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The impact of IPM training on farmers' subjective estimates of economic thresholds for soybean pests in central Java, Indonesia

Joko Mariyono PhD Candidate in International and Development Economics [a]

[a] Crawford School of Economics and Government, The Australian National University , Canberra , Australia

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JOKO MARIYONO

Crawford School of Economics and Government, The Australian National University, Canberra, Australia

Abstract

This study aims to analyze econometrically the impact of IPM training on farmers' economic way of thinking about pest management. The IPM training is expected to increase farmers' acceptable level of pest attack, and reduce pesticide use. The study was conducted in Java, where the training has been widely performed. Panel data on soybeans during 1990 – 1998 were collected from provincial agricultural agencies. Simultaneous equation models were employed to estimate a function of economic threshold and a function for pest control. Estimation was conducted using random effect panel regressions. The results indicate that pesticide use decreased as the amount of IPM training increased. This means that after participating the training, farmers' subjective economic thresholds for soybean pests increased and pesticide use was delayed.

Keywords: *Economic threshold, maximum acceptable level of pest attack, pesticide use, IPM-training, 2SLS regression*

1. Introduction

The Government of Indonesia has revolutionized its policy on plant protection, having implemented the Integrated Pest Management (IPM) programme in 1986 when Presidential Decree No. 3, 1986 was generated. The programme was motivated by the facts that pesticides are no longer used judiciously, and that this led to economic losses associated with pest outbreaks in the 1960s (Settle et al. 1996) and the 1980s (Barbier 1989). In addition, other adverse impacts include environmental and health problems (Kishi et al. 1995; Bond 1996; Pawukir and Mariyono 2002). The programme was then realized 3 years later (Rölling and van de Fliert 1994), with the objectives of guarded pest population (i.e. to maintain pests below economic threshold levels), limited use of chemical pesticides, and an improved environment and better public health (Untung 1996).

The programme has been institutionally implemented, and there exist strong claims that IPM is able to reduce the use of pesticides significantly (Useem et al. 1992; Bond 1996; Cuyno et al. 2001; Irham and Mariyono 2001a; Mariyono 2003). However, the mechanics of reducing pesticide use due to IPM training have not been clearly elucidated. This paper aims to analyse the impact of IPM training on subjective estimates of economic threshold for pests, using the economic threshold (ET) concept, in which the modern plant protection strategy applies ET as a fundamental strategy. Soybeans, major commodities and one of the main targets of the Indonesian IPM Program (World Bank 1993), were chosen for the study.

2. Theoretical framework

In an economic view of plant protection, pesticides are considered protective inputs, not productive inputs. This means that pesticides will provide a significant contribution if there is serious pest attack and if the pesticide works effectively to control the pest attack (Lichtenberg and Zilberman 1986). If farmers do not observe the level of pest attack, they will use pesticides more than necessary. In addition, improvements in agronomical technology, such as new varieties, are able to influence pest attack. Thus, pest attack is not only dependent on pesticide use, but also an agronomical technology.

However, in the economic way of thinking, the objective of plant protection is not only high yield, but also economic feasibility. The ET has been introduced in plant protection strategy to account for the economic feasibility. Based on a concept of IPM explained by Rola and Pingali (1993), the ET can be defined as:

> **Definition**: For any level of pest attack, there exists a maximum acceptable level of pest attack such that the expected value of yield loss associated with the pest is equal to the cost of pest control using pesticides. The maximum acceptable level of pest attack is called economic threshold (ET).

Correspondence: Joko Mariyono, PhD Candidate in International and Development Economics, Crawford School of Economics and Government, J.G. Crawford Building # 13, The Australian National University, Canberra, Australia. E-mail: joko.mariyono@anu.edu.au

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The maximum acceptable level of pest attack is not static. Economically, it is dependent on the price of the product that determines the expected value of yield loss, and the price of pesticides. Any change in both prices will lead to a change in maximum acceptable level of pest attack. Importantly, the maximum acceptable level of pest attack is very subjective. The subjectivity comes from the farmers' expectation on predicting the expected value of yield loss associated with a certain level of pest attack they observe. The target of IPM training is farmers' knowledge (Feder et al. 2004). The training is expected to be able to change farmers' expectation on the value of yield losses by giving more information on the agro-ecosystem. Thus, pesticide use is not only dependent on pest attack, but also on price of soybean, price of pesticides, and IPM training. This analytical framework is used in this study to explain the mechanism of reducing use of pesticides associated with IPM training.

3. Material and methods

3.1. Mathematical modelling and econometric estimation

In this study, a mathematical model is used to examine the empirical mechanism of the IPM training that reduces pesticide use, expressed in simultaneous equations as:

$$A = \alpha_0 + \alpha_1 X + \alpha_2 \ln T + u \qquad (1)$$

and

$$X = \beta_0 + \beta_1 A + \beta_2 P + \beta_3 \ln TR + v \qquad (2)$$

where A is the level of pest attack; X is the level of use of pesticide; T is the time trend, thus ln T represents growth in agronomical technology; $P = P_X/P_Y$ is the relative price of pesticide (P_X) to price of soybean (P_Y); TR is the number of IPM training, thus ln TR represents growth in IPM training; α_i and β_j are coefficients to be estimated; and u, v are the error terms.

The price of pesticides and the price of soybeans are expressed as ratios because both prices have opposite impacts on pesticide use. Taking price in ratio terms will reduce any multicolinearity problems in econometric estimations, and will need no adjustment for those prices to any price index. Equation (1) is over-identified (Verbeek 2002). The structural forms of these simultaneous equations represent farmers' decision-making models in using pesticides. Both variables A and X are endogenous, meaning that if one of the predetermined variables: ln T, P or ln TR changes, variables A and X will change simultaneously. If the equations are estimated using ordinary least square (OLS) methods the estimator will be biased, because the expected value of error terms are not equal to zero. One of the standard methods for dealing with over-identified simultaneous equations is two-stage least squares (2SLS), which has been extensively used in practice because this method for solving econometric models involving a large number of equations offers a practical method (Gujarati 2003). This method can be simply conducted by following two steps. First, estimate the reduced forms to get both predicted endogenous variables, A and X, by regressing them on the predetermined variables, that is:

$$A = \delta_0 + \delta_1 \ln T + \delta_2 P + \delta_3 \ln TR + \varepsilon \qquad (3)$$

$$X = \gamma_0 + \gamma_1 \ln T + \gamma_2 P + \gamma_3 \ln TR + \omega. \qquad (4)$$

From the estimate of reduced forms, then obtain the predicted values of $\overline{A}$ and $\overline{X}$.

Second, use the predicted values of both $\overline{A}$ and $\overline{X}$, in estimation of structural forms of Equations (1) and (2), respectively, that is:

$$A = \alpha_0 + \alpha_1^\star \overline{X} + \alpha_2 \ln T + u^\star \qquad (5)$$

$$X = \beta_0 + \beta_1^\star \overline{A} + \beta_2 P + \beta_3 \ln TR + v^\star \qquad (6)$$

where $\alpha_1^\star$ and $\beta_1^\star$ are corrected estimators. The parameter of $\alpha_1^\star$ is expected to be negative, meaning that pesticides are able to diminish pest attack, and the parameter of $\beta_1^\star$ is expected to be positive, meaning that pesticides will be used if there exists serious pest attack. Related to IPM training, β_3 is expected to be negative, meaning that farmers' expectations on values of yield losses fall. Because of the simultaneity of pest attack and pesticide use, the impact of IPM training on both use of pesticide and economic threshold can be traced by taking a static comparative approach, that is:

$$\frac{\partial X}{\partial \ln TR} = \beta_3 < 0 \qquad (7)$$

$$\frac{\partial A}{\partial \ln TR} = \frac{\partial A}{\partial \overline{X}} \cdot \frac{\partial X}{\partial \ln TR} = \alpha_1^\star \cdot \beta_3 > 0. \qquad (8)$$

This means that when farmers' knowledge increases, the acceptable level of pest attack will increase, and, at the same time, use of pesticides decreases. The decrease in pesticide use is due technically to the fact that farmers delay using pesticides. The impact of other factors on pesticide use and acceptable level of pest attack is also explainable using the same approach as for IPM training.

3.2. Estimation and testable hypotheses

Following Greene (2003), estimation is conducted using panel regression with a random effect model.

This is because the available data come from four regions during a 9-year period. Instead of a fixed effect, a random effect was selected because the time period is greater than number of regions. When this is the case, the characteristic of each region is no longer fixed and expected to vary over time. As a consequence, a fixed effect panel regression is no longer relevant (Druska and Horrace 2004).

The variable of pest attack in Equation (5) is measured in percentage of pest-attacked area of soybeans. This means that the measure is bounded between zero and 100. According to Greene (1996), OLS will not give unbiased estimators if the dependent variable is bounded. In the case of bounded dependent variables, one of the suggested estimations is to estimate Equation (5) using double bounded Tobit regression with the lower limit set to zero and the upper limit to 100. In addition, Equation (6) is slightly modified by adding a variable for soybean-sown area, L, because the area represents scale of farming. It is reasonable to say that when the scale of farming increases, the amount of pesticide use also increases. Thus, Equation (6) becomes

$$X = \beta_0 + \beta_1^{\star}\,\overline{A} + \beta_2 P + \beta_3 \ln TR + \beta_4 L + v^{\star}. \quad (9)$$

A testable hypothesis related to Equation (5) is formulated as:

H_0: $\alpha_1^{\star} = \alpha_2 = 0$
H_1: $\alpha_1^{\star} < 0$ and $\alpha_2 \neq 0$.

A testable hypothesis related to Equation (9) is formulated as:

H_0: $\beta_1^{\star} = \beta_2 = \beta_3 = \beta_4 = 0$
H_1: $\beta_1^{\star}, \beta_4 > 0$ and $\beta_2, \beta_3 < 0$.

H_0 will be rejected if z-value is greater than value of z at significance levels of 1, 5 and 10%.

3.3. Study site and data sources

The study was carried out in four regions of central Java where the IPM programme is intensively implemented, and data related to the programme are well documented and available. Secondary cross-sectional and time series data were employed in this study. The data comprise four districts in the 9-year period from 1990 to 1998, when the IPM project was being implemented. The data were taken from a number of sources such as the Annual Report of the Provincial Agricultural Office, and statistical data published by Provincial and District Statistical Offices.

The variables analysed were: pesticide use (kg), intensity of pest attack in soybeans (%), annual average price of soybeans (IDR kg^{-1}), annual average price of pesticides (IDR kg^{-1}), and IPM training (number of farmers' field schools in each region in each year). Pest attack studied here consists of armyworms (*Spodoptera* spp.), pod worm (*Helicoverpa armigera*, Hubn), pod borer (*Etiella zinckenella*, Tr) and pod suckers (*Nezara viridulla*, L and *Riptortus linearis*, L). Farmers were assumed to face multiple infestations of pests in their farms. All pests mentioned are important pests and likely to come in all stages of farming. It is assumed that farmers are responsive to pest attack in all stages of farming. Summary statistics for variables used in this study are given in Table I.

4. Results and discussion

Tables II and III, respectively, show Equations (5) and (9). The models are highly significantly estimated. This means that total variation in pest attack can be explained by significant variations in pesticide use and technological progress; and about 60% of total variation in pesticide use can be explained by variations in pest attack, relative price of pesticide, IPM training and scale of soybean farming. The intercept in Table III is automatically dropped because of nearly exact multicolinearity, that is, strong correlation between intercept and other independent variables.

Table II shows that an increase in use of pesticides brings about a significant decrease in level of attack. This means that using pesticides is possible to diminish the level of pest attack. The decrease in pest attack was very small because during the period 1990–1998, the average level of pest attack in soybeans was very small and the variation was very high, whereas the use of pesticide in soybeans was relatively high. Practically, pesticide use will be more useful when pest attack is relatively high.

Table I. Summary statistics for variables.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Pest attack in soybean (%)	36	5.85	5.78	0	26.07
Pesticide use in soybean (kg)	36	409.85	467.48	0	1,538.20
Price of pesticides (IDR kg^{-1})	36	6,931.38	1,696.60	5,237.75	11,229.48
Price of soybean (IDR kg^{-1})	36	1,278.19	663.55	825.00	3,148.09
Soybean-planted area (ha)	36	13,278.56	19,031.84	503.00	56,650.00
IPM training (number of FFSs)*	36	161.72	111.42	21.00	358.00

*Farmers' Field Schools.

Table II. Estimated model of pest control function.

Independent variable			Coefficient	z-ratio
Constant		α_0	16.1523***	3.99
Predicted pesticide use (kg)	$\bar{A}$	α_1^*	− 0.0058*	−1.60
Technology	ln T	α_2	−5.6213**	−2.94
Log likelihood = −108.2145				
$\chi^2(2) = 9.40$***				

Tobit panel regression; dependent variable: pest attack (%); ns, not significant; *significant at 10%; **significant at 5%; ***significant at 1%.

Table III. Estimated model of economic threshold function.

Independent variable			Coefficient	z-ratio
Constant			(dropped)	
Predicted pest attack (%)	$\bar{X}$	β_1^*	125.2042***	4.25
Relative price of pesticides	P	β_2	-32.88104^{ns}	−0.60
IPM training	ln TR	β_3	−89.1188 ***	−2.24
Soybean-sown land	L	β_4	0.02216***	5.46
$R^2 = 0.59$				
$\chi^2(3) = 46.98$***				

Random effect panel regression; dependent variable: pesticide use (kg); ns, not significant; *significant at 10%; **significant at 5%; ***significant at 1%.

With respect to technological progress, the coefficient for ln T is negatively significant. This implies that better agronomical technology is able to reduce pest attack, and simultaneously increase expected values of yields. The impact of technological progress is to decrease maximum acceptable level of pest attack and level of pesticide use simultaneously.

Table III shows that pesticide use increases significantly along with increases in the level of pest attack. This means that pesticides will be used if pest attack exists. This is in line with the findings of Irham and Mariyono (2001b) showing that IPM-trained farmers are different from non IPM-trained ones in terms of decisions on using pesticides. The former used pesticides based on observations they made, and the latter used pesticides based on a calendar system.

With respect to the relative price of pesticides, there is no significant impact on pesticide use. However, the increase in relative price tends to reduce pesticide use. The increase in relative price may results from one of the three causes. First, the price of pesticide increases, meanwhile the price of soybeans remains constant. Second, the price of pesticide is constant, but the price of soybeans falls. Last, both prices increase, but the price of pesticide increases faster than that of soybean. It is likely that the last case happens.

Related to the variable of interest—the impact of IPM training on subjective maximum acceptable level of pest attack—an increase in IPM training brings about significant fall in use of pesticides. The estimated model suggests that if the number of IPM training increases by 1%, use of pesticides will fall by around 89.12 kg. This means that IPM training leads to an increase in the maximum acceptable level of pest attack. The proposition that can be drawn from this observable phenomenon is that along with introduction of IPM principles, farmers' expectation on value of yield loss associated with a certain level of pest attack becomes lower. At the same time, pesticides will not be used immediately, because farmers delay using pesticides until the level of pest attack reaches the new maximum acceptable level.

The implication of this finding studied here is an enhancement in farmers' knowledge resulting from participating IPM training. Because farmer's knowledge is enhanced, farmers become tolerant towards the existence of insects. In other words, farmers' maximum acceptable level of pest attack has increased as IPM principles have been introduced; and as a consequence, the level of pesticide use has decreased. Farmers will not apply pesticides as soon as they observe some pest insects. This is because the farmers have been able to distinguish between insect pests and non-insect pests such as predators and/or parasites (Braun et al. 2000). Farmers acquire the knowledge of distinguishing insects from participating IPM training that intentionally introduces the components of agro-ecosystems (MOA 1996). This finding slightly contradicts the finding of Feder et al. (2004) stating that there is no significant impact of IPM training on pesticide use in rice.

5. Conclusion and policy implications

Plant protection strategy that uses pesticides as controlling agents has changed since a concept of economic threshold has been introduced. There are two requirements that should hold, that is, pesticides are capable of diminishing pest attack, and pesticides will be used when the level of pest attack marginally exceeds an acceptable level of pest attack. But, the acceptable level of pest attack varies because of subjectivity in predicting value of yield loss among farmers, although they observe the same object. The different expectations for yield loss come from different experiences, level of knowledge and behaviour toward risk. IPM training that disseminates IPM principles is expected to be able to influence farmers' economic way of thinking about plant protection. When the expectation for yield loss decreases, the acceptable level of pest attack will rise and at the same time, the level of pesticide use falls.

IPM training has impacted to increase in acceptable level of pest attack; and as a result the use of pesticide decreases. In other words, IPM training brings about farmer's expectations for yield loss to fall. Thus, this is one of the explanations of why IPM training can reduce use of pesticides. The policy implication of these findings is that IPM principles need to be continually disseminated, since the training is able to enhance farmer's knowledge related to the strategy of economical plant protection. As stated by Feder et al. (2004), however, it is important to note that IPM training needs some modification in order to make it easy for farmer to understand the IPM principles, such that farmers are expected to be capable of significantly diminishing pesticide use in rice and other crops obviously.

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