ADVERSE HEALTH IMPACTS OF PESTICIDE USE ON INDONESIAN RICE PRODUCTION: AN ECONOMIC ANALYSIS

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ABSTRAK

Pestisida bak pisau bermata dua. Di satu sisi, pestisida memberikan manfaat bagi pengguna, dan di sisi lain pada waktu yang bersamaan pestisida mempunyai efek yang merusak. Oleh karena itu pelarangan penggunaan secara total tidak efisien, dan menentukan penggunaan pestisida yang optimal sangatlah diperlukan, dengan cara mempertimbangkan dampak kesehatan. Tujuan kajian ini adalah menentukan penggunaan pestisida yang optimal dengan mempertimbangkan dampak kesehatan, dan mengestimasi nilai moneter kehilangan produktivitas petani. Manfaat penggunaan pestisida dicari dengan fungsi produksi, sedangkan dampak kesehatan dicari dengan fungsi biaya kesehatan. Data produksi padi selama kurun waktu 1974-2000 digunakan untuk mencari fungsi produksi. Fungsi biaya kesehatan diperoleh dari kajian sebelumnya yang telah dilakukan oleh peneliti pendahulu. Hasil kajian ini menunjukkan bahwa penggunaan pestisida yang optimal sangat rendah dan nilai ekonomi kehilangan produktivitas sangat tinggi. Hal ini karena adanya perbedaan yang besar antara penggunaan pestisida yang optimal dengan penggunaan pestisida yang aktual selama kurun waktu tersebut. Faktor penting yang menyebabkan besarnya perbedaan tersebut adalah elastisitas produksi dari pestisida sangat rendah. Saran yang dapat disampaikan adalah petani menggunakan pestisida secara efisient, yaitu mendekati tingkat penggunaan yang optimal.

Kata Kunci: Kehilangan Produktivitas, Pestisida, dan Biaya Kesehatan.

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INTRODUCTION

The international agricultural community currently has much greater awareness to the health and environmental hazards associated with pesticide use than it was the case thirty years ago. The range of technically and economically feasible non-chemical crop protection methods and systems has also expanded rapidly during the same period. 'Consumer awareness of the environment and preferences for more environmentally benign products appears to be growing steadily around the developed world and in selected developing countries' (Erickson and Kramer-LeBlanc 1997:196), and sustainable development of a competitive agriculture is the major goal of agricultural production system (Reinhard and Thijssen 1998). This is supported by Agenda 21 that makes a decision to perform the concept of sustainable economic development in various sectors (UNDP/EC 1999), and the International Organization for Standardization (ISO) 1400s that forces producers to improve its policies and measurements in producing goods that are free of toxic residues and maintain a sound environment to meet the requirements of the importing countries, mainly USA, EU, and Japan (Sombatsiri 1999).

In the food crops productions, one of the focuses that have largely been on environmental issues is due to excess application of detrimental agrochemicals (Barbier 1989; and Conway and Barbier 1990). Since the agricultural sector uses the detrimental inputs improperly, the sector had become one of the largest contributors in environmental pollutions notably non-point source pollutions (Archer and Shogren 1994). Furthermore, the externalities caused by agrochemical inputs use had brought about considerably high external costs (Bond 1996). These environmentally adverse impacts are mostly due to excessive pesticide use that is socially much larger than that of what was necessarily required.

Pesticides have been introduced since 1960s through the well-known campaign called green revolution because of their benefits. Pesticides are still used widely in agricultural sector around the world. One of the reasons is that producer will be guaranteed to get larger income because the product are more valuable (Farrel 1998). Furthermore, many modern farming practices, such as new cultivation techniques, large single cropping, and the new high-yielding crop varieties that are central to the successful green revolution are made possible mostly by the availability of pesticides. This is due to the fact that pesticides give economic benefit –reducing yield losses caused by pest attacks– to the farmers. It has been reported that estimated crop losses because of pest attacks vary considerably. In Indonesia, it has been estimated that crop losses caused by stem borer amounted to up to 95% in 1967, while during the periods 1969-1971 rice loss caused by *tungro* amounted for 21,000 hectares (Rola and Pingali 1993).

Because of the fact that pesticide give the benefits, ‘it will not be optimum to ban the pesticide because the total positive benefit when no pesticide is used are less than can be attained with some use of pesticides’ (Halcrow 1984:264). This study, therefore aims to review the following questions: (1) what is the optimal social level of pesticide use when health cost of pesticides used is internalized in rice production? (2) to what extent is the gap between actual, social uses of pesticides? (3) how much is the value of fall in farmers’ productivity associated with adverse health impact of pesticide use?.

LITERATURE REVIEW

Pesticide is a poisonous agent designed to kill living things –bacteria, weeds, insects and fungus. Humans share a great deal of genetic material in common with other living things – including plants and insects as well as animals (Ikerd 1999). Because of the fact that ‘at subcellular level organisms have many similarities with one another, all pesticides are associated with a certain measure of … the probability that some adverse effects will occur’ (Wilkinson 1988:11). Degree of the risk, however, will vary considerably depending upon the kind, amount and time of exposure (Manahan, 1983). Furthermore, Nhachi (1999:128) stated that ‘the risk and hazard from toxic pesticide exposure are associated with … misuse or unsafe handling/application (occupational exposure), and … insecticides perhaps possess the greatest hazard of toxic exposure to humans’.

Although there is safety precaution stated by Matthews (1979:291) is that ‘appropriate protective must be worn wherever a … pesticide is applied or when application equipment contaminated with such pesticide is repaired …’ however ‘often climate conditions are not conducive to wearing protective clothing, especially in tropical countries’. It is, consequently, inevitable that Indonesian farmers are occupationally contacted with pesticides when they are applying the pesticides. Khisi et al. (1995:127) proved that ‘no farmer wore industry-recommended protective clothing, and what clothing did cover the skin was mostly permeable cotton’. As a result, 21 % farmers spraying pesticides suffer from three or more signs and symptoms of poisoning.

Commonly, pesticides go into human body by inhalation exposure, dermal exposure and oral exposure (Matthews 1979), and furthermore 'inhalation and dermal exposure can lead to mild and serious illness' (Nigg et al. 1988:105). Contrary to common belief, pesticides enter the human body through the skin, not the respiratory track (Rola and Pingali 1993). These exposures medically may bring about acute and chronic poisonings.

The active ingredients in many agricultural pesticides have been linked with cancer in humans and other animals. The whole linking process for agricultural chemicals is complex. Disruption of immunity and endocrine systems can take so many forms and be characterized by so many different symptoms that it is mind-boggling to even to think about how linkages of disruptions with multiple possible causes might be disentangled. Potential problems with human reproduction may take several generations to even become apparent. However, there is a growing body of empirical evidence suggesting that farmers are less healthy than are otherwise similar members of the general population, regardless of the source of their maladies. Disruptions of human health due to pesticide exposure has been comprehensively discussed by Ecobichon et al. (1988) Blair et al. (1988), Thomas et al. (1988), (Mattison et al. 1988) and Johnson, et al. (1988) in neurotoxic effects, carsinogenic effects, immunologic effects, reproductive effects and developmental effects respectively.

Moreover, the empirical evidence for the existence of negative impacts of pesticides on farmers' health and productivity in developing countries has been summarized by Ajayi (2000:129-130), that is

> With its average contribution of 86% of all farm labor inputs, the household is clearly the most important supplier of labor inputs…. As a result, the health status of household members is critical for the management and productivity of family farms. Illness suffered by one or more members of the household affects the overall performance and productivity of the family farm in three major ways: First, health symptoms reduce the productivity of the victim on the family farm throughout the period of illness…. Second, health symptoms lead to production risk and resource constraint problems. When symptoms occur, the income that the household had earmarked to procure inputs for the family farm may be diverted to seeking medical help for the victim. … The third effect of health symptoms is the fallout on the productivity of other members of the household. In addition to the sick person not being able to work on the farm, some members of the household (usually women) are often assigned the task to look after the sick.

In economic terms, the adverse effects of pesticide application on human health can be revealed with the additional cost associated with the illness due to pesticide exposure.

This is can be monetized by calculating treatment cost consisting medication and doctor’s fees, and the opportunity cost of farmer’s time lost in recuperation formed a measure of the health cost per farmer (Rola and Pingali 1993).

THEORETICAL FRAMEWORK

Monetary Valuation of Externality of Pesticide Use

The externality is defined as ‘costs or benefit from production activities that are not fully reflected in market incentive’ (Monke and Pearson 1989:5). Externality brings about market does not work efficiently (Greenaway and Milner 1994; Papps 1994). With respect to the use of pesticides, Jungbluth (1999:29) defines that negative externalities are ‘unintentional side effects of pesticide use like … pesticide residues and health effects’. These can be subdivided into two categories. The first harming the user directly and the second concerning both the user and the society in total.

In order to valuate the externality of pesticides in monetary terms, the study employs *human capital approach* that measure the impact of agent on health which represents quality of workers. Garrod and Willis (1999:34) state that it is applicable to use this approach ‘in case where there is a clear relationship between environmental degradation and illness … and where the cost of labour supply and medical treatment are readily quantifiable in monetary terms’. In this case, environmental degradation is reasonably associated with pesticide use. Kishi et al. (1995) and Pawukir and Mariyono (2002) have proved that relationship between pesticide use and illness is significant.

Since health costs associated with pesticide use in Indonesia have not been well estimated, it is adequate to use the benefit transfer concepts that ‘refers to the process by which a demand function or value, estimated for one environmental attribute or group of attribute at a site, is applied to assess the benefits attribute to similar attribute or site’ (Garrod and Willis 1999:331). If it is the case, the health cost function is obtained from a study conducted in the Philippines by Rola and Pingali (1993).

The health cost computation was based upon the medical examinations. A medical team of doctor, nurse and an X-ray technician, and a medical technologist conducted the medical examinations. These examinations provided an assessment of each farmer’s illness and their seriousness. The treatment needed to restore the farmer’s health was assessed. Treatment cost including medication and doctor’s fees and time loss in recovery of farmer’s health was used as a measure of health cost. The health cost function modeled by Rola and Pingali (1993) is

$$HCx = g(A, S, x) \quad \ldots\ldots \quad (1)$$

where HCx: health cost associated with pesticide use
A: ages (year)
S: dummy (1=smokers)
x: Pesticide (kg per hectare)

Economic Benefit of Pesticide Use

The benefit of pesticide use, which measured in economic terms for farmers, is the value of expected loss in yield or quality that can be saved by applying pesticides. The benefit of pesticide use can be approximately derived from aggregate production function

$$Y_t = q(X_t, Z_t, L_t) \quad \ldots\ldots \quad (2)$$

where Y_t is production
X_t is level of pesticide
Z_t is level of fertilizer uses
L_t is rice-planted area
Subscript t represents year t

For the sake of simplicity, assumptions held in this study are the production function exhibits constant return to scale, and the other factors excluded from the model are constant. The production is therefore can be revealed in intensive form

$$y_t = q(x_t, z_t) \quad \ldots\ldots \quad (3)$$

where y_t is production per hectare (tones)
x_t is level of pesticide per hectare (kg)
z_t is level of fertilizer uses per hectare (kg)

If the agricultural market is competitive, the price of product (Py) is known as well as the prices of tradable inputs. The benefit of pesticide use per hectare (Bx) that can be formulated from the equation (3) is

$$Bx = Py \bullet q(x_t, z_t) \quad \ldots\ldots \quad (4)$$

On the other hand, farmers should finance the pesticide use in order the save the loss in both quantity and quality of product. The private cost (Cx) associated with pesticide use is the amount of pesticides multiplied by its price (Px), that is

$$Cx = x_t \bullet Px \quad \ldots\ldots \quad (5)$$

Thus, problem of net benefit (NBx) faced by farmers is

$$
\begin{aligned}
NBx &= Bx - Cx \\
&= Py \bullet q(x_t, z_t) - x_t \bullet Px \quad \ldots\ldots\ldots\ldots \quad (6)
\end{aligned}
$$

As previously mentioned, the pesticide use has the adverse effect or externality. Pincus et al. (1999) suggest that the value of the externality –called health cost (HC)– must be subtracted from the benefit of pesticide use in order to obtain the net social benefit (SB). The final problem faced by the farmers is

$$
\begin{aligned}
NSBx &= Bx - Cx - HCx \\
&= Py \bullet q(x_t, z_t) - x_t \bullet Px - g(A, S, x) \quad \ldots\ldots\ldots\ldots \quad (7)
\end{aligned}
$$

In the concept of optimization, to reach the maximum value of NSBx, 'the derivative of the function must be zero' (Salvatore, 1996:50). With respect to the use of pesticides, it can be formulated as

$$\partial NSBx / \partial x = 0$$

$$\partial[\{Py \bullet q(x_t, z_t)\} - x_t \bullet Px - g(A, S, x)] / \partial x = 0$$

$$Py \bullet \partial q(x_t, z_t)/\partial x = Px - \partial g(A, S, x)/\partial x$$

$$MBx = MCx + MHCx \quad \ldots\ldots\ldots\ldots \quad (8)$$

The equation (8) is in line with a concept of optimization analysis is that the maximum net social benefit can be obtained when the marginal benefit (MBx) is equal to marginal social cost (MSCx). Diagrammatically, the equation (8) can be drawn in Figure 1.

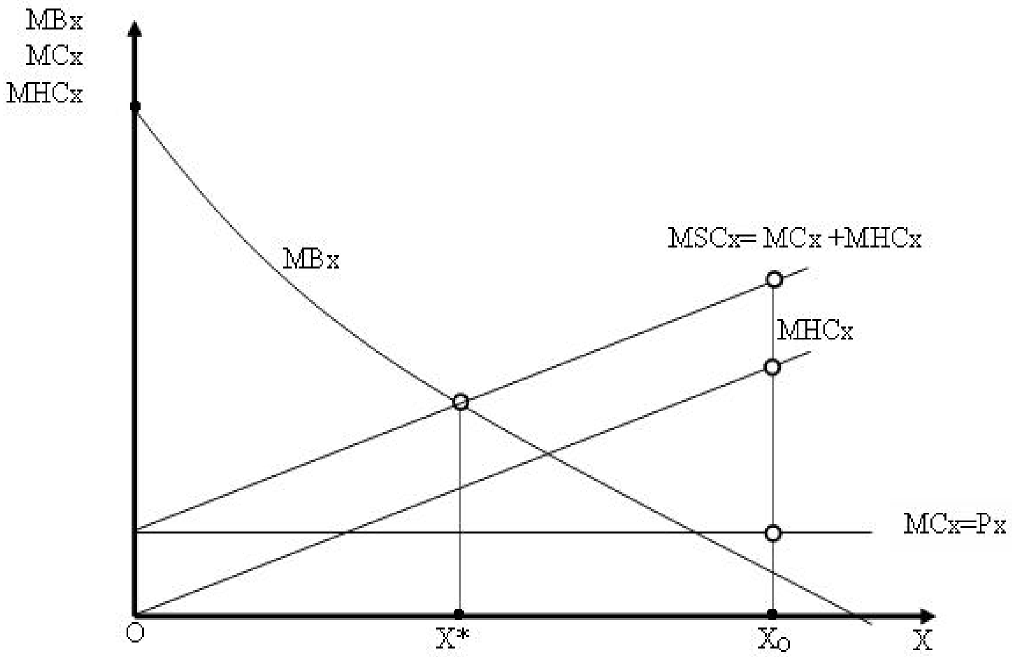

Figure 1. Optimal level of pesticide use

Figure 1 shows that there are two conditions in which use of X give the different levels of benefit. First, actual social benefit, which is benefit resulting from actual use of X_0. The actual net social benefit can be determined

$$Bx_{ac} = \int_0^{Xo} (MBx - (MCx + MHCx) \; dx$$

$$= B(X_0) - [C(X_0) + HC(X_0)] \quad \ldots\ldots (9)$$

Second, socially maximum benefit, that is benefit resulting from the use of X*. It is reached when MBx is equal to MSCx. The social benefit can be determined

$$Bx_{soc} = \int_0^{X^*} (MBx - [MCx + MHCx)] \; dx$$

$$= B(X^*) - [C(X^*) + HC(X^*)] \quad \ldots\ldots (10)$$

To find the socially optimum use of pesticides, X*, the *goal seek* program provided by *MS-EXCEL* is employed. The difference between actual benefit and social one is called social inefficiency. If it is the case, the social inefficiency represents the loss of productivity associated with health impact of pesticide use.

Source of Data

This study employs data of rice production, use of tradable inputs and rice-planted area at national level during 1974-2000, collected from Center of Statistical Bureau and annual reports of Ministry of Finance reported by Useem et al (1992). In order to estimate the current value of benefit and cost of pesticide use, the average prices of rice and pesticides in year of 2000 are used.

Economic and Econometric Modeling

The health cost function of pesticide use which is modeled by Rola and Pingali (1993:62) is

$$EC = K\,A^{\theta}\,e^{\sigma DS}\,x^{\delta}\,e^{\upsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

where K represents initial health condition
A: ages (year)
θ, σ, δ are coefficients to be estimated
υ is disturbance error

With respect to production function, Soekartawi et al. (1986) suggest that Cobb Douglass model is suitable for estimating production function in agricultural sector. The aggregate production function is modeled

$$Y_t = T\,X_t^{\alpha}\,Z_t^{\beta}\,L_t^{\gamma}\,e_t^{\varepsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

Since the production function is assumed to exhibit constant return to scale, it can be expressed in yield function

$$y_t = T\,x_t^{\alpha}\,z_t^{\beta}\,e_t^{\varepsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

where T is level of technological acquisition
α, β is elasticity of production with respect to x and z
ε is disturbance error

Taking natural logarithm both left and right sides makes yield function linear in parameter, that is,

$$\ln y_t = \ln A + \alpha\, x_t + \beta\, z_t + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

The log-linear yield function is estimated by employing *generalized least square* (GLS) as suggested by White et al. (1990). Using GLS is able to avoid from facing problems of heteroskedasticity and serial-correlation that are usual in time-series data. The estimate resulting from GLS is therefore unbiased and efficient. The estimated yield function, then, is used to calculate the benefit of pesticide use.

RESULT AND DISCUSSION

Health Cost of Pesticide Use

The health cost (HCx) resulting from use of pesticides that has been econometrically estimated by Rola and Pingali (1993) is

$$HCx = 3.7810 \bullet AGE^{1.82} \bullet e^{1.1\ SMOKE} \bullet x^{0.62} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (15)$$

where HCx: health cost (Peso Philippine)
A: ages (year)
DS: dummy (1=smokers)
x: Pesticide (kg)

By holding assumption is that farmers are, on average, 40 years old and they are smokers, the external cost can be simply expressed as

$$HCx = 9{,}355.26 \bullet x^{0.62} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (16)$$

When the exchange rate of 1 Peso Philippine is equivalent to 173,50 Indonesian rupiahs (IDR)[1], the health cost converted in to Indonesian rupiah is

$$HCx = 1{,}623{,}137.34 \bullet x^{0.62} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (17)$$

and marginal health cost is

$$MHCx = \partial\, HCx/\partial X = 1{,}006{,}345 \bullet x^{-0.38} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (18)$$

Benefit of Pesticide Use

The yield function estimated by GLS is

$$\ln y_t = 0{,}6299 + 0.07 \ln x_t + 0.14 \ln z_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (19)$$

t_{ratio}: (3.1295) (1.9001) (3.1780)

$R^2 = 0.81$ $F = 49.702$ (sig. α: 0.01); DW=1.86

Based upon the statistical parameters, it is clear that the yield function is significantly estimated and efficient. More than 80% of variation in yield of rice can be explained by the variation in uses of pesticides and fertilizers. In terms of power function or Cobb Douglass model, the yield function is expressed

$$y_t = 1.8774\, x_t^{0.07}\ z_t^{0.14} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (20)$$

[1] Exchange rate is downloaded from http://finance.yahoo.com/m5?a=1&s=PHP&t=IDR

Since the average use of fertilizer during the periods 1974-2000 is approximately 795 kg per hectare, the benefit function of pesticide use is

$$Bx = Py\ 1.8774\ x_t^{0.07}\ 795^{0.14}$$
$$= Py\ 4.78\ x_t^{0.07} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

and marginal benefit of pesticide use is

$$MBx = Py\ 0.3346\ x_t^{-0.93} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

Optimal Use and Net Social Benefit of Pesticide

So-called that agricultural market is competitive, farmers posit as price taker in the economy. Based upon BPS (2000a), the average price of rice (Py) is 1,098,711 IDR per ton and the average price of pesticides (Px) is 43,014 IDR per kg, the benefit function become

$$Bx = 1.098.711 \bullet 4.78\ x_t^{0.07}$$
$$= 5,254,019\ x_t^{0.07} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

and marginal benefit of pesticide use (MBx) is

$$MBx = 367,781\ x_t^{-0.93} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

At the same time, farmers should finance the pesticide use to avoid yield loss. In addition, farmers also suffer from illness brought about by the pesticides. Therefore, farmers face problem of maximization of net benefit function of pesticide use. The maximum benefit is reached when the marginal benefit of pesticide use is equal to the marginal cost plus marginal health cost:

$$MBx = Px + MHCx$$
$$367,781\ x_t^{-0.93} = 43,014 + 1,006,345 \bullet x^{-0.38} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

By employing *goal seek* program provided by MS-EXCEL, the optimum level of pesticide use based upon equation (25) is 0.1544 kg per hectare.

The socially optimum level of pesticide use, in this case is very low. This is due to the fact that the elasticity of production with respect to pesticides is so low, that the marginal benefit of pesticide is low as well. On the contrary, the health cost associated with pesticide use is relatively high. As a consequence, the marginal net benefit of pesticide becomes very low when the health cost is internalized in cost of pesticide use. In addition to the socially optimum use of pesticides, net social benefit of pesticide use resulting from such level is

$$Bx_{soc} = \int_{0}^{0.1544} (MBx - Px - MHCx)\ dx$$

$$= 4{,}093{,}614 \text{ IDR/hectare/year}$$

On the other hand, the actual average use of pesticides per hectare during the periods 1974-2000 is approximately 49 kg per hectare. The net social benefit of pesticide use at such level is therefore

$$Bx_{ac} = \int_{0}^{49} (MBx - Px - MHCx)\ dx$$

$$= -13{,}333{,}327 \text{ IDR/hectare/year}$$

It can be seen from the calculation that the net social benefit is negative. This indicates that farmers actually suffer from loss in social terms. Furthermore, the amount of actual net social benefit (in absolute value) is very high. This is caused by the high level of pesticide use. The average level of pesticide use is very high because it includes the use of pesticides during the green revolution, at which it was promoted and supported by considerable subsidy (Useem et al. 1992) and intensive training (Barbier 1989) in order to escalate national rice production. It is obvious that level of rice production with actual level of pesticide use (49 kg per hectare) is greater than that with socially optimum level (0.1544 kg per hectare). In this case, net social benefit that takes externality into account was ignored since it would make the national rice production fall.

The gap between actual net social benefit and maximum social benefit is 4,093,614- (-13,333,327) = 17,426,942 IDR per hectare per year. The amount can be reasonably expressed as loss in farmers' productivity, as stated by Antle and Capalbo (1994) that farmers would be more productive if they were healthier. It is, of course, understandable since farmers suffer from illness caused by pesticides when they were applying pesticides. In fact, particularly in tropical areas, being ill associated with pesticide exposure is unavoidable (Kishi et al. 1995).

If the annual rice-planted is, on average, approximately ten million hectares, the loss in productivity is around 17 trillion IDR per year. In other words, such amount ought to be required to cover health cost of farmers suffering from illness caused by pesticides. In fact, it was not available. This means that farmers' health has been sacrificed for the sake of boosting up national rice production.

However, along with the awareness of public policies, the level of pesticide use continually decreases. Factors that have great impact on reducing pesticide use are policies of prohibiting certain pesticides and eliminating subsidy (Untung 1996), and program of integrated pest management (Mariyono and Irham 2001; Mariyono et al. 2002). For instance, the level use of pesticides dropped considerably from 130 kg per hectare in 1989 (Useem et al. 1992) to 3.42 kg per hectare in 2000 (BPS 2000b). It is obvious that farmers' productivity increased as well.

Now, it is really required that the objective of pesticide policy at both international and national level should bring social costs in line with social benefits. The available policy remedies include regulation and economic instruments. Regulations, including bans on individual chemicals or classes of chemicals, are an effective means of stopping the introduction of hazardous compounds into the environment. Economic instruments, for example taxes, registration fees and import duties, work to redistribute the costs of pesticide use from the public to pesticide producers and consumers and adjust the private costs to the total social costs occurring for pesticide use (Pearce and Turner 1990). Environmental tax is not only expected to be able to reduce demand for pollutants but also provides revenues for the government. The revenue then can be used to cover health costs and environmental clean-up activities.

CONCLUSION AND RECOMMENDATION

Conclusion

In conclusion, it should be pointed out that the optimal level of pesticide use is extremely low, compared with the average actual use of pesticides during the period. This is because of the fact that marginal benefit of that is very low as well. The high level of pesticide use is able to cause illness. The Illness suffered by one or more members of the household affects the overall performance and productivity of the family farm. This occurs in three manners: (1) health symptoms reduce the productivity of the farmers on the family farm throughout the period of illness, (2) health symptoms lead to production risk and resource constraint problems, (3) fallout on the productivity of other members of the household. The economic value of loss in productivity is considerably high, as a result of high level of average use of pesticides. Thus, it is understandable that in the past many farmers suffered from poisoning and died at young age, because they did not get medical treatment to cure their intoxication.

Recommendation

It is highly recommended to reduce pesticide use in rice production since the level of socially optimal use of pesticides is very low. This is logic since the elasticity of rice production with respect to pesticide use is low, and therefore reducing pesticide will not have big impact on rice production. Many economic instruments and regulations can be done to do so. Furthermore, it is wise to apply the agricultural technology that is environmentally benign.

Limitation

The limitation of this study is that it is sensitive to performance of economy that influences prices of agricultural products, and exchange rate. When the prices change, the marginal benefit and marginal cost will change as well. Related to exchange rate of IDR, it will affect the health cost of pesticide use. However, since the production function estimated in this study is purely technical relation between output and inputs, it is not affected by the economy. Thus it can be used to re-estimate loss in productivity of farmers when there are changes in economic indicators.

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