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THE IMPACT OF CHANGES IN RICE INNOVATION SYSTEM COMPONENTS ON AGRICULTURAL SECTOR AND POVERTY

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ABSTRACT

This study aims to: (a) analyze the factors that affect the performance of rice innovation system and its impact on the performance of the agricultural sector and poverty alleviation; and (b) conduct policy simulations on major component of rice innovation system. This study uses simultaneous regression equations. The results show that the increase in real rice research budget allocations have significant and positive impact on the number of high yielding varieties produced by BBPadi. Number of PPL is significantly and positively influenced by the number of farmers group and planting area that use improved seed. Planting area using improved seed as indicator of the level of technology adoption significantly and positively influenced by the price of paddy improved seed, the number of KUD, and improved seed production. Simulation results show that without offset by the development of delivery and receiver capacity system, technology creation efforts were not optimally encourage increased rice production and vice versa.

Key words: agricultural research, econometric model, sustainability production

INTRODUCTION

In New Order era, positioning of paddy as a strategic commodity apparently continues to this day. As the consequence, all efforts have been made by the government to increase rice production on sustainable basis to offset the increasing rice demand every year. The invention of paddy high yielding varieties which marked the start of green revolution era, has been used optimally by the New Order government so that Indonesia can achieve self-sufficiency in rice for the first time in 1984. However this achievement cannot be maintained on an ongoing basis, and since the early 1990s the rate of rice production growth declining slowly (Simatupang, et al, 2006; Fuglie, 2010).

Decreasing growth rate of paddy production that began in the early 1990s is due to, among others: (1) decrease in paddy field area, (2) decrease in the rate of productivity growth, and (3) integrated package to increase rice production experiencing partial and gradual deconstruction (Simatupang, et al, 2006; Fuglie, 1999; Timmer, 2004). In this case, one of the biggest concerns is the increase in rice price, which will encourage increasing the number of poor and undernourished population (Ivanic and Martin, 2010). World Bank (2011) reported that the impact of rising food prices in late 2010 has resulted in approximately 44 million of near-poor households falling into the poor group.

Volatile food prices make government in many countries revived their concern to invest in agricultural research activities (CGIAR, 2009; Ivanic and Martin, 2010). The study of Warr (2011) and Fuglie (2010) concluded that Indonesian agricultural research budget has significant affect on agricultural TFP growth, while studies of Rada et al (2010) showed the opposite result, where the research activities carried out by the government has no significant effect on the improvement of agricultural productivity. The difference in this empirical study finding is exciting to be explored in the context of agricultural innovation system that consisting of creation, delivery, receiver and technologies subsystems. Operationalization of the Third subsystem involves institutional and government policy aspects. Indonesia has very good experience in the implementation of rice innovation system since New Order era to the present. To the end, this paper focuses on rice innovation system. This study aims to: (a) analyze the factors that affect the performance of rice innovation system and its impact on the performance of the agricultural sector and poverty alleviation; and (b) conduct policy simulations on major component of rice innovation system.

Problems Formulation

The success of Mexico in increasing wheat production up to six times during the period of 1944-1963 marked the beginning of green revolution success triggered by high yielding varieties. This success is further followed in other countries, and for Asia in addition to wheat also introduced high yielding varieties of paddy (Zeigler and Mohanty, 2010). Since the establishment in the late 1960s to the present, the International Rice Research Institute (IRRI) has produced more than 1,000 improved varieties of rice and has been used in many countries including Indonesia.

The use of high yielding varieties combined with fertilization technology and good irrigation system, during the first two decades (1970-1990) have been successful in increasing rice production in Indonesia, namely 24.8 million tons to 37.7 million tons (Table 1). The highest performance of rice production growth was achieved in the period 1980-1989 that was triggered by an increase in harvested area (1.64 percent per year) and the productivity (2.33 percent per year).

Table 1. Performance of rice production in Indonesia, 1970-2009

Description	1970-1979	1980-1989	1990-1999	2000-2009
Harvested Area				
Average (million ha)	8.43	9.68	11.14	11.92
Growth (%)	0.86	1.64	1.40	0.99
Coefficient of variance (%)	3.30	5.36	4.84	3.66
Productivity				
Average (million ha)	2.94	3.86	4.34	4.61
Growth (%)	2.05	2.33	-0.13	1.36
Coefficient of variance (%)	6.26	7.44	1.66	4.37
Production				
Average (million ha)	24.84	37.47	48.30	55.06
Growth (%)	2.92	3.96	1.26	2.39
Coefficient of variance (%)	9.17	12.20	4.57	7.98

Source: BPS

The remarkable achievement of rice production increase during the period 1980-1989 can not be separated from technology support combined with the development of physical infrastructure and institutional and input-output price subsidies policy as well as farm credit. Very comprehensive government strategy resulting the achievement of rice self-sufficiency in 1984, but the golden era of rice farming is not lasted long. The performance of rice farming has declined sharply in the 1990s, which was triggered by sharp decline in productivity and harvested area. The decline in harvested area was due to decrease in the growth of wet rice field, while the decline in productivity growth caused by saturation of technology.

In the future, the challenge to increase rice production will be heavier when the gap between actual productivity and potential yield widens (Table 2). This indicates two important facts, namely soil fatigue due to over-intensification and/or technology adoption is sub-optimal. The gap between potential yield and actual productivity will be more attractive when associated with the dynamics of research funding, research and extension institutions, farmer groups, economic institutions, and government policy.

The research budget of the Indonesian Center for Rice Research and Development (BBPadi) in real terms since 1976 tended to decline and increase sharply since 2007. During the period of 1970-2009 more than 200 high yielding rice varieties (wet land paddy, dry land, and swamp/lowland) were produced by BBPadi. Similarly, since 1996, IRRI's research budget in real terms continued to decline and increased again in 2009. As efforts to deliver the technology to the users, since 1995, the government has also established the Institute for Agricultural Technology Assessment (BPTP) that currently has been established in 33 provinces.

Table 2. Gap between rice potential yield and actual productivity, 1970-2009 (tons ha^{-1})

Description	1970-1979	1980-1989	1990-1999	2000-2009
Actual Productivity	2.94	3.86	4.34	4.61
Potential Yield	5.07	5.30	6.61	7.86
Gap	2.13	1.44	2.27	3.25

Source: BPS and Puslitbangtan (2009)

Despite the diminished role since the reform era to the present, extension institutional still exists and is being revitalized. Likewise, cooperatives institutions (KUD), seed providers, and farmers groups are also being revitalized to support rice farming. Government policy support in the form of input and output prices subsidies are also still exist, although not as complete as in the 1980s. On the other hand, in line with the development of consumers preferences and information technology, creation workflow and delivery of technology from research institutions to the users (farmers) are undergoing significant change. The presently developed innovation system requires balance and harmony among components in technology creation, delivery, and receiver sub-system. This condition should occur in the rice innovation system.

Definition of Inovation System

Innovation system is defined as the institutional network between public and private sectors that interact to initiate, import (bring in), modify and diffuse new technologies (Freeman, 1987). Lundvall (1992) enhanced the understanding of innovation system as elements and relationships which interact to generate, diffuse and use new knowledge and use economically within a state boundary. He also stated that the innovation system is a social system in which learning, searching, and exploring become central activity, which involves the interaction between people / society and reproduction of individual and collective knowledge through remembering.

Nelson (1993) and Metcalfe (1995) also contributed to the definition of innovation system and then pursed by OECD (1999) which states that innovation system is a set of market and non-market institutions in a state that affects the direction and rate of innovation and technology diffusion. These definition are synthesized by Taufik (2005) which describes the innovation system as a set of actors entities, institutions, networks, relationships, interactions and productive processes that influence the direction and rate of innovation and the diffusion (including technology and the best good practice), as well as the learning process.

Agriculture Innovation System

Based on the above definition, agricultural innovation systems can be defined as a set of agents (such as farmers' organizations; input supply, processing, and marketing; research and education institutions; credit institutions; extension and information units, consulting firms, international development agencies, and government) that contribute jointly and/or individually to the development and diffusion of new technologies as well as providing direct or indirectly effect to the process of technological change in agriculture (Temel et al, 2002).

Indonesian Agency for Agricultural Research and Development-IAARD (2004) defines agricultural innovation system consists of the creation of appropriate innovative technology (generating system); production, distribution, and dissemination of information or extension about innovative technologies (delivery system); and the application of innovative technologies by users (receiving systems) (Figure 1). Agricultural innovation system developed by BPTP has already requires the interaction between actors as shown by reciprocal relationship among the actors.

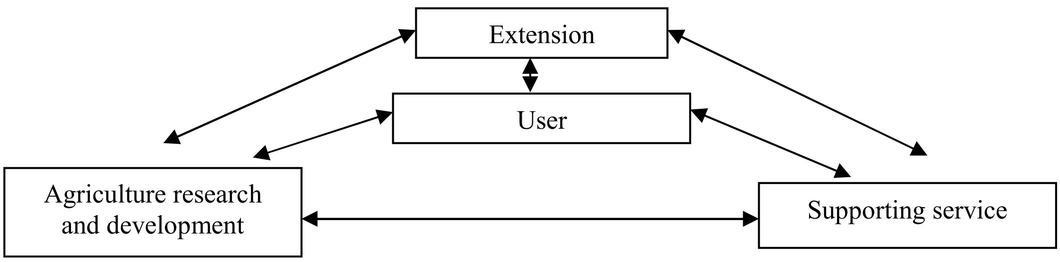

Figure 1. Agricultural Innovation System (IAARD, 2004)

Interaction that includes all actors in agricultural innovation system is expected to ensure the development of responsive and appropriate agricultural innovations to the needs of the user. Commercially, agricultural innovation system can be more fully developed as shown in Fig. 2. Although the basic model is linear, but the relationship among the actors have led to modern innovation model. Characteristics of modern innovation system model as shown in Figure 2, among others: (a) the existence of reciprocal relationship among the actors, (b) technology users have many technology sources, and (c) consumer preference communicated with technology users as producers of primary commodities or processed products.

This flowchart is dominant today, although in the last decade flow of rice innovation system has led to the modern innovation system. Modernization of rice innovation system is characterized by development of hybrid rice seeds in which the private sector can exclusively protecting rice seed multiplication process. In addition, the increasing middle-income groups have triggered the development of rice product diversification that create value added of rice products higher than conventional rice processing. Instantly processed rice product increasingly have prospect to grow along with the increasing couples who work and public awareness to better food management (waste food).

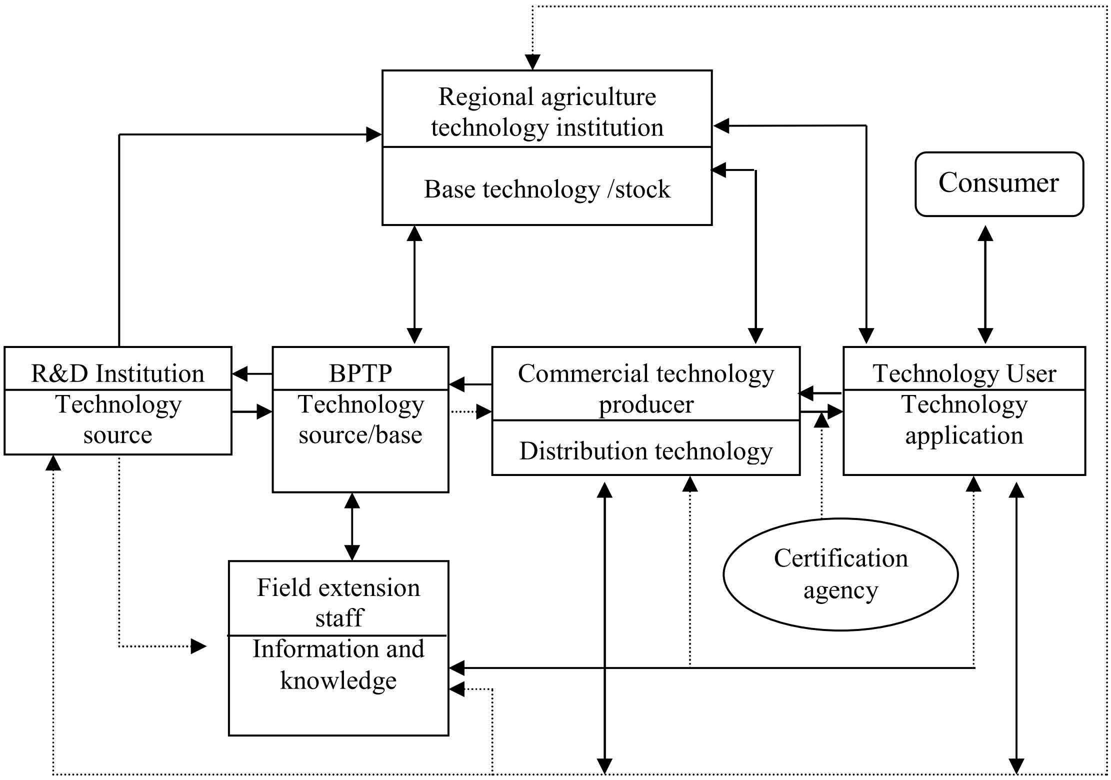

Figure 2. Commercial Agricultural Innovation System (IARRD, 2004)

Induced Innovation Model

This model emphasizes that technical changes in production lines is determined by the presence of abundant and relatively limited production factors. Empirical studies prove that the development of technology has very significant role in facilitating changes in the use of relatively abundant production inputs (so the price is relatively cheap) to the relatively limited production inputs (so the price is relatively expensive). For example, Ruttan (1998) showed that in Taiwan and Japan that have limited land, the suitable technology is high yielding varieties which capable to generate high productivity per hectare. Meanwhile, in United States, Canada, and Australia which have limitations in labor supply, the mechanization technology is a key to replace human labor.

METHODOLOGY

Data

The data used in this study is secondary data for the period 1974 – 2011. This time series data comes from the Central Bureau of Statistics, Ministry of Agriculture, Agricultural Research and Development Agency, the Food Agricultural Organization (FAO), and other relevant literature.

Analysis Method

Methods of analysis include: (a) descriptive analysis and (b) regression analysis using simultaneous equations system. Framework of simultaneous equations model are as follows:

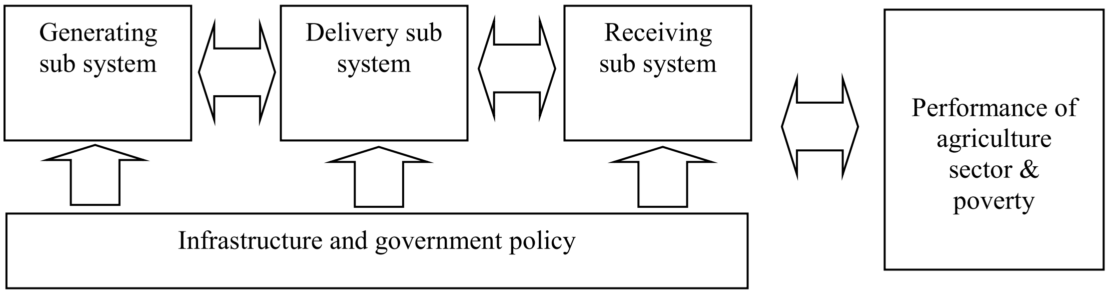

Figure 3. Framework of rice innovation system model

Overall, the constructed model has 29 equations consisting of 18 structural equations and 11 identities equation (in detail see Appendix 1). Identification of the model show that all equations are over-identified. The estimation method used 2SLS (two-stage least squares).

RESULTS AND DISCUSSION

Estimation result of Econometric model

Overall, estimation results of econometric model show good results. The coefficient of determination (R^2) is relatively high, with 16 equations have coefficient of determination above 0.70 and only 2 equations under 0.50. All explanatory variables has sign in accordance with constructed theory or hypothesis, but not all statistically significant. The influence of individual explanatory variables to endogenous variable were tested by t-test at significance level 10 percent. Meanwhile, F test used to determine jointly influence of explanatory variables on the endogenous variables. In general, jointly explanatory variables can significantly explain the endogenous variable as indicated by the value (Prob>F) <0.0001. Detailed discussion of this paper will focus on the performance of rice innovation system, the performance of the agricultural sector, and poverty.

Performance of Rice Innovation System

Technology Generating System

Technology generating system represented by research budget equation of BBPadi (Indonesian Center for Rice Research) and number of rice high yielding varieties released by BBPadi. Table 3 shows that the allocation of research budgets BBPadi positively and significantly influenced by the budget allocation of Indonesian Agency for Agricultural Research and Development (AARD) and domestic rice demand. Based on the elasticity values, the dynamics of domestic rice demand is more responsive affect the budget allocation of BBPadi compared to the budget allocation of AARD. In the short term, changes in domestic rice demand by 1 percent would increased BBPadi budget allocation by 6.59 percent, while the increase in AARD budget by 1 percent will increase BBPadi budget by 2.35 percent.

Table 3. Estimation results of budget BBPadi

Variable	Terms	Estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Intercept	-	-4646667	0.0932	-	-
AARD budget	ABDNR	0.019170	0.0705	2.352	-
Domestic rice demand	KBRS	0.250889	0.0087	6.587	-
R^2 = 0.29 F-hit= 6.85					

Budget dynamics of BBPadi have positive and significant effect on the number of improved varieties produced by BBPadi (Table 4). Large contribution of IRRI to the development of BBPadi statistically has no significant effect on the number of rice high yielding varieties produced by BBPadi. Similarly, the number of researchers and dummy BPTP has positive effect but not statistically significant.

Table 4. Estimation results of the number of rice varieties variable that released by BBPadi

Variable	Terms	Estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Intercept	-	-3.30922	0.5252	-	-
Real BBpadi budget	ARPR	4.916E-7	0.0637	0.070	-
Real IRRI budget	IRRI	0.000096	0.4386	0.409	-
Number of BBPadi researcher	PENP	0.007763	0.7856	0.083	-
Dummy BPTP	DBPTP	4.155659	0.2204	-	-
R^2 = 0.45 ; F-hit= 6.48					

Not significant effect of the three variables may be related to statistical issues (eg multicollinearity) and/or less suitable of proxy variables used. In fact, IRRI support and increasing number of researchers in BBPadi and presence of BPTP contributed greatly to productivity BBPadi research, particularly in the creation of high yielding rice varieties.

Technology Delivery System

Technology delivery is represented by equation of Agricultural Extension Number (PPL) and seed production of improved rice varieties. The presence of PPL in Bimas era contributed greatly to technological innovation dissemination and implementation, while seed production plays an important role in the provision of improved seed that can be accessed by farmers. Table 5 shows that PPL positively and significantly affected by the number of farmer groups and improved seed planting area. Due to the elasticity value, increase in number of farmer groups and improved seed planting area respectively by 1 percent leads to increasing number of PPL by 0.86 percent and 12.26 percent respectively.

Improved rice seed production positively and significantly affected by the price of improved seed and the number of high yielding rice varieties produced by BBPadi. planting area of improved rice seed and irrigated rice area also have positive effects but are not significant (Table 6). Based on the elasticity values, if the price of improved rice seed and the number of high yielding rice varieties produced by BBPadi increase by 1 percent, this will encourage the production of improved rice seed by 0.41 and 0.21 percent, respectively. The relatively low response of improved rice seed production to the number of high yielding rice varieties produced by BBPadi may be associated with fanaticism of certain farmers to certain improved rice varieties. For example, IR64 can last up to two or more decades as the most widely planted rice varieties by farmers.

Table 5. Estimation results of the agricultural extension number variable

Variable	Terms	Estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Extension budget	ExtR	7.334E-6	0.6744	0.018	-
Number of rice farmer group	KLPTN	0.088221	<.0001	0.856	-
improved seed planting area	UMV	0.894102	0.0515	0.265	-
R^2 = 0.98; F-hit= 556.03					

Table 6. Estimation results of the improved rice seed production variable

Variable	Terms	Estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Intercept	-	-599 280	0.0088	-	-
Improved seed price	HBNHR	77.76355	0.0449	0.410	-
Number of rice variety	VARP	9 545.936	0.0004	0.212	-
Improved rice planting area	UMV	13.46372	0.3042	0.269	-
Irrigated rice area	LSIRI	120.6740	0.1115	1.392	-
R^2 = 0.81; F-hit= 34.27					

Technology Receiving System

Technology receiving system represented by the equation of improved rice seed planting area (UMV) and local seed (UNMV). Dynamics of improved seed planting area positively and significantly influenced by the number of cooperatives and improved rice seed production; and negatively and significantly by price of improved rice seed. Rice price and the number of PPL have positive effect but these were not significant (Table 7).

The high elasticity value of cooperatives number as compared to other variables, indicated the importance of cooperatives as driving force for technology adoption by providing relatively complete the means of production and easily accessible to farmers. The significant effect of improved rice seed production on improved rice seed planting area also increasingly emphasized the importance of technology institutions multiplier to encourage adoption of the technology.

Table 7. Estimation results of the improved rice seed planting area variable

Variable	Terms	Estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Intercept	-	2145.220	0.0826	-	-
Rice price	HPADIR	1.694330	0.1511	0.231	-
Improved seed price	HBNHR	-0.94788	0.0176	-0.250	-
Number of PPL	PPL	0.052150	0.1208	0.176	-
Number of KUD	KUD	0.422389	0.0353	0.452	-
Improved seed production	BNH	0.003262	0.0999	0.163	
R^2 = 0.83; F-hit= 29.27					

The development of improved seed planting area has consequences on the rice seed planting area. Table 8 shows local varieties planting area is negatively and significantly affected by rice fields; while the production of improved seed also has negative effect but this is not significant. In fact, the development of irrigated rice field has very large influence on the reduction of local varieties area, except for certain areas where farmers are still fanatical on local varieties, such as in south Kalimantan. Based on the elasticity value, development of irrigated area by 1 percent, in the short term will reduce planting area of local rice varieties by -3.5 percent and and in the long term by -6.09 percent.

Table 8. Estimation results of the local varieties planting area variable

Variable	Terms	Estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Intercept	-	3940.61	0.0409	-	-
Improved seed production	BNH	-0.00011	0.8931	-0.049	-0.085
Irrigated rice field	LSIRI	-0.68539	0.0892	-3.500	-6.090
Lag local seed planting area	LUNMV	0.42537	0.0146	-	-
R^2 = 0.73; F-hit= 29.96					

Performance of the Agricultural Sector

Rice Production

Rice farming productivity is positively and significantly affected by the use of urea; while rainfall, improved seed and local seed planting area have positive effects that are not significant (Table 9). Based on elasticity values, the use of urea fertilizer and improved seed planting area are most responsive to the dynamics of rice farming productivity, compared to rainfall and local seed planting area. In general, low responsiveness of the variables that affect rice farming productivity may be associated with reduced growth rate of rice productivity. Sloping on rice productivity growth can be triggered by stagnation of technological innovation, agricultural inputs have reached the limit of optimal use, and soil fatigue (Adiningsih, 1997; Simatupang, et al, 2004; Fuglie, 2003). To this end, the use of new varieties that are responsive to fertilization is needed to push the rate of rice productivity growth.

Table 9. Estimation results of the rice productivity variable

Variable	Terms	estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Intercept	-	2.315996	0.3454	-	-
Urea application	UREA	0.013984	0.0678	0.072	0.515
Rainfall	CH	0.000220	0.2752	0.010	0.069
Improved seed planting area	UMV	0.000087	0.6235	0.016	0.111
Local seed planting area	UNMV	0.000142	0.7481	0.003	0.020
Rice productivity Lag	LPVTS	0.860055	<.0001	-	-
R^2 = 0.98; F-hit= 423.78					

Rice harvested area was positively and significantly influenced by the price of rice and irrigated area; while farm labor availability has positive but not significant effect. The prices of urea and corn has negative but no significant effect (Table 10). Based on the elasticity value, the response of the increase in rice price on harvested area is lower than expansion of irrigated area. In the short term, the increase in rice irrigated area by 1 percent would encourage increasing rice planting area by 0.87 percent and in the long run by 2.27 percent. Meanwhile, the increase in rice prices by 1 percent would only lead to an increase in the total harvested rice area in the short term by 12.14 percent and 12.37 percent in the long run.

Table 10. Estimation results of the rice harvested area variable

Variable	Terms	Estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Intercept	-	-1421129	0.1391	-	-
Real rice price	HPADIR	1170.460	0.0647	0.110	0.381
Real urea price	HUREAR	-194.216	0.5615	-0.014	-0.047
Irrigated rice area	LSIRI	792.6929	0.1043	0.609	2.112
Real corn price	HJGR	-389.459	0.4109	-0.033	-0.113
Farm labor	TKTP	16.08930	0.4972	0.032	0.111
Lag of harvested area	LLUARTP	0.711489	0.0002	-	-
R^2 = 0.96; F-hit= 114.76					

The low effect of urea price dynamics on rice harvested area may be related to the high dependency of farmers on urea. Although the urea prices increase, farmers will still attempt to use urea according to their habits. Similarly, the price of corn, although have negative effect, but if the supply of water is adequate, then the farmer will tend to continue to grow rice.

Farmer exchange rate

The performance of the agricultural sector is represented by farmers exchange rate, labor wage, and rice price. Table 11 shows that farmers exchange rates is positively affected by the value of rice production and farmer exchange rates lag of the previous year, while non-agricultural GDP negatively affect the exchange rate of farmers. The elasticity value shows that an increase in the value of rice production by 1 percent leads to an increase in NTP at 0.12 percent and 0.41 percent for short and long term, respectively. The opposite happens if non-agricultural GDP rises by 1 percent, NTP will decrease by 0.09 percent in the short term and 0.29 percent in the long term.

Table 11. Estimation results of the farmer exchange rate variable

Variable	Terms	Estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Intercept	-	28.27797	0.0015	-	-
Rice production value	PDBPADI	0.000272	0.1207	0.186	0.607
Non agricultural GDP	PDBL	-9.23E-6	0.1298	-0.155	-0.506
Lag NTP	LNTP	0.694045	<.0001	-	-
R^2 = 0.71; F-hit= 27.37					

Farm labor wage approached using cost for hoeing. Table 12 show that labor wage are positively and significantly influenced by the provincial minimum wage, rice production, and employment growth of crops. The strong influence of the provincial minimum wage related to the improvement of means of transport, so that the mobility of rural labor (including agricultural labor) is higher, especially for work in urban areas when the need for labor in rural areas is declining. The elasticity value shows that increase in provincial minimum wage by 1 percent will increase in labor wage by 0.66 percent; meanwhile, the increase in rice production and employment growth of crops respectively by 1 percent, will increased labor wage by 0.53 percent and 0.001 percent respectively.

Table 12. Estimation result of farm labor wage variables

Variable	Terms	Estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Intercept	-	-2491.79	0.0098	-	-
Provincial minimum wage	UMPR	0.022660	<.0001	0.659	-
Rice production	PRODP	0.000011	0.0012	0.526	-
Employment growth of crops	GTKTP	1981.200	0.5343	0.001	-
R^2 = 0.89; F-hit= 93.42					

Rice prices are positively and significantly affected by the price of grain and negatively but not significantly by domestic rice supply growth (Table 13). The elasticity values show that increase in grain prices by 1 percent, will lead to an increase in the price of rice in the short term by 0.51 and in the long run by 1.51 per cent.

The relationship between the price of grain and rice are not symmetrical. That is, if the price of rice increase, it will be slowly transmitted to the price of grain at the farm level and if the price of rice decrease it will be quickly transmitted to a decrease in the price of grain. However, the increase in grain prices rapidly transmitted to increasing rice price, while decrease in grain price will be transmitted to slow decrease in rice prices (Simatupang, 2001; Natawidjaja, 2001).

Table 13. Estimation results of rice price variable

Variable	Terms	Estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Intercept	-	-360.364	0.0445	-	-
Real rice price	HPADIR	1.060365	0.0001	0.508	1.510
Rice supply growth	GKBRS	-403.703	0.6056	-0.004	-0.012
Lag of real rice price	LHBERASR	0.663568	<.0001	-	-
R^2 = 0.87; F-hit= 72.30					

Poverty

One of the ultimate goals in the development process is the reduction in the number of poor population and likewise with efforts to increase rice production triggered by rice innovation system development. Table 14 shows that number of poor population are negatively and significantly affected by per capita consumption of rice, farmers exchange rate, and crop labor. The increase in rice consumption per capita can be used as an indicator of welfare improvement, because increase in rice consumption means increased public accessibility to the rice. The increase in farmer exchange rate and labor wage is indicator of increase in rural household income. Thus increase in all the three variables can be considered as factor to reduce number of poor population, especially in rural areas.

Table 14. Estimation results of poor population variable

Variable	Terms	Estimation	Pr > |t|	Elasticity	
				E_{sr}	E_{lr}
Intercept	-	157.8080	<.0001	-	-
rice consumption per capita	KONS	-0.59895	0.0002	-0.004	-
farmers exchange rate	NTP	-0.27122	0.0743	-1.180	-
Real wage	UPAHR	-0.00118	0.0119	-0.629	-
R^2 = 0.86; F-hit= 67.76					

Policy Impact Simulation

The simulations were performed to evaluate policy alternatives through ex-post simulation. Simulation were focused on the interaction of all components in rice innovation system. The simulations include, among others: (1) research budget of BBPadi and IRRI each rose by 10 percent and 3 percent, the number of researchers in BBPadi increase 3 percent, and the government purchase price (HPP) of grain rose by 15 percent; (2) BBPadi budget rose by 10 percent, the number of cooperatives (KUD) and improved rice seed production each rose 3 percent and 5 percent, and irrigated rice area and HPP grain each rose 3 percent and 15 percent; and (3) improved rice seed production rose by 5 percent, the number of cooperatives (KUD) and farmer groups each rose 3 percent and 5 percent, and irrigated rice area and HPP grain each rose 3 percent and 15 percent. Percentage changes that being used in the simulation was using the assumption of trend changes in each variable over the last decade.

Table 15 shows the performance improvement of technology generating system supported by increase in HPP grain was able to encourage increased paddy and rice production by 1.93 percent.

Increased rice production primarily driven by increase in productivity and harvested area respectively by 0.35 percent and 1.55 percent. In addition, HPP also help increase in the price of grain and rice respectively by 6.17 and 4.86 percent percent.

Increased rice production followed by increase in grain and rice price further contributes to the increased labor wage of rice farming and farmers exchange rate respectively by 1.01 and 3.03 percent. The increase in the two variables reinforced by the increase in per capita rice consumption will contribute to reducing the number of poor people in rural areas of by -11.37 percent. Moreover, crops GDP and agricultural GDP has also increased respectively by 4.65 percent and 2.26 percent.

Table 15. Impact simulation on rice innovation system

Variable	Base	Simulation 1	Simulation 2	Simulation 3
Budget of BBPadi	8071686	10.000	10.000	5.261
Number of rice variety	10.2027	8.575	6.991	2.047
Number of extension staff (PPL)	33893.4	0.506	1.027	4.947
Improved seed production	382307	3.548	5.000	5.000
Improved seed planting area	9239.2	2.028	4.097	4.840
Local seed planting area	962.7	-2.264	-24.140	-24.140
Irrigated rice area	4911.4	0.454	3.000	3.000
Rice productivity	47.7722	0.346	1.028	1.060
Rice harvested area	12471038	1.551	3.503	3.497
Paddy production	5.96E+08	1.929	4.613	4.642
Domestic rice production	35767605	1.930	4.614	4.641
Labor	23538.7	0.360	0.923	0.918
Labor wage	12806.4	1.014	2.413	2.426
Grain price	1284.3	6.167	2.460	2.429
Rice price	2698.4	4.858	1.230	1.201
Farmer exchange rate	99.7779	3.029	2.828	2.828
Rice consumption /capita	153.4	1.890	4.563	4.563
Number of poor population	23.7739	-11.371	-22.345	-22.458
Domestic rice supply	35901549	1.923	4.597	4.624
Crop GDP	139820	4.654	4.027	4.025
Agriculture GDP	287 944	2.260	1.956	1.955

The performance improvement of the rice innovation system through increased budget of BBPadi, improved seed production, and the number of cooperatives (KUD); then combined with an increase in paddy fields planting area and HPP (simulation 2), was able to encourage increased production of paddy and rice up to 4.61 percent. Relatively high increase in paddy and rice production depresses the price of grain and rice that only increase by 2.46 and 1.23 percent respectively or lower than the increase in simulation 1.

Increased rice production followed by increase in the price of grain and rice contributed to increase in labor wage of rice farming, farmer exchange, and consumption of rice per capita namely 2.41 percent, 2.83 percent, and 4.56 percent, respectively. An increase in all three variables contribute greatly to the reduction in the number of poor population in rural areas by -22.35 percent.

Simulation 3 focused on improving the performance of delivery and receiving system combined with creation of irrigated paddy area and increase in HPP grain. This simulation was able to encourage the highest increased in paddy and rice production than simulations 1 and 2, namely 4.64 percent. Relatively high increased rice production is resulting from increased paddy productivity and harvested area respectively by 1.06 and 3.50 percent.

Increased rice production followed by increase in grain and rice price lead to increased labor wage of rice farming, farmer exchange, and rice consumption of per capita. The increase in the three variables reduce the number of poor population in rural areas by -22.46 percent. Moreover, crops GDP and agricultural GDP also increased respectively by 1.96 percent and 4:03 percent.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Performance of rice innovation system consisting of technology generating, delivery, and receiving system is influenced by the following components: (a) BBPadi budget as part generating system was significantly and positively affected by AARD budget allocations and domestic rice demand. The number of high yielding rice varieties significantly and positively affected by budget allocation of BBPadi; (b) number of Agricultural Extension Staff (PPL) as the main actor in technology delivery system was significantly and positively affected by the number of farmer groups and the development of the rice planting area using improved seed. Production of improved rice seed was significantly and positively influenced by the price of improved seed and the amount of improved seed produced by BBPadi; and (c) rice planting area using improved seed as indicator of the level of technology adoption significantly and positively influenced by improved rice seed, number of cooperatives (KUD), and production of improved seed.

Performance of agriculture sector and poverty is influenced by several factors, namely: (a) paddy productivity was significantly affected by the use of urea, while harvested area significantly and positively influenced by the price of rice and irrigated rice area; (b) rice prices was significantly and positively influenced by the price of grain, but have asymmetrical relationship; (c) wage labor in rice farming was significantly and positively influenced by the regional minimum wage and rice production, while farmers exchange rate is influenced positively by rice production values and negatively by non-agricultural GDP, but not significantly; and (d) number of poor population in rural areas was negatively and significantly influenced by rice consumption of per capita, farmer exchange rate, and labor wage in rice farming.

Simulation results show that the integration of generating, delivery and receiving system accompanied with supporting policies (infrastructure development and output prices) has large contribution in promoting rice production and poverty alleviation.

Recommendations

Sufficient research budget allocation was required to improve the quality and maintain the sustainability of rice technology generating system. This effort would be optimal if offset by the availability of human resources, in particular researchers, according to the needs and capacity of the rice research institute; and build research networks among research institutions both domestic and abroad.

An increase in the number of PPL and the formation of farmer group institutions are needed to improve the quality of the distribution system and technology adoption at farm level. In addition, cooperatives (KUD) institutions also need to be revitalized and re-empowered to facilitate farmers' access to technology, capital assistance, and marketing of products.

To increase rice production that can benefit producers and consumers, it is necessary to improve rice innovation system performance as a whole, supported by infrastructure development as well as input and output price subsidies. However, if the government budget is limited, performance improvement of delivery systems, such as by revitalizing the performance of extension service and increase the availability of improved rice seed become the primary choice.

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Appendix 1. Model Specifications of Indonesian Rice Innovation System

Technology Generating System

$ARPR_t = a_0 + a_1ABDNR_t + a_2KONST_t + u_1$ .... (1)
Hypothesis: $a_1.\ a_2 > 0$
$VARP_t = b_0 + b_1ARPR_t + b_2IRRI_t + b_3PENP_t + b_4DBPTP_t + u_2$ .... (2)
Hypothesis: $b_1, b_2, b_3, b_4 > 0$
$ABDNR_t = ARPR_t + ARNPR_t$ .... (3)
$APBNPR_t = ABDNR_t + ExtR_t + APBNLR_t$ .... (4)

Technology Delivery System

$EXTR_t = c_0 + c_1APBNPR_t + c_2KONST_t + c_3LEXTR_{t-1} + u_3$ .... (5)
Hypothesis: $c_1, c_2 > 0; 0<c_3<1$
$PPL_t = d_0 + d_1EXTR_t + d_2KLPTN_t + d_3UMV_t + u_4$ .... (6)
Hypothesis: $d_1, d_2, d_3 >0$
$BNH_t = e_0 + e_1HBNHR_t + e_2VARP_t + e_3 UMV_t + e_4LSIRI_t + u_5$ .... (7)
Hypothesis: $e_1, e_2, e_3, e_4 >0$

Technology Receiving System

$UMV_t = f_0 + f_1HPADIR_t + f_2 HBNHR + f_3PPL_t + f_4KUD_t + f_5BNH_t + u_6$ .... (8)
Hypothesis: $f_1, f_2, f_3, f_4, f_5 >0$
$UNMV_t = g_0 + g_1BNH_t + g_2LSIRI_t + g_3LUNMV_{t-1} + u_7$ .... (9)
Hypothesis: $g_1, g_2 <0; 0<g_3<1$
$TOTMV_t = UMV_t + UNMV_t$ .... (10)
$LSIRI_t = h_0 + h_1DAIRI_t + h_2KONST_t + h_3LLSIRI_{t-1} + u_8$ .... (11)
Hypothesis: $h_1, h_2 >0; 0<h_3<1$

Rice Production Performance

$PVTS_t = i_0 + i_1UREA_t + i_2CH_t + i_3UMV_t + i_4UNMV_t + i_5LPVTS_{t-1} + u_9$ .... (12)
Hypothesis: $i_1, i_2, i_3, i_4 >0; 0<i_5<1$
$LUARTP_t = j_0 + j_1HPADIR_t + j_2HUREAR_t + j_3LSIRI_t + j_4HJGR_t + j_5TKTP_t + j_6LLUARTP_{t-1} + u_{10}$ .... (13)
Hypothesis: $j_1.\ j_3.\ j_5 >0; j_2.\ j_4 <0; 0<j_6<1$
$PRODP_t = PVTS_t * LUARTP_t$ .... (14)
$UREA_t = k_0 + k_1HUREAR_t + k_2BNH_t + k_3LUARTP_t + u_{11}$ .... (15)
Hypothesis: $k_1 <0; k_2, k_3 >0$
$HUREAR_t = l_0 + l_1UREA_t + l_2SPPKR_t + l_3LHUREAR_{t-1} + u_{12}$ .... (16)
Hypothesis: $l_1 >0; l_2 <0; 0<l_3<1$
$TKTP_t = m_0 + m_1UPAHR_t + m_2LUARTP_t + m_3LTKTP_{t-1} + u_{13}$ .... (17)
Hypothesis: $m_1<0; m_2>0; 0<m_3<1$
$NTP_t = n_0 + n_1PDBPADI_t + n_2PDBL_t + n_3LNTP_{t-1} + u_{14}$ .... (18)
Hypothesis: $n_1>0; n_2<0; 0<n_3<1$
$UPAHR_t = o_0 + o_1UMPR_t + o_2PRODP_t + o_3GTKTP_t + u_{15}$ .... (19)
Hypothesis: $o_1, o_2, o_3 >0$
$HPADIR_t = p_0 + p_1PRODP_t + p_2HBERASR_t + p_3RDPPK_t + p_4LHPADIR_{t-1} + u_{16}$ .... (20)
Hypothesis: $p_1<0; p_2, p_3 >0; 0<p_4<1$
$HBERASR_t = q_0 + q_1HPADIR_t + q_2GKBRS_t + q_3LHBERASR_{t-1} + u_{17}$ .... (21)
Hypothesis: $q_1 >0; q_2 < 0; 0<q_3<1$

$PDBPADI_t = PRODP_t * HPADIR_t$ .... (22)
$PDBBM_t = PDPADIR_t + PDBNP_t$ .... (23)
$PDBP_t = PDBBM_t + PDBNBM_t$ .... (24)
$BRSD_t = PRODP_t * fk$ .... (25)
$KBRS_t = BRSD_t + IMPBT_t + STOK_t – EKSPOR_t$ . ... (26)
$KONST_t = KBRS_t$ .... (27)
$KONS_t = KBRS_t/PDDK_t$ .... (28)

Poverty

$KDESA_t = r_0 + r_1KONS_t + r_2NTP_t + r_3UPAHR_t + u_{19}$ .... (29)
Hypothesis: $r_1, r_2, r_3 < 0$

Term Abbreviations:

ARPR	= Real BBpadi budget (000 Rp)
VARP	= number of improved rice varieties releashed by BBPadi
ABDNR	= Real AARD budget (000 Rp)
ARNPR	= Real research budget of non BBPadi (000 Rp)
EXTR	= Real Agriculture extension budget (000 Rp)
PPL	= Number of extension staff (PPL) (person)
APBNPR	= Agricultural sector state budget (000 Rp)
APBNLR	= Agriculture budget non AARD and extension service (000 Rp)
IRRI	= Real IRRI budget (000 US$)
PENP	= Number of BBPadi researcher (person)
DBPTP	= Dummy before and after establishment of BPTP
KBRS	= Domestic rice availability (ton)
KONST	= Domestic rice damand (ton)
KLPTN	= Number of rice farmer group (unit)
KUD	= Number of village cooperative Unit (KUD) (unit)
BNH	= Improved rice seed production (ton)
HBNHR	= Improved rice seed price (Rp/kg)
UMV	= Improved rice seed planting area (000 ha)
UNMV	= Local rice seed planting area (000 ha)
TOTMV	= Total of improved and local seed planting area (000 ha)
LSIRI	= Irrigated rice area (000 ha)
DAIRI	= Delta of real irrigation budget (000 Rp)
PVTS	= Rice productivity (kw/ha)
LUARTP	= Paddy harvested area (ha)
PRODP	= Paddy production (ton)
BRSD	= Domestic rice production (ton)
CH	= Rainfall (mm)
UREA	= Urea use (kg/ha)
HUREAR	= Real Urea price (Rp/kg)
HJGR	= Real corn price (Rp/kg)
TKTP	= Number of farm labor (000 person)
NTP	= Farmer exchange rate (tahun 2007=100)
UPAHR	= Wage of rice farming labor (Rp/day)
SPPKR	= Real fertilizer subsidy (000 Rp)
HPADIR	= Real grain price (Rp/kg)
HBERASR	= Real rice price (Rp/kg)

RHDPPK	= Ratio HPP grain and real Urea price
PDBPADI	= Rice production value (million Rp)
PDBBM	= Staple food GDP (million Rp)
PDBNBM	= Non staple food GDP (million Rp)
PDBP	= Agriculture sector GDP (million Rp)
PDBL	= Non agriculture sector GDP (million Rp)
UMPR	= real provincial minimum wage (Rp/month)
KONS	= rice consumption per capita (kg/ person)
PDDK	= Indonesian Population Number (person)
KDESA	= number of rural poor population (million person)
GKBRS	= growth of domestic rice supply
LEXTR	= lag of agriculture extension budget
LBNH	= lag of Improved rice seed production
LUNMV	= lag of local rice seed planting area
LLSIRI	= lag of Irrigated rice area
LPVTS	= lag of rice productivity
LLUARTP	= lag of paddy harvested area
LHUREAR	= lag of real Urea price
LTKTP	= lag of crop labor
LNTP	= lag of farmer exchange rate
LUPAHR	= lag of rice farming labor real wage
LHPADIR	= lag of real paddy price
LHBERASR	= lag of real rice price