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?)  

Joko Mariyono  
PhD Student at The Australian National University, Canberra;  
Researcher in Bahtera Foundation, Yogyakarta  

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: fertilizer, 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 berlaku pada satu pihak yaitu meningkatkan hasil dan mencegah kehilangan hasil di satu pihak, dan mengancam kesehatan manusia dan lingkungan di lain pihak, maka diperlukan suatu kajian yang mengubah suatu manfaat input kimia terhadap produksi padi:  


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 sub-cellular 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
Maret 2006

MARIYONO, J.: AGRO CHEMICAL

43

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., 19%).

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 hu-
man 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 poison-
ing, 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 contri-
bution of agro-chemical input use on rice pro-
duction 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 eco-
nomics 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 produc-
tion function (Pindyck and Rubinfeld, 1998).
The production function of rice can be formu-
lated simply as:

\[ Y = f(X_i) \] ................................. (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 mea-
sured in economic terms for farmers, is profit-
ability of intensification that depends on the cost
of additional pesticide uses compared to the ex-
pected loss in yield or quality. Farmers will reach
a microeconomic optimum of chemical pesti-
cide uses in the long term, where the profit of
pesticide uses is in the maximum (Gerken et
al., 2001). To incorporate the special proper-
ties 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., poten-
tial yield obtainable and potential loss to pests.
Pesticides are incorporated in the latter com-
ponent and are conceptualized in terms of their
role in reducing output losses. With the addi-
tion of a new component to take account of
the unique role of pesticides, equation (1)
becomes:

\[ Y = f(X_i, D(P)) \] ................................. (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 linear model as expressed below:

\[ Y = f(X_i) - D(P) \]  

(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). 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:

\[ Y_t = C_t + bL_t + bF_t + bP_t + bT_t + e_t \]  

(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 below:

\[ Y_{t} - Y_{t-1} = C_t - C_{t-1} + \beta_1 (L_t - L_{t-1}) + \beta_2 (F_t - F_{t-1}) + \beta_3 (P_t - P_{t-1}) + \beta_4 (T_t - T_{t-1}) + \epsilon_t - \epsilon_{t-1} \]  

(5)

The equation (5) can be simply expressed as:

\[ \Delta Y = \Delta C + \beta_1 \Delta L + \beta_2 \Delta F + \beta_3 \Delta P + \Delta \beta_4 \Delta T + \Delta \epsilon \]  

(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 \( \Delta C \) is equal to zero and value of \( \Delta T \) is constant. Hence, the equation (6) can be expressed as:

\[ \Delta Y = \Delta T + \beta_1 \Delta L + \beta_2 \Delta F + \beta_3 \Delta P + \Delta \epsilon \]  

(7)

\( \Delta Y \) is change in production, \( \Delta T \) is trend of production, \( \beta_1, \beta_2 \), and \( \beta_3 \) are estimated coefficients representing the marginal response of production resulted from changes in rice-planted area, fertilizer and chemical pesticide uses respectively, and \( \Delta \epsilon \) 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 DISCUSSION**

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-
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>
<thead>
<tr>
<th>No</th>
<th>Explanatory Variables</th>
<th>Coefficient</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Change in rice-planted area (millions. ha)</td>
<td>1.9497***</td>
<td>3.8630</td>
</tr>
<tr>
<td>2</td>
<td>Change in fertilizer use (100,000 tons)</td>
<td>0.3481**</td>
<td>2.1663</td>
</tr>
<tr>
<td>3</td>
<td>Change in chemical pesticide uses (1,000 tons)</td>
<td>0.0144ns</td>
<td>0.1852</td>
</tr>
<tr>
<td>4</td>
<td>Constant (trend)</td>
<td>0.4338***</td>
<td>2.5093</td>
</tr>
<tr>
<td>5</td>
<td>R-square</td>
<td>0.6023</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Adjusted R-square</td>
<td>0.5228</td>
<td></td>
</tr>
</tbody>
</table>

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

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

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.

REFERENCES


Sjahrir, 1990. Ekonomi Politik Kebutuhan

Pokok, Sebuah Tinjauan Prospektif. LP3ES, Jakarta. p. 221-223


