AGRO-CHEMICAL INPUTS USE IN INDONESIA DURING 1970-1989: IS ITS CONTRIBUTION ON RICE PRODUCTION SIGNIFICANT?

(Penggunaan Input Kimia Pertanian di Indonesia Periode 1970-1989: Signifikankah Sumbangannya pada Produksi Beras?)

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Abstract

Agro-chemical inputs (fertilizer and pesticides), have contributed in growing economics of Indonesia, which in 1970-1989 demonstrated a spectacular increase in rice production. Since the agro-chemical inputs possess two contradictive characteristics of enhancing yield and preventing yield loss on one hand, and threatening human health and environment on the other hand, a study that reviews the real contribution of agro-chemical inputs on rice production is needed.

The objective of the study is to determine whether or not the contribution of agro-chemical inputs on rice production in the 1970-1989 periods is significant. Estimation is conducted by using time series data comprising four main factors of rice production: rice-planted area, nitrogen-fertilizer, chemical pesticides, and technological progress. Data were compiled from GOI report. The results of estimation indicate that the increase in rice production during 1970-1989 was not caused by increasing chemical pesticides use, but by the enlargement of planted-rice area, rise in nitrogenous fertilizer use, and technological progress.

Key words: fertilicer, pesticides, rice production

Abstrak

Pupuk dan pestisida kimia, telah membawa kemajuan ekonomi Indonesia yang pada periode 1970-1989 menunjukkan peningkatan produksi padi yang luar biasa. Mengingat input kimia mempunyai dua sifat yang berlawanan yaitu meningkatkan hasil dan mencegah kehilangan hasil di satu pihak, dan mengancam kesehatan manusia dan lingkungan di lain pihak, maka diperlukan suatu kajian yang mengupas sejauh mana sumbangan input kimia terhadap produksi padi.

Tujuan studi ini adalah untuk menunjukkan sumbangan input kimia terhadap peningkatan produksi padi selama periode tesebut. Estimasi dilakukan dengan menggunakan data runtun waktu dari empat faktor penting dalam peningkatan produksi padi yaitu: perluasan lahan, penggunaan pupuk, penggunaan pestisida dan kemajuan teknologi. Data tersebut dihimpun dari laporan keuangan Pemerintah Indonesia. Hasil estimasi menunjukkan bahwa peningkatan produksi selama tahun 1970-1989 tidak disebabkan oleh peningkatan penggunaan pestisida kimia, tetapi disebabkan oleh perluasan lahan, peningkatan penggunaan pupuk nitrogen, dan kemajuan teknologi.

Kata kunci: pupuk, pestisida, produksi padi

INTRODUCTION

Background

Indonesia, over the last twenty years, has emerged as one of Asia's fastest growing economy countries, beginning as a primarily agricultural based economy. In 1980s, with the growing agricultural based economy, more jobs have become available, income has doubled, and poverty has decreased (World Bank 2000). Agricultural policy has been primarily concerned with implementing production-based policies designed to pursue food self-sufficiency since 1967, and this goal was reached in 1984 (Sjahrir, 1990). The Government of Indonesia (GOI) achieved food self-sufficiency in rice through an intensive government investment and through the implementation of subsidy programs for fertilizer, chemical pesticides and irrigation. In 1986-1987 the total cost of these input subsidies reached US$725 billion (Barbier, 1989).

Agro-chemical input uses, which plays role on the increase in rice production, have adverse effects on human health and the environment. It happened since nitrogenous fertilizer is susceptible to various loss mechanisms such as ammonia volatilization, leaching and *denitrification*. Ammonia that emanates from the nitrogenous fertilizer applied in agricultural field, contributes to acid rain, while nitrates produced in soil contribute to contamination of ground water because of leaching of nitrates, and ozone depletion because of release of nitrogenous oxides by *denitrification* process (Sutanto, 1999). The excessive chemical fertilizer uses lead to compaction since fertilizer has a relatively high content of ballast material accumulated in the soil and has a cementing effect. It also leads to the killing of bio-life in the soil, since the fertilizer concentration use is often toxic to the micro-life in the soil (Bond, 1996). Excess nutrients in runoff from agricultural fields can also deplete surface water quality. This runoff supports population explosions of algae and invasive aquatic weeds (such as Salvinia molesta and water hyacinth, Eichhornia crassipes) which in turn leads to oxygen deletion when these aquatics die and decompose. This process is well-known as eutrophication. With regard to human health, high levels of nitrates in drinking water can cause *methemoglobinemia* ("blue baby syndrome") in infants and the formation of carcinogenic *nitrosamines* in human digestive tracts, whereas the additional nitrous oxide added to the atmosphere contributes to respiratory illness (McLaughlin, 1999).

Pesticides are chemicals, which are synthesized with the sole intention of causing death or harm to living organisms (Nhachi 1999). Since chemical pesticides are developed specifically for their biological activity or toxicity to some forms of life and because at the subcellular level organisms have similarity with one another, all chemical pesticides are associated with a certain measure of risk.

Human exposure to chemical pesticides may occur occupationally or may occur from any of several involuntary non-occupational sources (Wilkinson 1988). The degree of risk, however, will vary considerably. This depends on the intensity and duration of exposure, which in turn, relate to the circumstances under which exposure occurs (Manahan 1983). Because of the potentially harmful effects of agro-chemical inputs, for the larger society on the other hand, its use involves negative impact that reduces the reached gains by improved agricultural production. These negative impacts include the effects on human health and the environment (Bond 1996; McLaughlin, 1999; Gerken *et al.* 2001).

The negative impacts of the chemical pesticide uses in Indonesia have been well documented. The inappropriate uses and over-applications of chemical pesticides by Indonesian farmers led to the evolution of pests resistance, pests resurgence, secondary pest outbreak, and the elimination of natural predators and parasitoids that help control pests naturally. For example, in 1986-1987, an estimated 50,000-60,000 hectares of cultivated rice were lost to an outbreak of a chemical pesticide resistant brown plant-hopper species. This loss of 1 million tons of rice was equivalent to US$180 million (Barbier 1989). Prior to 1986, an outbreak rice brown plant-hopper was also happened in 1977. The outbreak had caused Indonesia lost 10 millions Mg of rice to the rice brown plant-hopper that is enough to have fed two millions people for 1 year. Overall, during 1970s Indonesia was estimated to have lost upward of US$ 10 billion worth of rice to the rice brown plant-hopper, not including the cost of pesticides, opportunity costs or the social and health cost of exposure of pesticides (Settle *et al.*, 1996).

In addition to these direct user costs, contamination of environment by chemical pesticides runoff resulted in the decline of beneficial wild life, and in costs of human health. In environmental problem, Carson (1962) seriously describes that chemical pesticides has caused adverse ecological impact on the environment. It has destroyed a large amount of organisms in the world. Meanwhile, in human health problem, the exposure varies from acute poisoning of farmers with chemicals they work with long-term, to low-level exposure to chemical in human diet. The WHO estimated that there were a million cases per year of occupational poisoning by various chemical pesticides, and 20,000 of the cases were fatal cases (Fleischer, 1999). Whereas in Indonesia, in 1983 there were 168 cases human poisoning, and 96 of cases were deadly cases (Bond, 1996). Kishi *et al.* (1995) states that many cases of human chemical pesticides poisoning were not recorded well, so the number of cases is higher than those reported.

Objective of Study

Since agro-chemical contamination and eutrophication threaten human health and the environment (Hewitt and Smith, 1995; Pincus *et al.*, 1999), it is required to know how much the agro-chemical inputs uses play their roles on rice production. Therefore, the objective of this study is to determine the economic contribution of agro-chemical input use on rice production in Indonesia during 1970-1989, where Nitrogenous fertilizer and pesticide uses were highly supported by subsidies, extensions and trainings.

Literatur Review

This study employs the theory of economics production as fundamental analysis. The theory postulates that the relationship between the input to the production process and the resulting output is described by a production function (Pindyck and Rubinfeld, 1998). The production function of rice can be formulated simply as:

$$Y = f(X_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where Y is production and X_i are inputs included technology. If one of the inputs is chemical pesticide, it will need special model. Benefit of chemical pesticides use, which measured in economic terms for farmers, is profitability of intensification that depends on the cost of additional pesticide uses compared to the expected loss in yield or quality. Farmers will reach a microeconomic optimum of chemical pesticide uses in the long term, where the profit of pesticide uses is in the maximum (Gerken *et al.*, 2001). To incorporate the special properties of pesticide uses into production functions, Lichtenberg and Zilberman (1986) suggest that "the contribution to production by damage control agents may be understood best if one conceives of actual (realized) output as a combination of two components: potential output and losses caused by damaging agents present in the environment". The output that a producer obtains is regarded as a net result of two interdependent components i.e., potential yield obtainable and potential loss to pests. Pesticides are incorporated in the latter component and are conceptualized in terms of their role in reducing output losses. With the addition of a new component to take account of the unique role of pesticides, equation (1) becomes:

$$Y = f(Xi, D(P)) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where the first component is essentially made up of equation (1) and the second component D(P) is the damage function. The D(P) is defined as a measure of the effectiveness of pesticides, or the proportion of the destructive capacity of pests which is eliminated by the application of pesticides quantity P. The importance of pesticides depends on the level of yield loss. The yield loss is in turn determined by the extent of pest pressure in the production system. But given that the pressure from pests cannot be predicted with certainty, potential yield loss and hence the productivity of pesticides is an uncertain event, i.e. a stochastic event having the characteristics of a probabilistic distribution. Theoretically, this proportion of potential yield loss ranges from zero (i.e. total destruction of the crop) to unity (i.e. perfect control of pests). But, biological science suggests that in real life it is more realistic to assume that D(P) takes values in the range $0 < D(P) < 1$. This implies that the damage function follows a cumulative probability distribution. As a result, it can be expressed in various econometric forms and then be tested empirically. Right now, the exact probability distribution function of pesticides is not yet known (Ajayi, 2000), so the production function can be modified in the simplest linier model as expressed below:

$$Y = f(X_i) - D(P) \qquad (3)$$

METHODOLOGY

Source of Data

Data for this study is a time-series data during 1970-1989. The data is obtained from annual budget plan of GOI that has been well collected and officially published by Useem *et al.* (1992). The data (appendix 2) consist of:

1. National quantity of rice-planted area (millions of hectares),
2. National production of milled-rice (millions of tons),
3. Milled-rice per hectare (tons per hectare),
4. National use of nitrogenous fertilizer (100,000s of tons),
5. National use of chemical pesticides –particularly insecticides– (1,000s of tons).

Pesticide uses includes numerous active ingredients such as endosulfan, diazinon, carbaryl, and quinalphos in various formulations such as emulsifiable concentrate (EC), wettable powder (WP), granule (G) and water soluble concentrate (WSC)[1]. In the said periods, pesticides were used in scheduled method, namely prophylactic plant protection or using pesticides without taking into consideration the level of pest infestation, and of course they were applied appropriately based on its formulation.

Statistical Procedure

Based on fundamental theory and availability of data, the statistical procedure is designed to trace the reaction of actual rice production by changed explanatory variables (productive inputs and chemical pesticides). The model was of the form:

$$Y_t = C_t + bL_t + bF_t + bP_t + bT_t + e_t \qquad (4)$$

where Y_t is actual rice production as dependent variable, while C_t is constant value, L_t is land, F_t is fertilizer, P_t is chemical pesticides, T_t is trend as explanatory variables, e_t is disturbance error, and subscribe letter t in each variables indicate year. Trend, which reflected by value 1 for first year of the periods (1970=1) and 2 for second year and henceforth, represents the technological progress from time to time. Disturbance error represents the uncontrolled factors that excluded from the model such as post-harvest process, weather, climate and catastrophe.

Some problems of estimation based on aggregate time-series data in model (4) include: *multicolinearity* in explanatory variables,

[1] Republic of Indonesia (1996), Presidential Instruction No. 3 dated November 5th, 1986

lagged adjustment in response, and gross averages for long time periods that conceal many individual changes (Purcell and Raunikar 1971). Such problems cause the estimated values of the coefficients do not reflect to real condition (Gujarati, 1997). In order to deal with such problems, therefore, the statistical procedure of estimation can be modified in first difference (form year-to-year changes) as expressed bellow:

$$Y_t - Y_{t-1} = C_t - C_{t-1} + \beta_1(L_t - L_{t-1}) + \beta_2(F_t - F_{t-1}) + \beta_3(P_t - P_{t-1}) + \beta_4(T_t - T_{t-1}) + \varepsilon_t - \varepsilon_{t-1} \quad (5)$$

The equation (5) can be simply expressed as:

$$\Delta Y = \Delta C + \beta_1 \Delta L + \beta_2 \Delta F + \beta_3 \Delta P + \Delta\beta_4 \Delta T + \Delta u \quad (6)$$

The subscript of letter t indicates the value in the year t, subscript of letter t-1 indicates the value in the previous year, and D symbol indicates the change in values of related variables. Since C is constant value and difference between T and the following T is equal to one, the value of DC is equal to zero and value of DT is constant. Hence, the equation (6) can be expressed as:

$$\Delta Y = \Delta T + \beta_1 \Delta L + \beta_2 \Delta F + \beta_3 \Delta P + \Delta u \quad (7)$$

ΔY is change in production, ΔT is trend of production, β_1, β_2 and β_3 are estimated coefficients representing the marginal response of production resulted from changes in rice-planted area, fertilizer and chemical pesticide uses respectively, and Du is residual. The model (7) can be estimated directly by employing ordinary least square (OLS) method. OLS method is performed by running econometrics computer program, namely Shazam ver. 6.2 (White *et al.* 1990).

RESULT AND DISCUSION

Figure 1 describes the dynamics of rice production, rice-planted area, Nitrogenous fertilizer use, and pesticide uses in Indonesia during 1970-1989.

As can be seen from the Figure 1, rice production and all factors simultaneously increase continually, except pesticide uses fall-

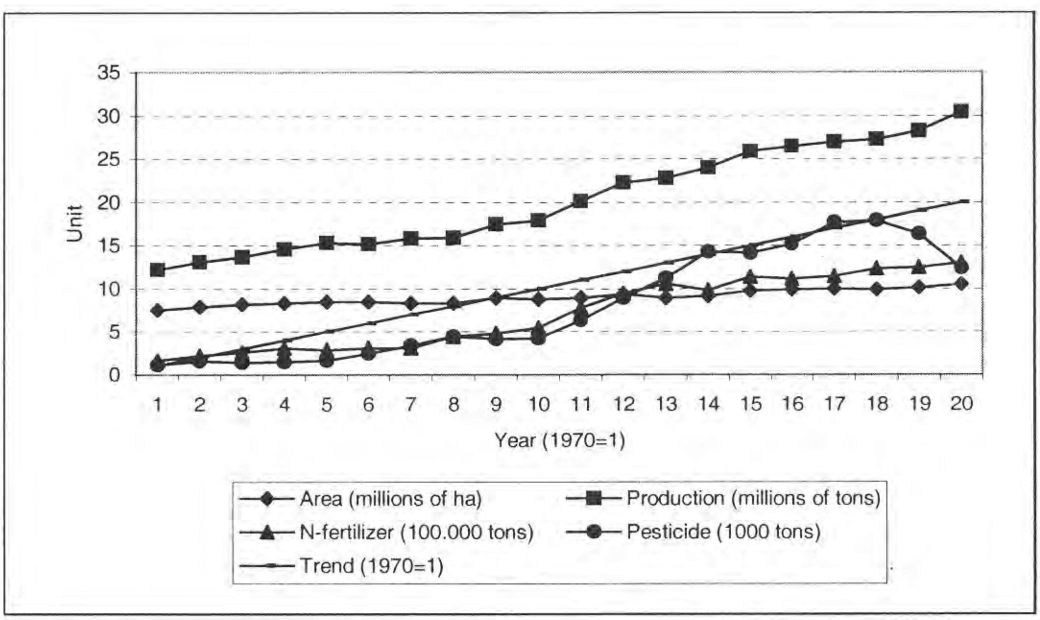

Figure 1. The Dynamics of Rice Production, Area-planted, N-fertilizer, and Pesticides Use.

ing after the 18th year. It is suspected that emerging President Instruction No.3 1986 that banned 57 brand names of pesticides for rice farming caused the fall in pesticide uses. The fall in pesticide uses, however, did not affect rice production, since rice production constantly increased although there was a decrease in pesticide uses. Because the Figure 1 is unable to explain which factors actually influence the increase in rice production, it needs to do a statistical procedure to determine the partial role of each factor. Table 1 explains the result of the statistical procedure.

Table 1 indicates that around sixty percent of variation of the increase in rice production in Indonesia during 1970-1989 is explained simultaneously by the variation of changes in rice-planted area, nitrogenous fertilizer use, chemical pesticide uses and trend, whereas the remainder, about forty percent, is explained by uncontrolled variables which are excluded from the model.

Partially, by holding *ceteris paribus* assumption, positive trend, which is expressed by positive value of constant, means that change in rice production from year to year, increased significantly. It indicates that technological progress influenced significantly rice production. Technological progress in the said periods comprised seed technology, water irrigation and infrastructure. Seed technology has been developed continuously since the International Rice Research Institute (IRRI), together with the National Rice Research Institute have discovered high yielding and pest-resistant varieties of rice like IR and PB-series (Settle *et al.* 1996). In connection with water irrigation and infrastructure, GOI has improved water irrigation. Over the period 1970-1984, the total irrigated land area increased from 3.7 million to 4.9 million hectares. This increase was accomplished by investing large amounts of government funds into infrastructure projects, such as the building of roads and processing facilities, and the development of new irrigation networks (Barbier 1989).

Change in rice-planted area significantly increased the rice production, and so did change in fertilizer use. It could be understood well because the land and fertilizer are productive agricultural inputs. However, because of potentially undesirable effects of fertilizer, it does not imply that excessive use of fertilizer have to be carried out continually, even though fertilizer really contributes the increase in rice production. It really needs wise considerations.

The change in chemical pesticide uses did not influence significantly the rice production. In this case, chemical pesticide uses did not donate an essential contribution to national rice production. In other word, it could be said that chemical pesticide uses did not prevent yield loss caused by pest infestation, because there was no yield loss that have to be saved. At

Table 1. Estimated Response of Rice Production in Indonesia During 1970-1989

No	Explanatory Variables	Coefficient	T-ratio
1	Change in rice-planted area (millions. ha)	1.9497***	3.8630
2	Change in fertilizer use (100,000 tons)	0.3481**	2.1663
3	Change in chemical pesticide uses (1,000 tons)	0.0144^{ns}	0.1852
4	Constant (trend)	0.4338***	2.5093
5	R-square	0.6023	
	Adjusted R-square	0.5228	
6	F-ratio	7.573 ***	

Dependent variable: change in rice production (1,000,000 ton); ***) significant at 99%; **) significant at 95%; ^{ns}) insignificant.

least there are two possible factors that cause why it occurred.

First, in the said periods chemical pesticides were not actually required in plant protection, because pest-resistant varieties of rice were being cultivated. During the time, many discovered pest-resistant varieties of rice were released and introduced to the farmers to support the green revolution implementation. Therefore, by cultivating such varieties, the existence of pests on rice-planted areas did not affect rice production, and certainly chemical pesticide uses were not useful anymore.

Second, farmers used more chemical pesticides than what was economically efficient. Chemical pesticide uses will offer benefits significantly to plant protection if there is serious pests infestation in susceptible varieties of rice. If serious pests infestation did not exist, the excessive chemical pesticide uses will be ineffective. Actually, there was no serious pests infestation on rice. Pest outbreak, particularly *brown plant-hopper* that occurred in 1970s and 1985-1987, were caused by chemical pesticides application. The first one was triggered by chemical pesticide uses that addressed to control rice stem borer (Settle *et al.*, 1996), and the second one was caused by unwise chemical pesticides application (Oka, 1995). This excessive chemical pesticide uses was understandable, since chemical pesticides was highly supported by government subsidy and farmers were not responsible for paying the full cost of their chemical pesticides. As a result, application of pesticides was in over and wasteful. Pimentel (1993) supports that only one percent of chemical pesticide uses was on target, and the remainder was wasted. The above factors had caused chemical pesticide uses did not contribute any benefits except wastefulness of money, threatening human health and polluting environment as seriously mentioned by Conway and Barbier (1990).

Based on the above indications is that the excessive chemical pesticide uses did not give significant contribution to rice production, but made external spending instead, the enormous amount of government chemical pesticides subsidy was a bulky wastefulness. Therefore, the prohibition of 57 pesticide trade names used in rice that have been started in 1986 (Republic of Indonesia 1986) and elimination of pesticide subsidy that have been started in 1990 by GOI (Untung 1996) were proper decisions, as the goal to stop useless expenses and to prevent greater damaged agriculture, risky human health and polluted environment. World Bank (2001) supports the decision by seconding the policy that works significantly in saving the environment, that is, cutting down chemical pesticide uses without affecting rice production.

CONCLUSION AND RECOMMENDATION

1. Conclusion

Based on results of analysis and discussion, this study can be concluded as:

1. Agrochemical input uses, which consists of Nitrogenous fertilizer and pesticides, simultaneously played an important role on rising rice production in Indonesia during 1970-1989. In particular, however, the chemical pesticide uses insignificantly demonstrated their contribution to the rice production, and of course it created wastefulness of money and polluted environment. Meanwhile, the Nitrogenous fertilizer use really enhanced the rice production.
2. The spectacular increase in rice production during the 1970-1989 was a significant function of extending rice-planted area. The increase in rice production was also supported by technological progress.

2. Recommendation

Because of the potentially harmful effects of chemical pesticides, their use has to be carefully regulated in order to maximize benefits and minimize the adverse effects on health of farmers, consumers and the environment. Additionally, these effects of chemical pesticide uses have to be included into economic analysis in order to achieve the social optimum of chemical pesticide uses.

Although Nitrogenous fertilizer significantly contribute to rice production, but since fertilizer also causes adverse impacts on human health and the environment, the impacts ought to be taken into account in order to optimize the benefits of fertilizer.

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