Journal of Agricultural Technology 2011 Vol. 7(1): 19-28
Available online http://www.ijat-rmutto.com
ISSN 1686-9141

Double gains in productivity: Impacts of integrated pest management technology on productions of rice and soybean in Java

Mariyono, J.*

Independent Researcher of Agricultural and Rural Economics, Indonesia.

Mariyono, J. (2011). Double gains in productivity: Impacts of integrated pest management technology on productions of rice and soybean in Java. Journal of Agricultural Technonogy 7(1): 19-28.

This paper examines simultaneous impact of technology on integrated pest management (IPM) in Indonesia. IPM was introduced to farmers via training package called farmers' field school. Despite the fact that IPM was mostly introduced for rice production, one of expected impacts was a simultaneous improvement in productivity of rice and soybean. This is because farmers growing rice also grew soybean at the same piece of land. In economic analysis, impact of such training can be examined using joint increase in production of rice and soybean, which was shown by increasing on supply response. This study chose Java since rice and soybean are the main crops cultivated intensively. Aggregate panel data consisting of four regions during nine years of implementation of IPM program were used to examine the expected impact. The result showed that the technology has been successfully increased the production of rice and soybean at the same time. This implies that IPM technology introduced in rice was also applicable to soybean.

Key words: integrated pest management, product transformation curve, supply function, rice and soybean

Introduction

In Indonesia, Farmers field school (FFS) is a famous method to disseminate new agricultural technologies and production practices. In the recent past, one of the largest disseminations of technologies through FFS in Indonesia has been on integrated pest management (IPM), when the Government of Indonesia revolutionized its policy on plant protection strategy by implementing the Integrated Pest Management (IPM) Program by issuing Presidential Decree No. 3 in 1986. At that time, the presidential degree (and need of IPM program) was motivated by the fact that pesticides were no longer

*Corresponding author: Mariyono J.; e-mail: mrjoko28@gmail.com

effective for controlling few selected pests in paddy field, largely also due to unwise use of pesticides, leading to huge economic losses associated with pest outbreaks in the 1960s (Settle *et al*., 1996) and in the 1980s (Barbier, 1989). In addition, there were other adverse impacts of unwise use of pesticides on local environmental and health of farming communities including farm labor (Bond, 1996; Kishi *et al*., 1995). The comprehensive packages of IPM related farmers level training on paddy was then implemented three years later (Rölling and Fliert, 1994), with the objectives of: higher productivity, increased farmers' income, guarded pest population (i.e. to keep pests below economic threshold levels), limited use of chemical pesticides, and an improved environment and better public health (Untung, 1996).

It is stated by Untung (1996) that one of objectives of IPM training is higher productivity, this study, therefore, aims to assess the introduction of IPM technology on the joint productivity of rice and soybean since the farmers who got the training grow rice and soybean sequentially, it is relevant to see the impact of the program introduction on both commodities simultaneously. This study identifies the change in supply curve, that is,' a schedule showing the various amounts of a product that will be produced at each specified price in a set of possible prices during some specified period of time' (Halcrow, 1984). It is worthwhile to examine the shift in supply for product since it reflects the changes of benefit for both consumers and producers (Nas, 1996).

Materials and methods

Location and data collection

This study was conducted at Jogjakarta province where the development of IPM program is indeed implemented (Soenanto, 2000). Rice and soybean were chosen since both are major commodities in those areas and the main targets of the Indonesian IPM Program (World Bank, 1993). The data were compiled from a number of sources including the Annual Report of the Provincial Agricultural Office, and statistical data published by the Provincial and District Statistical Offices. This study that covers data collection, data database management, data transformation and econometrical analysis was carried out in 2002-2003. This study used secondary time series data. Locations were selected based on the availability of data. The selected locations were expected to be sufficiently representative since the collected data were aggregation of number of products of all farmers in each location during one year.

The data used in this study consist of four regions in Java in nine-year period (1990-98), in which there was introduction of IPM technology. Analyses were made for annual production of rice and soybean (kg), annual use of pesticides (kg), number of IPMFFSs (unit), annual average price of rice (Rp/kg), annual average price of fertilizers and pesticides (Rp/kg), and the amount of planted areas (ha).

Analytical methods

Supply function of joint product will be used as the fundamental theory. The building blocks underlying this analysis are competitive market and price taker and maximizing-profit producers. In one year, farmers cultivate rice and soybean in the same land and resources with existing technology. Thus, rice and soybean can be considered as a variable joint product. On the subject of joint production of two commodities produced with the same resources, it follows a theory of economies of scope. The centre to the theory is a strictly concave product transformation curve that describes the different combinations of two outputs that can be produced with the same production inputs (Pindyck & Rubinfeld, 1998). The concavity means that the firm's production inputs are not perfectly adaptable in, or cannot be perfectly transferred between, the productions of product (Salvatore (1996). The joint production can be mathematically expressed as:

$$Z = \psi(\widetilde{Q}_r, \widetilde{Q}_s) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where $Z=X+L+T$ is resources jointly used in productions of rice and soybean, X is material input, L is land, T is technology, $\widetilde{Q}_r$ is production of rice, $\widetilde{Q}_s$ is production of soybean, and ψ is a strictly concave and twice-differentiable function. Revenue of joint production is:

$$V = P_r\,\widetilde{Q}_r + P_s\,\widetilde{Q}_s \ldots\ldots\ldots\ldots\ldots (2)$$

where V is revenue, P_r is price of rice, and P_s is price of soybean.

Maximizing revenue of equation (14) subject to equation (13) will result in supply function of rice and soybean. The supply of rice is affected by price of rice, price of soybean, prices of inputs, fixed input and technology. Similarly, the supply of soybean is affected by the same factors. The important feature of supply in the joint production analysis is that supply of rice is affected by price of soybean, and vice versa.

Related to an improvement in agricultural technology, Halcrow (1984) stated that increases in agricultural supply have depended on many advances in technology. Todaro (1984) explained that the impact technology on joint production is an outward movement in the product transformation curve. The implication is that supply of two products move simultaneously. Mathematically, the supply of rice and soybean is expressed as:

$$\widetilde{Q}_r^* = R(P_r, P_s, P_X, L, T) \text{.................(3)}$$
$$\widetilde{Q}_s^* = S(P_s, P_r, P_X, L, T) \text{.................(4)}$$

The expected impact of the improvement in agricultural technology is obtained by taking first derivative in equation (3) and (4) with respect to *T*, that is, $\partial \widetilde{Q}_r^* / \partial T > 0$, and $\partial \widetilde{Q}_s^* / \partial T > 0$. The impact of cross price is expected as $\partial \widetilde{Q}_r^* / \partial P_s < 0$ and $\partial \widetilde{Q}_s^* / \partial P_r < 0$.

Model estimation

For the sake of simplicity, the production function and the product transformation are assumed to be quadratic functional forms, and consequently supply for rice and soybean derived from profit maximization are linear functional forms. The linear supply function for both rice and soybean are:

$$\widetilde{Q}_r^* = \alpha_0 + \alpha_1 P_r + \alpha_2 P_U + \alpha_3 P_P + \alpha_4 P_S + \alpha_5 P_X + \alpha_6 L + \alpha_7 T + \varepsilon \text{ .....(5)}$$

where $\widetilde{Q}_r^*$ and $\widetilde{Q}_S^*$ are quantity of rice and soybean produced a year respectively, P_r is average price of rice, P_S is average price of soybean, P_U is average price of Urea, P_P is average price of Phosphates, P_X is price of pesticide, L is the amount of land, T is the number of training, ε and ω are disturbance errors, and α_i and β_i for i=0, 1,…,7 are coefficients to be estimated. Overall testable hypothesis is formulated as:

H_0: $\alpha_i = \beta_i = 0$, for i=0, 1,…,7

H_1: at least one not equal zero

Testable hypothesis related to the impact of IPM technology is formulated as:

H_0: $\alpha_7 = \beta_7 = 0$

H_1: $\alpha_7 > 0$ and $\beta_7 > 0$

Following Johnston & Di'Nardo (1997), the supply function of rice and soybean is estimated using pooled ordinary least square. The assumption held is this estimation is that ε and ω is normally distributed with the zero mean and constant variance.

In the OLS running, *multicollinearity* problem may occur between the prices of products and the prices of inputs. Taking relative prices of inputs, i.e. the ratio of inputs price to rice price, and the relative price of soybean, i.e. the ratio soybean price to rice price, is able to cope with the problem. In this case, the own price of respective commodity is disappear in the supply function.

Another advantage of taking price ratio is that there is no need to adjust those prices to any price index.

Results and discussion

Summary statistics for variables used in this study can be seen in Table 1. The standard deviation of each corresponding variable is relatively high. This means that there is variation in each variable across region and time. The variation is expected to provide good estimation of supply of rice and soybean.

Table 1. Summary statistics for variables.

Variable	Obs.	Mean	Std. Dev.
Pesticide use in rice (kg)	40	863.29	725.31
Rice Production (kg)	40	146,310.50	94,106.09
Pesticide use in soybean (kg)	40	409.85	467.48
Soybean production (kg)	40	17,179.17	22,621.46
Price of rice (Rp/kg)	40	439.47	213.44
Price of pesticides (Rp/kg)	40	6,665.61	1,798.68
Price of fertilizers (Rp/kg)	40	735.14	281.84
IPM (Unit of training)	40	159.10	129.67
Area (ha)	40	24,599.67	15,697.02

Note: Author's calculation

The estimated supply functions for rice and soybean respectively. In general, approximately 99% of the variations in supply for rice are explainable by the variations in variables of price ratio of pesticides, Urea, Phosphate, soybean (rice), introduction of IPM technology, and lands as seen in Table 2 and 3. At the same year, more than 98% of the variation in supply for soybean is explainable with the same variables. In overall, the variables have highly significant effect on the supply for both rice and soybean. Note that the statistic of D-W in both supply functions is close to two, meaning that those functions are correctly estimated (Johnston & Di'Nardo, 1997).

Table 2. Supply function for rice.

Explanatory variables	Coefficient	t-ratio
Constant	-45,768.0**	-1.57
Ratio of pesticides price to rice price	-1.906.2ns	-0.70
Ratio of Urea price to rice price	204.780**	2.45
Ratio of Phosphate price to rice price	-62,732.0*	-1.65
Ratio of soybean price to rice price	-7.267.7*	-1.54
Rice-planted area (ha)	5.8579***	28.69
Technology (unit IPMFFS)	82.638*	1.55
R^2	0.99	
F-ratio	601.29***	
D-W	2.01	

Dependent variable: Rice production (ton) ***) significant at 0.01; **) significant at 0.05; *) significant at 0.1; ns) not significant

The individual effect of all variables on the supply for both rice and soybean is in line with the theory of supply, except the ratio of urea price to rice price. The rise in the price ratio of phosphate price to rice price pushes the supply for rice and soybean down. This is consistent with the fact that the phosphate plays an important role in rice and soybean productions. The role of phosphate is to strengthen the plant's tissues especially in stems to inhibit the falling down and accelerating the maturity process of grains (Luther, 1993).

Table 3. Supply function for soybean.

Explanatory variables	Coefficient	t-ratio
Constant	17,619.0***	3.05
Ratio of pesticides price to soybean price	-305.37ns	-0.01
Ratio of Urea price to soybean price	174.010*	1.77
Ratio of Phosphate price to soybean price	-83,775.0**	-2.66
Ratio of rice price to soybean price	-214.57ns	-0.01
Soybean-planted area (ha)	1.1368***	55.53
Technology (unit IPMFFS)	36.621**	2.01
R^2	0.98	
F-ratio	315.92***	
D-W	2.11	

Dependent variable: Soybean production (ton) ***) significant at 0.01;
**) significant at 0.05; *) significant at 0.1; ns) not significant.

The rise in price ratio of soybean price to rice price reduces the supply for rice. Theoretically, it can be explained by maximizing revenue of rice and soybean farming in the same land. When the price of soybean rises, it causes a change in prices ratio. The change will be responded by reducing rice production until the MRPT is equals to the new ratio of prices. The change in area under cultivation causes increases in supplies for rice and soybean. This is obvious that the increase in supply will happen if the fixed input (for example land) is extended.

However, the rise in price ratio of urea price to rice price leads to the rise in supplies for rice and soybean. This contradicts the theory of supply in which the rise in price input causes a decrease in supply for product. This is still acceptable since the farmers still hope to add urea without taking into account the fact that the use of urea that has reached maximum level can still raise the production. This is in line with research by Irham (2001) which revealed that the urea has a propensity to reduce rice productivity. Zuhaida (2000) also proves that Ammonium Sulphate (ZA), as a substitute of urea, reduces productivity of rice significantly.

In the case of soybean production, Triastono (2000) showed that urea use is likely to reduce soybean productivity and this is also understandable. Farmers still use urea without taking into account the fact that soybean does not necessarily require urea because of its ability to fixate nitrogen from the air using a mutual symbiosis with a certain microorganism to form the root's nodules (Luther, 1993). It could be the case that the (excessive) use of urea is able to affect the natural balance of soil ecosystem (Bond, 1996). Such condition causes the fixation of nitrogen possibly will not optimal and can reduce soybean production.

Partial impact of each variable on the supplies for rice and soybean are significant, except the price of pesticides. This indicates that a rise in price of pesticides does not cause the rice and soybean productions to fall. Suharno (1995) found that pesticides use does not cause increase in rice production. Irham (2001) also stated that pesticides use does not influence the productivity of rice. In the case of soybean, Triastono (2000) showed that the marginal product of pesticides is statistically equal to zero. This means that an increase in pesticide used does not enhance soybean productivity. Another variable having insignificant effect on the supply for soybean is the price of rice. Theoretically, this has the same explanation as in rice production. The rice, however, needs irrigated lands, and therefore, it does not replace the soybean that is predominantly cultivated in non-irrigated lands. The important thing to note is that the introduction of IPM technology is able to escalate the supplies for rice and soybean. As expected, the technology and organizational improvement lead to the increase in production, which is shown by the rightward shift in supply. The principle of such technology has a good farming-base management because 'in the field, IPM involves not only pest control but also other aspects of farming such as balanced and efficient fertilizing, efficient use of water, crop rotation and soil conservation. It also makes use of the farmers own experiences in terms of reduction or total elimination of pesticide use as well as other external inputs' (Untung, 1996).

Adoption of IPM technology could be used not only to cut down pesticides use in rice farming (Pincus, 1991; Useem et al., 1992; Mariyono, 1998; and Kusmayadi, 1999) but also in soybean farming (Irham & Mariyono, 2002). The decrease in pesticides use associated with the adoption of the technology means the reduction of production cost (Hewitt & Smith, 1995). Since the supply function for product represents the marginal cost of production (Papps, 1994; Nicholson, 1999), the introduction of IPM technology that shifts the marginal cost downward has the same meaning as the introduction of IPM technology that shifts the supply for products rightward. The government of Indonesia has revolutionized plant protection strategies by introducing a new technology called Integrated Pest Management (IPM). Farmers who cultivate rice and soybean on the same land sequentially is expected to adopt the technology, and the adoption of the technology is then expected to contribute significant impact on both rice and soybean production. Using microeconomic theory, this study demonstrates that IPM training during the period 1989-1998 where IPM program was performed has significantly escalated productivity of both rice and soybean. Productivity generated with more advanced technology is higher, and the cost of production is lower than those with a conventional technology. The introduction of the right technology has enhanced the productivity of both rice and soybean.

Acknowledgments

The author thanks The Head of Provincial Agricultural Services who permits to access agricultural data related to this article. The gratitude is also addressed to the reviewers who have given comments and suggestions on this article. However, the author is responsible for any error in this article.

References

Agro-Chemical Report. (2002). Pesticide and policy: the impact of integrated pest management (IPM) on the Indonesian economy. Agro-Chemical Report 2: 18-20.

Barbier, E.B. (1989). Cash crops, food crops and sustainability: the case of Indonesia. World Development 17: 879-875.

Bond, J.W. (1996). How EC and World Bank policies are destroying agriculture and the environment. Singapore: AgBé Publishing,
Feder, G. & Savastano, S. (2006). The role of opinion leaders in the diffusion of new knowledge: the casa of integrated pest management. World Development 34: 1287-1300
Feder, G., Murgai, R. and Quizon, J.B. (2004a). Sending farmers back to schools: the impact of farmer field school in Indonesia. Review of Agricultural Economics 26: 45-62.
Feder, G., Murgai, R. and Quizon, J.B. (2004b). The acquisition and the diffusion of knowledge: the case of pest management training in farmer field schools, Indonesia. Journal of Agricultural Economics 55: 217-239.
Godtland, E.M., Sadoulet, E., de Janvry, A., Murgai, R., and Ortiz, O. (2004). The impact of farmer field schools on knowledge and productivity: a study of potato farmers in Peruvian Andes. Economic Development and Cultural Changes 53: 63-92.
Halcrow, H.G. (1984). Agricultural policy analysis. New York, McGraw-Hill Book Co.
Hewitt, T.I. and Smith, K.R. (1995). Intensive agriculture and environment quality: Examining the newest agricultural myth. Henry A. Wallace Institute for Alternative Agriculture.
Irham (2001). Impact of IPM Program on rice production and income. Paper presented in the International Workshop on Toward the Harmonization between Development and Environmental Conservation in Biological Production. The University of Tokyo, Japan.
Irham and Mariyono, J. (2002). The impact of Integrated Pest Management on pesticide demand for soybean farming in Yogyakarta, Indonesia. In: Herrmann, A. and Schumann S. (eds) Proc. Int. Workshop on Environmental Risk Assessment of Pesticides and Integrated Pesticide Management in Developing Countries 6-9 Nov. 2001 Kathmandu, Nepal. Landschaftsökologie und Umweltforschung 38, Braunschweig, pp. 62-72.
Johnston, J. and Di' Nardo, J. (1997). Econometric methods. New York: The McGraw-Hill Co., Inc.
Kishi, M., Norbert, H. Djayadisastra, M. Satterlee, N.L. Strowman S. and Dilts, R. (1995). Relationship of pesticides spraying to signs and symptoms in Indonesian farmers. Scandinavian Journal of Work, Environment, Health 21: 124-133.
Kusmayadi, A. (1999). Integrated Pest Management in rural poverty alleviation: Case study of Indonesia. Ministry of Agriculture. Paper presented in the SEARCA Workshop, Philippine.
Lilja, N. and Dixon, J. (2008). Operationalising participatory research and gender analysis: new research and assessment approaches. Development in Practice, 18, 467-478
Luther, G.C. (1993). An agro-ecological approach for developing an integrated pest management system for soybeans in Eastern Java. PhD Dissertation. University of California, Berkeley.
Mancini, F. and Jiggins, J. (2008). Appraisal of methods to evaluate farmer field schools. Development in Practice 18: 539-550.
Mariyono, J. (1998). Laporan pendataan nasional IPMFFS oleh Sekretariat PHT Pusat Jakarta. Jakarta: Program Nasional PHT,
Mariyono, J. (2009). Integrated pest management training in Indonesia: does the performance level of farming training matter? Journal of Rural and Community Development 4: 93-104.
Mariyono, J., Kompas, T and Grafton, R.Q. (2010). Shifting from Green Revolution to environmentally sound policies: technological change in Indonesian rice agriculture. Journal of the Asia Pacific Economy 15: 128–147.
Nas, T.F. (1996). Cost-benefit analysis: Theory and application. London, SAGE Publication.
Nicholson, W. (1999). Teori mikroekonomi: Prinsip dasar dan perluasan, (Jilid 1). Jakarta: Binarupa Aksara.

Papps, I. (1994). Teknik penilaian proyek. In: Gemmell (ed.), Ilmu Ekonomi Pembangunan: Beberapa survai. (pp. 444-487) Jakarta: LP3ES.
Pincus, J. (1991). Farmer field school survey: Impact of IPM training on farmer's pest control behavior. Jakarta: IPM National Program.
Pindyck, R.S. and Rubinfeld, D.L. (1998). Microeconomics. New Jersey: Prentice Hall International, Inc.
Rölling, N., and van de Fliert, E. (1994). Transforming extension for sustainable agriculture: the case of integrated pest management in rice in Indonesia. Agricultural and Human Value, 11 (2/3): 96-108.
Salvatore, D., 1996. Managerial economics in a global economy. New York: McGraw-Hill.
SEARCA. (1999). Integrated pest management training project, World Bank loan 3586-IND: Impact evaluation study. Report prepared for the SEAMEO SEARCA, Laguna, Philippines.
Settle, W.H., Ariawan, H. Astuti, E.T. Cahyana, W. Hakim, A.L. Hindayana, D. Lestari, A., Pajarningsih and Sartanto (1996). Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. Ecology 77: 1975-1988.
Soenanto, F.N. (2000). Evaluasi kemajuan, perkembangan dalam pelatihan dan pengembangan PHT di Yogyakarta. Disampaikan pada Pertemuan Teknis Perlindungan Tanaman Tingkat Nasional, Semarang.
Suharno. (1995). Analisis efisiensi dan pendapatan usaha tani tebu dan usaha tani padi lahan sawah beririgasi di Kabupaten Bantul. Tesis S-2, Program Pasca Sarjana Universitas Gadjah Mada, Yogyakarta.
Todaro, M.P. (1984). Ilmu ekonomi bagi negara sedang berkembang. Buku I. Jakarta: Akademika Presindo.
Triastono. J. (2000). Pengaruh introduksi kedelai varietas Bromo terhadap produktivitas, keuntungan dan kesempatan kerja pada sawah tadah hujan di Kabupaten Boyolali. Tesis S-2, Program Pasca Sarjana Universitas Gadjah Mada, Yogyakarta.
Untung, K. (1996). Institutional constraints on IPM implementation in Indonesia. Publication of the Pesticide Policy Project, Publication Series 3: 37-47
Useem, M., L. Setti & Pincus, J. (1992). The science of Javanese management: organizational alignment in an Indonesian Development Programme. Public Administration and Development 12: 447-471.
van den Berg, H. (2004). IPM Farmer Field Schools: a synthesis of 25 impact evaluations. Wageningen University, The Netherlands. 53 pp.
van den Berg, H., and Jiggins, J. (2007). Investing in farmers – the impacts of farmer field schools in relation to integrated pest management. World Development 35(4): 663-686.
World Bank. (1993). Staff appraisal report: Indonesia integrated pest management training project. Washington: The World Bank.
Yamazaki, S. & Resosudarmo, B.P. (2008). Does sending farmers back to school have an Impact? Revisiting the issue. Developing Economies 42: 153-150.
Zuhaida, I. (2000). Kajian produktivitas usaha tani padi dan distribusi pendapatan di area Irigasi Riam Kanan Kalimantan Selatan. Tesis S-2, Program Pasca Sarjana Universitas Gadjah Mada, Yogyakarta.

(Received 11 July 2010; accepted 30 October 2010)