer uses is estimated to decrease to 15 percent from the current level with a 100 percent eco-tax, the quantity of rice yield would be nearly unchanged. (see Table 2). This means that the estimated fertilization-quantity response function for rice crop is nearly flat in at current level of fertilizer use.

Next, when we look at the influence on 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 in the normal paddy rice farmers' income is estimated to not exceed 3.6 percent even when a 100 percent eco-tax is imposed.

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.

3. Effects on Reducing Fertilizer Subsidy

As a result of implementation of price subsidy system to compensate the loss from the fertilizer sale, the rate of subsidy to total inorganic fertilizers is approximately 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.³ 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 meaning the price subsidy is entirely eliminated, the estimate shows that 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 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 significant

³ Korea has one of the most fertilizer-intensive agriculture in the world although chemical fertilizers consumption has decreased since 1990. Nitrogen balance of total agricultural land (253kg/ha) exceed only by the Netherlands (262kg/ha) (OECD, 2001, p.123). Fertilizer subsidy had contributed to one of heaviest users of chemical fertilizers in the OECD countries.

influence on yield of rice per tan and the decrease in rice farmers' income is estimated to only 0.5 percent (see Table 3).

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 PPP for sustainable agricultural development and hold farmers liable for maintain certain level of environment quality liable. They are continuously making efforts to conduct agricultural policy reform 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 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. The analytical results of the effects of eco-taxes on the economy are summarized as follows:

First, in case where a 10 percent environmental tax was imposed on the sale of chemical fertilizers, it is estimated that the consumption of fertilizer would be reduced by 1.5 percent, the yield would remain essentially unchanged and income would be

decreased by 0.6 percent. In the case of imposing a 100 percent tax the results show that fertilizer consumption would decrease by 14.6 percent, the yield per ha would decline by 0.4 percent and the farmer's income would decrease by 3.6 percent.

Second, it is estimated that government's tax revenue from the imposition of environmental taxes on chemical fertilizers will increase by 51.5 billion won in case of 10 percent tax rate; 242.1 billion won in case of 50 percent tax rate; and 446.3 billion in case of 100 percent tax rate. The analysis shows the farmers' tax burden to be 95 percent of total tax revenue, whereas fertilizer producers pay only about 5 percent of the total tax burden. This is because the fertilizer demand is price inelastic while the supply price is elastic.

Third, the quality of the environment will be improved by the reduction in pollution loads from the imposition of environmental taxes. Total social welfare will be increased if the tax rate is equal to the amount of external damage caused by unit of fertilizer sold. It is estimated that the increase in total social welfare will be 800 million won if the pollution damage were equal to 10 percent of the fertilizer cost and a 10 percent tax rate were imposed. If pollution damages were 200 percent of the fertilizer price and a tax rate of 200 percent were imposed the increase in net social benefits would be 456 billion won. Net social welfare was measured to be at approximately 50 percent level of total social welfare at each tax rate respectively.

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. Further 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 rate and the selection of targets for taxation which will create a series of debates. There may be political difficulties related to the introduction of environmental taxes on chemical fertilizers. Hence, still thorough review should be done not only to increase positive environment welfare but also to reduce negative influence to the environment for eventual maximization of agricultural multifunctionality. The introduction of environmental taxes is a task which should be implemented on mid to long term basis. Especially the understanding and cooperation among farmers as producers, 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 have new policy developed which internalizes the external costs of environmental pollution loads from agricultural production within the system.

In the future, in relation 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 survey and analysis on farmers' responses to environmental regulations needs to be conducted before environmental taxes are imposed.

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