

INEFFICIENT USE OF PESTICIDES AND WELFARE LOSS ASSOCIATED WITH NEGATIVE EXTERNALITY IN INDONESIAN RICE AGRICULTURE

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Abstract

Pesticides provide economic benefits for the farmers in terms of saving yield loss; but also provide adverse impacts. It is therefore economically inefficient to totally ban the use of pesticides; and consequently, it is required to investigate an efficient level of pesticide use. This paper aims to determine the efficient use of pesticides by internalising the externality costs, and estimates the monetary value of net welfare loss. The benefit of pesticide use is estimated using a production function, and the economic value of the adverse impact on human health and the environment are represented by a health cost and consumers' willingness to pay for a kilogram reduction in pesticide use. Panel data on rice production used in this paper is compiled from publication of Indonesian Statistics Agency. The externality costs including are adopted and adjusted from previous researches. The socially efficient use of pesticides is determined when the marginal benefit is equal to the marginal social cost. The results of this study indicated that the efficient use of pesticides is lower than that of actual use. Consequently, there is welfare loss imposed on farmers and other community. The policy implication is that it is preferable for the farmer to use pesticide efficiently.

Keywords: *pesticides, negative externality, net social benefit, and social efficiency*

I. INTRODUCTION

One of the largest contributors to non-point source pollution –a form of pollution of which source and quantity are difficult to identify (Grafton et al. 2004) — is agricultural sector (Archer and Shogren 1994). This is because the agriculture discharges pesticides and

other chemicals that exceed an assimilating capacity of the environment. The accumulated wastes are then capable of polluting the environment. In food crops production, issues on environmental pollution are due to an application of detrimental agrochemicals (Barbier 1989; and

Conway and Barbier 1990). The use of agro-chemicals has increased dramatically after implementations of 'green revolution' in 1960s in developing countries. In Indonesia, the green revolution was addressed to achieve food self-sufficiency. Indonesian government has spent about US\$ 725 million of agricultural input subsidies (Barbier 1989), and about 40 per cent of the amount was allocated for subsidising pesticides (Conway and Barbier 1990).

Pesticides are capable of polluting the environment because they are poisonous and used enormously. Pimentel et al. (1993) point out that only one per cent of pesticides applied are on target, and the rest are discharged into the environment. The pesticides are poisonous because they are synthesised with the sole intention of causing death or harm to living organisms (Nhachi 1999). The pesticides, furthermore, are developed specifically for their biological activity or toxicity to some forms of life. Since at the sub-cellular level the organisms have similarity with one another, the uses of pesticides are associated with a certain risk of exposure to not-target living things including human. Human exposure to chemical pesticides may occur occupationally or may occur from any of several involuntary non-occupational sources (Wilkinson 1988). The degree of the risk, however, will vary considerably. This is dependent on the intensity and duration of exposure, which in turn, relate to the circumstances under which exposure occurs (Manahan 1983).

In spite of the adverse impacts of pesticides on human health and the environment, pesticides are still used widely in agricultural sectors around the world. One of the reasons is that farmers will earn more because the products are more valuable both in quantity and quality (Farrel 1998). Furthermore, many modern farming practices, such as new cultivation techniques, large single cropping, and the new high-yielding crop varieties are made possible mostly by the availability of pesticides (Bond 1996). Pesticides give an economic benefit by reducing yield losses caused by pest attacks.

However, the global community currently is more concerned about the health and environmental hazards associated with pesticide use than it was three decades ago. The global community has a property right to good quality of environment and safe consumer goods. This is indicated by the fact that '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). Reinhard and Thijssen (1998) claim that environmentally sustainable development of a competitive agriculture becomes the major goal of an agricultural production system. The International Organization for Standardization (ISO) 1400s forces producers to improve policies and measures in producing goods that are toxic-residue free and maintain a sound environment (Sombatsiri 1999).

If pesticides still give significant benefits, 'it will not be optimum to ban the pesticides because the total positive benefit when no pesticide is used is less than can be attained with some use of pesticides' (Halcrow 1984:264). This is because farmers will obtain less benefit. However, it will not be efficient to let farmers use pesticides without taking the adverse effects into account because society suffers from the adverse impact of pesticides. In addition, the farmers also suffer from illnesses associated with pesticides (Kishi et al. 1995). It is therefore required to find a solution that fulfils the community's concern for the environment without sacrificing the profitability of agricultural practices. This paper, aims to find a solution by answering the following questions: (1) what is the socially efficient level of pesticide use after taking into account the adverse impacts? (2) what is the gap between actual and socially efficient use of pesticides? (3) what is the monetary value of net welfare loss associated with the adverse impacts of pesticide use?

II. LITERATURE REVIEW

Studies on pesticide impacts have been conducted since the publication of 'Silence Springs' by Rachel Carson in 1962. The book describes environmental pollution by persistent pesticides. Barbier (1989) and Conway and Barbier (1990) highlight the green revolution as a starting point of non-point source pollution by pesticide use. Specifically in Indonesian agriculture,

the use of pesticides is no longer effective, and it has created a secondary pest outbreak. This is an undesirable impact of pesticides on an ecological balance. With respect to pesticide impact on human health, Kishi et al. (1995) found that farmers in Indonesia suffered from symptoms of pesticide intoxication after spraying pesticides. The farmers needed some days to recover. Hondekon and de Groote (1999) investigated the adverse impact of pesticides used in controlling locusts in Africa. The results show that the pesticide use led to the loss of a large number of livestock. It is also reported that a number of people suffered from intoxication. In Thailand, Jungbluth (1996) reports that vegetables and fruits were highly contaminated with pesticides. This resulted in loss of a large amount of money. These studies did not measure the benefits provided by pesticide use, and therefore one of the solutions proposed is to reduce pesticide use.

With regard to the benefits of pesticides, Rola and Pingali (1993) study pesticide productivity and farmers' health impact of pesticides in the Philippines. They found that the pesticides contributed significantly to the farmers' income. But the farmers suffered from poisoning such that they needed to spend more for some medical therapies after applying pesticides. The results suggest that the extra health cost should be subtracted from the farm revenue. With respect to the net welfare related to pesticide use, a study in Germany by Fleicher (1999) compares the benefit of pesticides with the costs

for dealing with agrochemical contamination. He found that there was a net welfare loss. Related to the value of environmental quality and pesticide-reduced residues in agricultural products Mourato et al. (2000) estimate consumers' willingness to pay (WTP) for a reduction in pesticide use. The assumption is that consumers will be willing to pay more for goods if the goods are produced with low or pesticide free. The results of this study imply that the prices of pesticides need some adjustments, because the pesticides reduce the welfare of community. Ajayi (2000) attempts to find an efficient level of pesticide in Côte d'Ivoire, West Africa'. The efficient level of pesticide use is established by internalising health costs associated with pesticides into production costs. This means that the health cost is considered as extra cost that needs payment. The result shows that an efficient level of pesticide use is determined by taking the health costs into account.

The previous studies mostly highlighted the impact of pesticide use in agriculture, and proposed some solutions for reducing the externalities. Ajayi's (2000) study is the only one that proposed an efficient use of pesticides because he realised that the pesticides still provide benefits for the farmers. However, he has not considered the pesticide externalities that impose on the community. As a result, there is no a win-win solution, because the community is still a loser. Thus, this study is different from the previous ones in terms of internalising the costs of

externalities that impose on the farmers and third parties mutually. It is expected that this study can find the win-win solution.

III. THEORETICAL FRAME WORK

A. Economic benefit of pesticide use

The benefit of pesticide use, measured in economic terms, is the value of loss in yield and/or quality that can be saved by applying pesticides. It can be approximately derived from an aggregate production function:

$$Y_{it} = F(L_{it}, Z_{it}, X_{it}, T) \quad (1)$$

where Y is value of product, Z is vector value of productive inputs (such as seed, fertilisers, labour), X is quantity of pesticide, L is land, T is time trend capturing smooth technological progress, and subscript i represents region and subscript t represents year. Let the production function be exhibiting constant return to scale, and the other factors excluded from the model be constant. The production therefore can be revealed in an intensive form as:

$$y_{it} = f(z_{it}, x_{it}, T) \quad (2)$$

where $y = Y/L$, $z = Z/L$, and $x = X/L$. Land, L , disappears in the function because it will be equal to unity. Since y is the value product, the benefit function of pesticide use per hectare (B) estimated from the equation (2) is:

$$B = b(\bar{z}_{it}, x_{it}) \quad (3)$$

where \bar{z} is average uses of productive inputs. The interpretation of equation (3) is that given averages use of productive inputs, loss in value of product that can be saved is dependent on the use of pesticides.

B. Externality and externality costs of pesticide use

Externality is defined as 'the result of an activity that causes incidental benefits or damages to others with no corresponding compensation provided to or paid by those who generate the externality' (Grafton et al. 2004:476). With respect to the use of pesticides, Jungbluth (1996:29) defines negative externalities as '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. Other external effects that have to be considered for understanding negative externalities are: reduction of biodiversity, health impact and non-agricultural consequences. There are additional cost, called externality cost (EC), resulting from the negative externalities. In this case, the additional cost imposed on farmers is considered as external cost because farmers do not take the costs into account. The EC will fall if the externality is reduced.

However, the EC is difficult to calculate in terms of monetary value, because the externalities are not marketable. Some methods of valuation for non-marketed goods including environmental amenities have been

developed. These methods can be sorted into three groups, based on their reliance on direct market prices, indirect market prices or values, and hypothetical values. The hypothetical value techniques take on a surrogate market approach by directly asking people for their preferences and valuation or making assumptions regarding proxy market conditions and how market agents will behave under different circumstances (Dixon et al. 1994; Pearce and Turner 1990).

One of the hypothetical value techniques is a contingent valuation method. This method is conducted using surveys of stakeholders' willingness to pay for a given quality of environmental goods and services. However, doing so is costly and time consuming. Thus, it is adequate to adopt the results of similar studies that have been conducted by other researchers to conduct environmental valuation. This approach called a concept of benefit transfer '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).

C. Efficient use of pesticides

Dealing with an efficient use of pesticides needs some mathematical formulations. As derived before that the benefit function of pesticides faced by farmers is:

$$B = b(\bar{z}_u, x_u) \quad (4)$$

It is assumed that $\frac{\partial B}{\partial x} > 0$ and $\frac{\partial^2 B}{\partial x^2} < 0$, meaning that pesticides provide benefit, and the marginal benefit of pesticides is positive and diminishing. Farmers need to finance the cost of pesticide used. The private cost of pesticide use (C) is the amount of pesticides multiplied by its price (P_x), that is:

$$C = x_u \cdot P_x \quad (5)$$

Thus, the farmers face a problem of net benefit (NB):

$$NB (= B - C) = b(\bar{z}_u, x_u) - x_u \cdot P_x \quad (6)$$

Pesticide use leads to EC . Ideally, farmers also need to pay the EC for compensating themselves and community. Pincus et al. (1999) suggest that the EC must be subtracted from the net benefit of pesticide use to obtain a net social benefit (NSB). Therefore, the real problem faced by the farmers is:

$$NSB = NB - EC \quad (7)$$

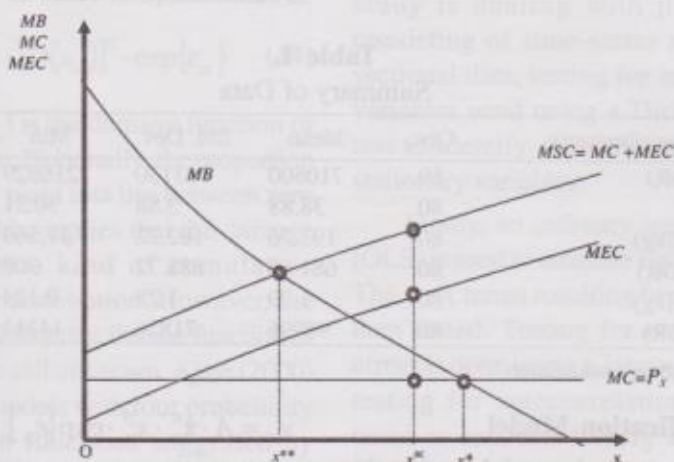
A concept of optimisation postulates that the maximum value of NSB will be obtained if the first derivative of the function is equal to zero (Salvatore 1996). If this is the case, it can be algebraically expressed as:

$$\frac{\partial NSB}{\partial x} = 0$$

$$\frac{\partial B}{\partial x} - \frac{\partial C}{\partial x} - \frac{\partial EC}{\partial x} = 0 \quad (8)$$

Equation (8) tells us that the optimal solution will be met if marginal benefit (MB) is equal to marginal social cost (MSC) which is the sum of marginal cost (MC) and marginal external cost (MEC) of pesticide use. The use of pesticides that meets equation (8) is socially efficient, and results in a maximised value of social benefit (SB).

Diagrammatically, equation (8) can be drawn in Figure 2 showing that there are three levels of pesticide use that give three distinct levels of SB .



Source: Adapted from Pearce and Turner (1990)

Figure 1.
Optimum Level of Pesticide Use

First, privately efficient use, x^* , in which the MB is equals to MC . This level results in maximum level of B . In this case, the externality is not taken into account, and B is then calculated as:

$$B_{max} = \int_0^{x^*} (MB - MC) dx \quad (9)$$

However, if the externality is internalised, SB resulting from this level of x^* is going to be:

$$SB = \int_0^{x^*} (MB - [MC + MEC]) dx \quad (10)$$

Second, an efficient use, x^{**} , in which MB is equal to MSC . This level results in a maximum of SB . The maximum of SB is calculated as:

$$SB_{max} = \int_0^{x^{**}} (MB - [MC + MEC]) dx \quad (11)$$

Third, an actual use, x^{ac} that results in an actual SB . The actual SB is calculated as:

$$SB_{ac} = \int_0^{x^{ac}} (MB - [MC + MEC]) dx \quad (12)$$

The difference between the actual SB and maximum one represents net welfare loss. The net welfare loss comes from decreases in the community's welfare and the health costs.

IV. METHODOLOGY

A. Definition variables and Data source

To estimate the benefit function of pesticides, this study employs a set of panel data on rice production. The data consists of output (rice), uses of inputs: fertilisers, pesticides, seed, manure and labour per hectare, and price of pesticide. The aggregate data covers five big regions in Indonesia during the periods 1982-2002. The number of observations is 80 because after 1996, the publication related to this data is three-yearly interval. The data is collected from the Indonesian Centre for Statistical Bureau (BPS). The data is summarised in Table 1.

Table 1.
Summary of Data

Variable (unit/hectare)	Obs.	Mean	Std. Dev.	Min	Max
Output (IDR)	80	710600	363130	216929	1774308
Seed (kg)	80	38.88	3.88	30.21	51.52
Fertilisers (kg)	80	193.76	102.22	11.569	403.7
Manure (IDR)	80	681.65	888.72	300	4124
Pesticides (kg)	80	1.79	1.28	0.124	7.63
Labour (IDR)	80	98996	71856	14211	352466

Source: Author's calculation

B. Specification Model

The economic model used in this study is Cobb-Douglas production technology, which is commonly expressed as:

$$y_{it} = \bar{A} \cdot z_{it}^\alpha \cdot x_{it}^\beta \cdot \exp\{\epsilon_{it}\} \quad (13)$$

where y_{it} is output, \bar{A} is total factor productivity; z_{it} is vector of productive input consisting of seed (s), fertilisers (f), manure (m) and labour (l); x_{it} is

pesticides; a and b is elasticity of production with respect to z and x respectively; e is disturbance error. However, estimating production functions involving pesticide use needs special attention, because pesticides are not productive input like fertilizers, but they are protective input. To incorporate the specific properties of pesticides into production functions, it is important to note that 'the contribution to production by damage control agent may be understood best if one conceives of actual output as a combination of two components: potential output and losses caused by damaging agents present in the environment' (Lichtenberg and Zilberman 1986: 262). Pesticides are incorporated in the component of potential loss to pests and are conceptualised in terms of playing a role in reducing benefit losses. According to Lichtenberg and Zilberman (1986), the Cobb-Douglas production technology should be expressed as:

$$y_{it} = \bar{A} \cdot z_{it}^{\alpha} \cdot [D(x_{it})]^{\beta} \cdot \exp\{\varepsilon_{it}\} \quad (14)$$

where $D(x_{it})$ is the damage function of the pesticide. Notionally, the proportion of potential yield loss lies between zero and one. This implies that the damage function is a kind of cumulative probability distribution. However, the exact probability distribution function of pesticides is still unknown. Ajayi (2000) estimates models with four probability distribution functions suggested by Lichtenberg and Zilberman (1986). The result indicates that the models do not provide statistical superiority, compared

with the common Cobb-Douglas production technology. Based on the results of Ajayi (2000), therefore the functional form in this study is modelled on Cobb-Douglas technology as:

$$y_{it} = \bar{A} \cdot z_{it}^{\alpha} \cdot x_{it}^{\beta} \cdot \exp\{\gamma T\} \cdot \exp\{\varepsilon_{it}\} \quad (15)$$

where T is time trend included to capture smooth technological progress. Taking logarithm both left and right sides makes yield function linear in parameter. That is:

$$\ln y_{it} = \ln \bar{A} + \alpha \ln z_{it} + \beta \ln x_{it} + \gamma T + \varepsilon_{it} \quad (16)$$

Testing for hypothesis that the pesticide use contributes financial benefit to the farmers is formulated as: $H_0: b = 0$; and $H_1: b > 0$.

Following Greene (2003) and Wooldridge (2000), a standard econometric method needs to be conducted to estimate the benefit function of pesticide use. Since this study is dealing with panel data consisting of time-series and cross-sectional data, testing for unit root on variables used using a Dickey-Fuller test to identify the existence of non-stationary variables.

Firstly, an ordinary least squared (OLS) is used to estimate equation (16). The error terms resulting from OLS are then tested. Testing for normality of errors is done using a Jarque-Bera test, testing for autocorrelation of error terms is conducted using a Breusch-Godfrey test, and testing for heteroskedasticity is carried out using a Breusch-Pagan test. A panel generalised least square (XTGLS) is

finally used to estimate the yield function if problems with error terms in the OLS exist. This is an asymptotic estimation, such that there is no need of normality of error terms. STATA Ver.8 is used to carry out econometric methods in this study.

V. EMPIRICAL RESULTS

A. Benefits of pesticide use

Yield functions estimated using OLS and XTGLS are shown in Table 1. It can be seen that testing for unit

root on variables rejects the existence of unit root. In OLS estimation, furthermore, testing for error terms on normality, autocorrelation and heteroscedasticity, indicate that there are problems of normality and heteroscedasticity. Therefore the yield function is estimated using XTGLS designed to overcome the problem of heteroscedasticity in panel model. This simultaneously copes with the problem of normality because the method is an asymptotic estimation (Greene 2003).

Table 2.
Estimated Yield Function of Rice

Variable	Pooled OLS		Panel GLS	
	Coefficient	t-ratio	Coefficient	z-ratio
<i>TFP</i> (\bar{A})	9.7428	10.36***	9.8132	14.88***
Seed (<i>s</i>)	0.5467	2.84**	0.4520	3.14***
Fertilisers (<i>f</i>)	0.0933	1.52	0.1131	2.41**
Manure (<i>m</i>)	0.0925	5.72***	0.0732	4.62***
Labour (<i>l</i>)	-0.0127	-0.16	0.0132	0.21
Pesticides (<i>x</i>)	0.0894	1.83*	0.0696	1.97**
Time trend (<i>T</i>)	0.0823	11.72***	0.0828	15.18***
<i>i</i> =5				
<i>T</i> =16				
Adj. R ²	0.92			
F(6, 73)	158.66***			
L-likelihood			61.61	
χ^2			2272.39***	
Breusch-Godfrey test	$\chi^2(1)=0.267$			
Breusch-Pagan test	$\chi^2(6)=178.93***$			
Jarque-Bera test	$\chi^2(1)=60.76***$			
Dickey-Fuller test	yield (-3.59***); seed (-4.07***); fertilisers (-3.21**);			
[Z(t)]	compost (-4.35***); labour (-3.97***); pesticides (-3.23**)			

Note: *) significant at alpha=10%; **) significant at alpha=5%; ***) significant at alpha=1%.

Source: author's estimation

Overall, the yield function of rice is significantly estimated. All coefficients on variables used are positive and less than unity. This implies that using Cobb-Douglass production technology is acceptable¹. Based upon the statistical parameters, the use of pesticides has a positive significant effect on the value of product. This means that pesticides contribute a financial benefit to the farmers. That is a value of yield loss associated with pest attack.

In terms of Cobb-Douglas model, the yield function can be expressed as:

$$\hat{y}_t = 18272 \cdot s_t^{0.452} \cdot f_t^{0.113} \cdot m_t^{0.073} \cdot l_t^{0.013} \cdot x_t^{0.0696} \cdot e^{0.0837} \quad (17)$$

The benefit function calculated from yield function at the average value of inputs and time trend is:

$$B = 657187 \cdot x_t^{0.0696} \quad (18)$$

The marginal benefit of pesticide use is:

$$MB = 45723 \cdot x_t^{-0.9304} \quad (19)$$

This means that an additional increase in pesticide use by one kilogram is relatively higher than the private cost (PC) of a kilogram of pesticide use². It indicates that pesticides in rice in Indonesia are not economically overused because the marginal benefit of pesticides is still below the cost of pesticides. This result implies that the opportunity cost of policies totally restricting pesticide use will be high in terms of the output that needs to be forgone.

B. Efficient Use of Pesticides

There are two levels of efficient use of pesticides. First, privately efficient use of pesticide, which is determined when the marginal benefit is equals to the marginal cost, that is:

$$MB = MC (= Price) \\ 45723 \cdot x_t^{-0.9304} = 3490 \quad (20)$$

Solving equation (20) for x results in an average level of privately efficient pesticides use, i.e. 15 kg per hectare. Second, socially efficient level of pesticide use that takes externality into account. The socially efficient level is determined when the marginal benefit of pesticides is equal to the marginal social cost. The marginal social cost consists of a price of pesticides and marginal external costs. In the case of pesticides, the marginal EC includes health cost of farmers, and environmental cost of community.

¹ Using Cobb-Douglas production technology is based on an assumption that farmer operates a farm in rational scale. This means that all inputs used have positive decreasing marginal product (Debertin 1986). However, a flexible functional form (translog) production technology has been estimated. Even though the test for restriction of Cobb-Douglas production technology is rejected, it does not make sense since there are a lot of coefficients insignificant. This is because there is a problem of severe multicollinearity between inputs and its interactions. The amount of multicollinearity in the model is then controlled by using the simplified translog form which assumes that inputs are separable from each other but not from time (Ahmad and Bravo-Ureta 1996). It still provides low t-ratios for most inputs and a highly significant intercept.

² The cost of a kilogram of pesticides is used as a proxy of price of pesticides. During the periods, the average cost of pesticides is IDR 3,490.

Using the concept of benefit transfer this study adopts an estimated consumers' WTP, which represents health and environmental values (HEV) revealed by community, and a health cost (HC) imposed on farmers. The consumers' WTP is estimated by Mourato et al. (2000) and the health costs is estimated by Rola and Pingali (1993). The calculation of consumers' WTP is shown in Box 1, and the derivation of health cost is shown in Box 2. By adopting a benefit transfer approach, the health cost function estimated by Rola and Pingali is:

$$HC = 34 \cdot P_x \cdot x_{it}^{0.62} \quad (21)$$

and the health and environmental value for a kilogram of reduction in pesticide use estimated by Mourato et al. (2000) is:

$$HEV = 0.6 \cdot P_x \quad (22)$$

where P_x is the average price of pesticides. The social cost of pesticides therefore is going to be:

$$\begin{aligned} SC &= PC + HEV + HC \\ &= P_x \cdot x_{it} + WTP \cdot x_{it} + 34 \cdot P_x \cdot x_{it}^{0.62} \\ &= 3490 \cdot x_{it} + 0.6 \cdot 3490 \cdot x_{it} + \\ &\quad 34 \cdot 3490 \cdot x_{it}^{0.62} \end{aligned} \quad (23)$$

and the marginal social cost (MSC) is:

$$MSC = \frac{\partial SC}{\partial x} = 3490 + 0.6 \cdot 3490 + 74614 \cdot x_{it}^{-0.38} \quad (24)$$

The efficient use of pesticides can be determined by equating the marginal benefit (equation (19)) to the marginal social costs (equation (24)), that is:

$$45723 \cdot x_{it}^{-0.9304} = 3490 + 0.6 \cdot 3490 + 74614 \cdot x_{it}^{-0.38} \quad (25)$$

Solving equation (25) using *goal seek programme* in EXCEL results in an average level of efficient use of pesticides, that is: 0.3749 kg per hectare.

Box 1. Derivation of consumers' WTP for reducing pesticide use

Mourato et al. (2000) estimate a willingness to pay (WTP) using a contingent ranking approach, a variant of the standard contingent valuation method, which is capable of tackling the multidimensional effects associated with pesticide applications.

The overall WTP per loaf for the protection of human health and the environment is (£0.007+£0.053=£0.06). It would be aggregated over the 160 loaves purchased on average each year by the U.K.'s 20 million households. This aggregated marginal WTP would then be divided by the total 15 million kg of pesticides used in cereal crops in the UK to obtain the external value of £12.59/kg of pesticide. Compared with a current average price of pesticides of the order of £20/kg, this would represent a value of over 60%.

From this calculation, the health and environmental value (HEV) of a kilogram of pesticides used in agriculture is:

$$HEV = 0.6 P_x$$

Source: Mourato et al. 2000. 'Evaluating Health and Environmental Impacts of Pesticide Use: implications for the design of ecolabels and pesticide taxes', *Environmental Science and Technology*, 34 (8): 1456-61

Box 2. Derivation and adjustment of health cost associated with pesticide use

Rola and Pingali (1993) estimate a health cost function associated with pesticides use in The Philippines. The health cost computation is based upon the medical examinations. A medical team of doctor, nurse and an X-ray technician, and a medical technologist conduct the medical examinations. These examinations provide an assessment of each farmer's illness and their seriousness. Medical treatments needed to restore the farmer's health are assessed. The treatment cost including medication and doctor's fees and time loss in recovery of farmer's health is then used as a measure of health cost.

The health cost function, estimated in local currency (Peso), is:

$$HC = 3.78 \text{ BODYINDEX}^{-0.05} \text{ AGE}^{1.82} e^{1.1 \text{ SMOKE}} x^{0.62}$$

Based on average conditions of Filipino farmers', health cost is:

$$HC = 7968.40 x^{0.62}$$

At the same time, the cost of pesticides in the Philippines is Peso 234

In terms of cost of pesticide, the health cost is going to be:

$$HC = 34 P_x x^{0.62}$$

If the health cost is then adjusted with the cost of pesticides and Indonesian conditions: farmers are on average 40 years old, smokers and non-alcohol-drinker, the health cost associated with pesticide use is:

$$HC = 34 \cdot 3490 x^{0.62}$$

Source : Rola, A.C. and Pingali, P. L., 1993. *Pesticide, Rice Productivity, and Farmers' Health: an economic assessment*. World Resources Institute, IRRI, Philippine.

Compared with the actual level of pesticide use, which is 1.79 kg per hectare, the privately efficient level is almost nine-fold. This means that the actual use of pesticides in Indonesia is, on average, much lower than that of the privately efficient one. This is different from Barbier's (1989) claim that pesticide use in Indonesia has economically exceeded the efficient level. However, when the externality is taken into account, the actual level

of pesticide use is lower than socially efficient level. This implies that pesticides are overused, and this consistent with Barbier's (1989) statement.

C. Net Welfare Loss

Net welfare loss is defined as the difference between the maximum SB and the actual SB. Table 3 shows the benefit, social cost, and net social benefit of pesticides at actual, private and social level.

Table 3.
Net Social Benefit of Pesticide Use

Level of pesticide use	Benefit	Social Cost	SB	
Actual	1.7863	684,265.00	176,261.55	508,003.46
Private	15.8815	796,655.10	714,392.77	82,262.32
Social	0.3749	613,808.76	65,894.03	547,914.73
Net welfare loss ($SB_{\text{actual}} - SB_{\text{social}}$)				39,911.28

Source: Author's calculation

The maximum SB resulting from the efficient level of pesticides use is IDR 547,914 per hectare³, and the actual SB resulting from the average use of pesticides is IDR 508,000 per hectare⁴. Therefore, the net welfare loss resulting from the actual use of pesticides is IDR 39,900 per hectare. It can be seen from the calculation that the net welfare loss exists. This is because the existing level of pesticides use exceeds the efficient level, and consequently there are decreases in society's and the farmers' welfare. On the national level, if the annual rice-cultivated area is, on average, approximately ten million hectares and there are two planting seasons per year, the net welfare loss is around IDR 798,226 million per year. This is equivalent to US\$ 88,691,788 per year⁵.

Pollution caused by pesticide use needs to be reduced to raise the welfare of farmers and the community. However, it is not straightforward to reduce the pollution because it is non-point source pollution. The objective of pesticide policy at national level should bring the social cost in line with social benefits. Some 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). The environmental tax, for example, is not only expected to be capable of reducing demand for pollutants but also provides government revenue. The tax-revenue can then be allocated to cover health

costs and environmental clean-up activities.

D. Caveats

This study has three limitations. First, this is estimation using market prices which fluctuate overtime. Thus, the estimated welfare loss is very sensitive to change in prevailing price. Second, the study uses a Cobb-Douglas production technology to estimate benefit function of pesticides. This contradicts proposition of Lichtenberg and Zilberman (1986) that damage functions in estimating the productivity of pesticide use matter. However, Ajayi (2000) has shown that the damage functions are not significantly different from the Cobb-Douglas production technology. In addition, dealing with non-linear estimations suggested by Lichtenberg and Zilberman (1986) is not straightforward. So, the Cobb-Douglas production function is adequate. Last, this study used an approach of benefit transfer to make a valuation of external cost of a kilogram of pesticide from different countries. This makes the estimated external cost biased, because different people with different socio-economic background have different

¹ The maximum SB is calculated using integration

$$\text{of } \int_0^{0.3749} (MB - P_x - MEC) dx$$

² The average use of pesticides during the periods is 1.7863 kg per hectare, and the actual SB is calculated using the integration of

$$\int_0^{1.7863} (MB - P_x - MEC) dx$$

³ US\$ 1= IDR 9,000

(<http://finance.yahoo.com/currency/convert?amt=1&from=AUD&to=IDR&submit=Convert>)

appreciation on environmental quality. However, the external cost associated with a kilogram of pesticide use has been adjusted proportionately with the average cost of pesticides; the adoption of benefit transfer in this case is still acceptable.

VI. CONCLUSION

Using the Cobb-Douglas production technology, the benefit of pesticide use was econometrically estimated. The efficient level of pesticide use then was calculated by equalising the marginal benefit to the marginal social cost, which consists of private cost and externality costs. This level of pesticide use is an optimal trade off for which social benefit of pesticide is maximised. If the actual level of pesticide is the same as the efficient one, the farmers and the community will be in to some extent ideal condition. From the calculation, it was found that the efficient level of pesticide use is much lower than that of actual level.

This indicates that the pesticide use is inefficient, that is, the use of pesticides is above the socially efficiency level. In other words, farmers and community suffered from the adverse impacts of pesticides. Therefore, because of the inefficiency in use of pesticides, there exists net welfare loss.

In this case, the net welfare loss associated with pesticide use per hectare is relatively low compared with the net social benefit resulting from the actual use of pesticides. However, it does not mean that the use of pesticides should be uncontrolled. Because of there is huge amount of rice-cultivated land, the total welfare loss becomes very high. Reducing use of pesticides will increase the level of the community's welfare. Hence, reducing the use of pesticides to an efficient level is the win-win solution. Farmers will be better off in terms of higher net social benefit, and community will be better off also from availability of healthier products and better environmental quality.

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