

技術革新や研究開発から見た
インドネシア農業社会にお
ける社会的経済関係性
- 社会規範・統治機構と経済
合理性の両立に向けて

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Preface

This book is the final report on a research project for the Graduate School Of Humanities And Social Sciences (GSHSS) in Chiba University, whose title is "Socioeconomic Relations in Indonesian Agricultural Society on Technological Innovation and Research and Development - Toward Making a Norm and a Governance of a Society Compatible with an Economic Rationality -". In this project, each of two member graduate students has published two research articles and one paper for the proceedings of a symposium, and written a manuscript of his/her doctoral dissertation. In the Chapter 1 of the report, the entire research in this project is over-viewed, the obtained results are explained by relating each with the other, and a conclusion of the research is stated. In the Chapter 2 of the report, unpublished theoretical works in this project by two member graduate students are shown with a significant editing by their main academic supervisor. All editing for this book has been done by Fumihiro Kaneko, the leader of the project.

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Chapter 1

OVERVIEW, RESULTS AND CONCLUSION

FUMIHIRO KANEKO

1.1 INTRODUCTION

In this chapter, the development of the research project is outlined, results of the research are explained and a conclusion derived from those results is stated. The title of the project is "Socioeconomic Relations in Indonesian Agricultural Society on Technological Innovation and Research and Development - Toward Making a Norm and a Governance of a Society Compatible with an Economic Rationality -". The objective of the project is to expose the way how a norm and a governance of a rural agricultural community affects positively on the behavior of its members in pursuing their economic interest to improve their economic welfare through a technological innovation and a research and development. The project was started with five members in April 2014. Two graduate students took a leading role and engaged in surveys of numerical and/or descriptive data, a simulation of a business model, field studies in South Sulawesi of Indonesia and theoretical analysis. A student finds that the paddy rice production in uplands may become non-commercial after the market system is introduced there, and the incentive of farmers to continue it under such a circumstance comes from a strong motivation to preserve the traditional economic value of their real or intangible assets. Such a value has been formed in a close relation to the informal sector of the economic institution, in which trades of goods and services are made by agreements without a common knowledge of a formal rule. Therefore a new technology in paddy rice production can be adopted by farmers in such a circumstance only if it improves the traditional value of their assets in relation to the informal sector without discrediting a role of the traditional method of production as an insurance. Another student finds that an installment of a palm oil plantation integrated with research and development (R&D) and manufacturing of Polyhydroxyalkanoates (PHA) to a rural agricultural area can be feasible if a strong non-coercive peer effect is created by a lo-

cal community in an interaction with its members through a community signal. For an installment to be successful, agricultural activities in the area should not be doing very well and the marginal utilities of income for farmers should be sufficiently high. However, sustaining the business requires a significant break-through by R&D in both a reduction of production cost and an introduction of various new commercial products made of PHA, so that a palm oil plantation firm must maintain a sufficiently high level of average efforts by R&D workers. A norm and a governance of a community affect greatly on how to determine a traditional value on assets owned by farmers and how a community signal works for creating a peer effect. Hence it is concluded that a good norm and/or a good governance of a community are prerequisites for both an adoption of a new technology in paddy rice production and a success of a palm oil plantation business that is integrated with R&D and manufacturing of PHA at the same site.

This chapter is organized as follows. A summary of the contents of this chapter is described in the section 1.1. The objective of research and the flow of tasks for this project is described in the section 1.2. In the section , the methods used in this research and the chronological development of the research are described in detail and an assessment on the methodology invented in this project is given. The methods and the development of research for the sub-project on an adoption of new technologies by paddy rice farmers are described in the section 1.3.1, while those for the sub-project on a feasibility of an agribusiness with R&D in a rural area are described in the section 1.3.2. The common methodology used in both sub-projects and an assessment on it are in the section 1.4. In the section 1.5, the results of each sub-project are described in detail. The conclusion of this research is given in the section 1.6.

1.2 THE OBJECTIVE AND THE FLOW OF THE RESEARCH

The objective of this research project is to examine a role of a community on coordinating the actions of its members who pursue their economic interest under the circumstance that either a new technology for an agricultural production is made available or an opportunity to engage in a research and development activity is brought by an agribusiness firm. A hypothesis is made that a norm and/or a governance of a community in a rural agricultural area, which is considered to be an obstacle to a so-called "modernization" in the development economics, can affect positively on the economic behavior of its members in improving their economic welfare through taking such opportunities. The idea comes from an intuition that a traditional value respected by farmers in a rural agricultural community is a result of their constant efforts to improve their technology for agricultural production, hence is made of entrepreneurship. It is unlikely that this entrepreneurship has been related to a commercial production in the market system, but its spirit may be adapted to a change of economic system surrounding them.

The hypothesis is checked by a series of simulation, field studies and theoretical analysis. Due to the interests of graduate students among members of the project, two cases related to rural areas of South Sulawesi in Indonesia are studied extensively as mutually independent sub-projects.

One is an adoption of new technologies for a paddy rice production at uplands of South Sulawesi. It is well known that farmers there are very reluctant to adopt new technologies for paddy rice production. A survey on literature reveals 1) a standard argument for the reason in development economics is that farmers are short of capital to implement them, 2) a standard argument for that in socioeconomics is that farmers fail to achieve a coordination which is necessary to implement them, due to an insufficient and asymmetric information. A field study in this sub-project, with interviews on farmers at uplands of South Sulawesi, shows that none of them is significant in farmers' decision making, and that the technologies offered by their developers and the government are out of points in farmers' current management strategies for agricultural production. Following this result, decision theoretic models of a farmer with different focal economic sectors in an economic institution exposes the findings theoretically, which gives some theoretical background for them.

The other is a feasibility of installing a palm oil plantation that integrates R&D and manufacturing of Polyhydroxyalkanoates (PHA) at one location in a rural agricultural area of South Sulawesi. PHA is a class of plastics produced by a fermentation without any chemical use, as such it is fully biodegradable and biocompatible. A survey on literatures reveals that two major obstacles for a commercial production of PHA are 1) a high cost for carbon sources used in the fermentation process to produce PHA, 2) a lack of a variety in commercial products made of PHA which have high added values. Palm oil products are produced at a cheap cost and are very efficient as carbon sources in the production of PHA. By integrating a palm oil plantation with R&D and manufacturing of PHA at a site, the cost for carbon sources in a production and R&D of PHA is minimized. Even if R&D for PHA does not achieve a desired level of cost reduction and/or introduction of new commercial products, a vast variety of commercial applications of palm oil products are already available for both edible and non-edible use in oleo-chemical industries, so that the business can be salvaged even in the case of a bad luck. In this sub-project, at first, a hypothetical business model for a standardized operation is constructed and evaluated for its feasibility under a reasonable uncertainty in CPO and PHA prices. The result shows that the business can be feasible but requires a significant break-through in R&D to avoid getting out of business. A high level of efforts on R&D must be sustained constantly for a possible success of R&D. It is hypothesized that a force to achieve it is a combination of diligence and cooperation brought by a strong peer effect in a rural community. A field study in this sub-project tests this hypothesis through a community symposium and interviews afterward in a village of South Sulawesi suitably located for installing the business. As a result, the hypothesis is rejected. The descriptive data so obtained suggests that a peer effect in the village is created by a coercion from the

old generation, hence a non-coercive peer effect may not contradict the hypothesis. To examine this point, a theoretical model of interaction among a firm, a local community and farmer groups in the community is constructed and its equilibrium is analyzed. In this model, the community signals publicly to each farmer group the level of efforts for R&D taken by other farmer groups, and each farmer group decides its optimal level effort for R&D given the signal from the community. The result shows that the interaction can be organized so that the relevant information for installing the R&D division to the area of a community is shared by both the firm and the local community through an identification of the local community with the firm, and that either the firm can guarantee the average level of efforts for a smooth operation of R&D by controlling its wage payment scheme or the firm comes to know that the installment of R&D is budget infeasible.

1.3 THE METHODS AND THE DEVELOPMENT OF THE PROJECT

The theme of the research is to prove that a norm and/or a governance of a local community in a rural area have a positive role in an enhancement of innovation thorough an adoption of a new technology for agriculture and an engagement on research and development activities for agribusiness. It consists of two separate sub-themes, each of which is extensively studied by a graduate student. One of them is to identify the socioeconomic reason why farmers in the uplands of South Sulawesi are reluctant to adopt new technologies promoted by their developers and the government. Mangilep Muhammad Agung Ady has taken charge of this line of research. The other is to assess a feasibility of installing a palm oil plantation integrated with R&D and manufacturing of PHA. Fitriwati has taken charge of this line of research.

The project was started with 5 members. Their identities and roles in the project are as follows.

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Director and Organizer of the Project, Direction of Simulation, Field Study in the Chiba Prefecture of Japan, Building and Analysis of Theoretical Models.

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Rie Ono Ph.D.

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Fitriwati M.A.

Graduate Student in the Ph.D. Program for Social Sciences, Graduate School of Humanities and Social Sciences, Chiba University,
Survey, Simulation, Field Study, Construction and Analysis of a Theoretical Model for the Sub-theme Related to Research and Development.

Mangilep Muhammad Agung Ady M.A.

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Survey, Field Study, Construction and Analysis of a Theoretical Model for the Sub-theme Related to Adoption of New Technologies.

In the following, the methods and the development of this project is explained for each line of research with a different sub-theme, then the common methodology for them is explained and assessed.

1.3.1 THE METHODS AND THE DEVELOPMENT OF THE SUB-PROJECT ON ADOPTION OF NEW TECHNOLOGIES IN A PADDY RICE PRODUCTION

For the sub-project about an adoption of new technologies for paddy rice production in uplands of South Sulawesi, at first, Mangilep surveyed literatures extensively from April 2014 and September 2014. The survey was to list up new technologies that could be implemented at uplands and to identify major explanations by economists for the reason why many farmers in Indonesia had been reluctant to adopt new technologies for paddy rice production though doing so was advocated to increase their income. First, he found a variety of technologies such as a genetic control of production, a planned control of weeds and soil fertility, an integration in farming and crop management, a method of intensification in planting and a mechanization with small equipments. He then sought to identify a standard explanation in development economics and that in sociological economics. The findings of this survey is elaborated in Mangilep (2015b). In short, he finds that the standard explanation in development economics is a shortage of capital for farmers due to a limited access to loans from financial institutions, and that in sociological economics is an insufficient and asymmetric information on new technologies for farmers. In relation to both explanations, a role of middlemen who are a seed producer and/or seller, a grain trader, a rice mill owner and a private loaner is emphasized in controlling financial needs of paddy rice farmers and information on new technologies such as new varieties of rice and new equipments.

To check the reality of these explanations, a comparative study on a motivation to adopt new technologies for paddy rice production between the Chiba prefecture in Japan and the uplands of South Sulawesi in Indonesia was planned. In this plan, Kaneko collects a descriptive data about an adoption of new technologies by farmers in the Chiba prefecture,

then Mangilep builds several theoretical models to rationalize the findings in the data, whose validity is checked by the descriptive data about an adoption of new technologies by farmers collected by Mangilep in South Sulawesi. To collect meaningful descriptive data, field studies in both the Chiba prefecture and South Sulawesi were planned.

From October 2014 to February 2015, Kaneko performed a field study on that theme in the Chiba prefecture. The method was a free-style interview in which an interviewed farmer took an initiative in the conversation and talked freely about the topic he chose from the list of six topics prepared by Kaneko in a sheet. These topics are 1) an experience of a significant change in the production method of paddy rice, with focuses on the social and economic environment surrounding the farm before it was done, the expectation on the influence of the change on the management of the farm at that time, the information about the nature of the new method or technology to be implemented before it was done, the way how the change was carried out, the result of the change and the assessment of it on the expectation held before the change etc., 2) deciding factors in motivating a change in the production method and the way how the consciousness and feeling about the change was evolved, 3) physical and/or financial aids for the change of the production method such as a supply of labors and/or equipments and special loans or grants, with focuses on the way how they were made available and the assessment of their usefulness, 4) the experience of engaging in activities which aim to improve the technology for paddy rice production, directly or indirectly, with focuses on the way how they were made available, the reason why the farmer has decided to participate in them, and the assessment of its usefulness, 5) the way how the motivation to continue an agricultural production is maintained and the way how it is related to an attitude toward adopting new technologies, with focuses on the consciousness and feelings for them, 6) the expectation to change a production method and/or to introduce a new production method in the future and the way how it is rationalized under the current state of the management of the farm and the information about the change and/or the new method, or the reason why such an expectation cannot be rationalized under the current circumstance surrounding the farm. After contacting the farmer in person by phone and obtaining an acceptance of getting interviewed, Kaneko sent a package of documents for the field study by mail, and by fax on the request by the farmer. The package included a letter to introduce Kaneko, a letter to introduce Mangilep, a guidance for the interview, the sheet of topics and the prescribed sheet for external attributes of the interviewed farmer. It had been sent to the Farmer at least a week before the interviews was taken place. Each interview started with filling in a sheet, prescribed by Kaneko, about external attributes of the interviewed farmer. Specifically, this sheet asks the scale of the paddy rice production, that of the entire agricultural production, the size of the firm, the ratio of income from the agricultural production to the entire income, the style of a farm management, varieties of agricultural products that are currently produced and the ratio of income from the paddy rice production to the income from the entire agricultural production. Kaneko promised in the guidance for the interview that the information obtained in the sheet would be used only to characterize the interviewed

Chapter 2

THEORETICAL STUDIES

FUMIHIRO KANEKO
MANGILEP MUHAMMAD AGUNG ADY
FITRIWATI

2.1 INTRODUCTION

FUMIHIRO KANEKO

In this chapter, the theoretical studies conducted in sub-projects are reported. These works are described extensively in the chapter 4 of Mangilep (2016b) and the chapter IV of Fitriwati (2016a), but both of them are filled with English errors and bad writings of mathematical expressions. They are reproduced in this chapter with a thorough editing by Kaneko. All references to the works of other researchers are omitted, as such a section in the draft of Fitriwati (2016a) about a relation to existing research results is eliminated entirely. All inadequate and/or superfluous contents, such as implications to a policy making by the government and the models without a stochastic population dynamics in the draft of Mangilep (2016b) and the appendix showing an numerical example for a wage payment scheme by a firm in Fitriwati (2016a), are omitted. Many superfluous figures are also omitted. All errors in mathematical expressions are corrected. Though both works are based on the findings in the field studies of Mangilep and Fitriwati in South Sulawesi of Indonesia, any reference to the regional characteristics of South Sulawesi is eliminated since the theoretical studies are to find implications which are universally applicable once the conditions for them are met. As a result, this chapter consists of genuine theoretical studies conducted by Kaneko, Mangilep and Fitriwati, excluding this section.

The chapter is organized as follows. A brief comment on the contents of this chapter is written in 2.1. The description of expository theoretical models for an adoption of new technologies by paddy rice farmers with model cases for an adoption is in 2.2, while 2.3 consists of the description of and the solution for the model of interaction among a firm, a local community and farmer groups in the community in the presence of an

opportunity that farmers are employed for R&D of an agribusiness installed in the area of the community without giving up their agricultural production. In each of 2.2 and 2.3, the structure of subsections follows those in the chapter 4 of Mangilep (2016b) and the chapter IV of Fitriwati (2016a), except that all contents of 4.4 in the former and of 4.2 in the latter are eliminated.

2.2 A DECISION THEORETICAL EXPOSITION OF THE RELATIONSHIP BETWEEN FARMERS' INCENTIVE FOR PADDY RICE PRODUCTION AND ECONOMIC INSTITUTION TOWARD AN ADOPTION OF NEW TECHNOLOGY

MANGILEP MUHAMMAD AGUNG ADY
FUMIHIRO KANEKO eds.

2.2.1 INTRODUCTION

In this section, a relationship between farmers' agricultural productions and a rural economic institution is exposed theoretically. The objective of this theoretical exposition is to explain a relationship between agricultural productions and a rural economic institution in which farmers make a sophisticated decision on associating various part of their agricultural productions with different economic systems. The expository decision model is based on a role of paddy rice production. A paddy rice production can be associated with either the formal sector or the informal sector of the economic institution. The purpose of a paddy rice production can be not only for a commercial one but also for other purposes such as preserving the agricultural land and preserving the asset value for the family of a farmer. Farmers have their own focal sectors, on which they choose which sector their paddy rice production should be associated with, either the formal sector or the informal sector, or both of them. A farmer's decision criterion for an adoption of new technologies in the paddy rice production is provided for each case of his focal sector, and decision criteria are proposed for switching of focal sectors. It is assumed that farmers produce rice every year and that they also produce other agricultural products such as water buffalo, red onion and plantation products. They manage their agricultural productions with a decision based on their knowledge of the agricultural production and the market information. The relevant information for making such a decision varies with their focal sector. Different focal sector gives different informational criterion to farmers.

Farmers' willingness to adopt new technologies depends on their incentive. It is a profitability of a paddy production if the production is associated with the formal sector, or is a contribution to the family's economic welfare if it is associated with the informal

sector. If the degree of incentive is at or beyond a critical level, farmers will adopt new technologies. The adoption of new technologies is judged on a series of information about benefits to adopt ones. Let $Q \in \mathbb{R}$ be an index of incentive toward an adoption of new technologies for a paddy rice production. Let a vector $a \in \mathbb{R}^m$ represent a profile of either productions or stocks of agricultural products at the end of a period. It is assumed that the incentive index is determined by a n -profiles of either productions or stocks in the $(n - 1)$ past periods and the current period. This relation is represented by a function f , hence $Q = f(a_{t-(n-1)}, a_{t-(n-2)}, \dots, a_t)$. Let us assume that $f(0_n) = 0$ when $0_n = \underbrace{(0, \dots, 0)}_n$.

Let Q^* be the threshold degree of incentive index at which new technologies are adopted and a^* be the n -profiles that achieves Q^* , $Q^* = f(a^*)$.

It is further assumed that $f(a_{t-(n-1)}, \dots, a_0)$ to be either $\frac{1}{n} \sum_{k=0}^n I(a_{t-k})$ or $\min\{I(a_{t-k}) | k = 0, \dots, n - 1\}$ where $I(a)$ represents an index of the information relevant for adoption of new technologies, which is a function of a profile of either productions or stocks, depending on the focal sector of a farmer.

2.2.2 EXPOSITORY DECISION MODEL FOR THE CASE THAT A FARMER'S FOCAL SECTOR IS THE FORMAL ONE

This subsection exposes how a farmer makes a decision to adopt new technologies when his focal sector is the formal one. The model makes the profitability of a commercial production to dominate others in information. Farmers will adopt new technologies for paddy rice productions led by an experience of commercial production of rice and other crops such as red onion and plantation products, and cattle like water buffaloes. If farmers see a positive trend of return from paddy rice production in the long-run and that trend is higher than the maximum returns from production of other crops and cattle, they will adopt new technologies on a paddy rice production.

Let c represents an agricultural product that can be trade in the market. There are four such products, rice (r), red onion (o), water buffalo (b) and plantation products (p). Hence $c \in \{r, o, b, p\}$. Let $a_t \in \mathbb{R}_+^4$ be a vector of produced amounts of these four agricultural products in period t . Let R_c be the return for the commercial production of crop c . It is assumed that missing data by no commercial production is substituted with the dummy return with the market price index in that period and the constant marginal cost of production for a standard commercial production, for each crop. Let p_c be the market price index of c and e_c be the constant marginal cost for a standard commercial production of c . If the crop c is not produced commercially, substitute R_c with $\frac{p_c - e_c}{e_c}$. It is also denoted as R_c .

Information about the return on a commercial production of paddy rice is defined by $I_r \equiv \frac{R_r}{\max\{R_o, R_b, R_p\}}$. Information about the return on a crop c other than paddy rice is defined similarly.

In each period t , R_c^t denotes the return on a commercial production of crop c in that

period. In case that the crop c is not produced commercially in period t , it is estimated with the market price index and the constant marginal cost of a standard commercial production in period t . Information about the return on a commercial production of crop c in period t is calculated with the use of R_c^t 's, and is denoted as I_c^t . It is assumed that the market price index and the marginal cost of commercial production for each crop is constant through time, so that R_c^t and I_c^t are determined by a profile of productions in period t .

Let \bar{Q}_r^t be defined by either $\frac{1}{n} \sum_{k=0}^{n-1} I_r^{t-k}$ or $\min\{t-k | k=0, \dots, n-1\}$, exclusively. Then \bar{Q}_c^t for $c \neq r$ is defined similarly.

Let $\hat{a}_{r,t}^* \equiv (a_{r,t-(n-1)}^*, \dots, a_{r,t}^*)$ be n -profiles of productions up to period t such that all crops are commercially produced in every period without introducing any new technology with $\min\{I_r^{t-k} | k=0, \dots, n-1\} = Q^*$ where $Q^* \equiv \max\{I_c^{t-k} | c \neq r \text{ and } k=0, \dots, n-1\}$. It is assumed that $a_{r,s}^*$ can be taken constantly for all s and denoted it as a_r^* . Then $\hat{a}_{r,t}^*$ does not depend on t , and it is denoted as \hat{a}_r^* . The profile a_r^* represents a model case of commercial agricultural production whose repetition makes a situation in which a paddy rice production dominates those of other crops in relative superiority. It is also assumed there is no uncertainty for achieving the production target a_r^* .

Assume that, if $\bar{Q}_r^t > \max\{\bar{Q}_c^t | c \neq r\}$ in period t , the farmer accepts to adopt the profile of productions a_r^* as the production target for the next year. Then, in period $(t+1)$, the n -profiles of productions becomes $\hat{a}^{t+1} = (a_{t-(n-2)}, \dots, a_t, a_r^*)$. If $\bar{Q}_r^{t+1} > \max\{\bar{Q}_c^{t+1} | c \neq r\}$ in period $(t+1)$, the farmer continues to adopt a_r^* as the production target for the next year. In period $(t+2)$, the n -profiles of productions becomes $\hat{a}^{t+2} = (a_{t-(n-3)}, \dots, a_t, a_r^*, a_r^*)$. By continuing in this way, if $\bar{Q}_r^{t+k} > \max\{\bar{Q}_c^{t+k} | c \neq r\}$ for all $k=0, \dots, n-1$, the n -profiles of productions in period $(t+(n-1))$ becomes \hat{a}_r^* . Since $Q^{t+(n-1)} = Q^*$, the farmer adopts new technologies for a paddy rice production in period $(t+n)$. If those technologies secure that $I_r^{t+n} \geq I_r^{t+(n-1)}$, the farmer will continue to adopt new technologies for paddy rice production regardless of a comparison between \bar{Q}_r^{t+n} and $\max\{I_c^{t+n} | c \neq r\}$, since the improvement of I_c^{t+n} for $c \neq r$ can be brought only by adopting new technologies for paddy rice production if it exists.

A farmer may switch his focal sector from the formal one to the informal one, when he is inclined to seek a satisfaction from agricultural activity, rather than monetary income. The decision for switching is triggered by getting jobs other than agriculture for his income source, and a switch will be made if the income from these jobs become more than enough to maintain his family's cost of living but he has no intention of giving up his agricultural activity.

2.2.3 EXPOSITORY DECISION MODEL FOR THE CASE THAT A FARMER'S FOCAL SECTOR IS THE INFORMAL ONE

This subsection exposes how a farmer makes a decision to adopt new technology when his focal sector is the informal one. Farmers may adopt new technologies for their paddy rice productions in pursuing economic welfare of their families beyond covering the costs of children education and health care. In relation to the informal sector, farmers' perception of life is greatly influenced by social customs of the society to which they belong, which has been developed by social interactions of their ancestors in the society for a long period of time. Such interactions might have been quite complex in their nature, but they are based on a postulate that an agricultural production should be sustained as much as possible. Hence farmers would like to keep their agricultural production as long as the economic environment supports it. It is assumed that the center of agricultural production is paddy rice, with a breeding of water buffaloes being the second important activity. It is assumed that, in order to maintain their rice stocks for a satisfactory economic welfare under population and productivity shocks, farmers improve continuously their traditional paddy rice production both in quality and in quantity. They will try to adopt new technologies only by insuring that action with their traditional paddy rice production. It is expected that most of those farmers who can do it are the big land owners. Many small-scale farmers would not be able to maintain the stock of agricultural products at a sufficient level for yielding a decent economic welfare, and some would choose to leave their home villages and seek other jobs at nearby villages and cities. The rest have no other options than increasing their commercial productions to make a living by monetary income, so that they would switch their focal sector to the formal one.

Let \bar{Q} represent to be an index for economic welfare of a farmer's family. Three thresholds on \bar{Q} are introduced in the increasing order of scale as follows.

- I' = the threshold below which a farmer commercializes his paddy rice production.
- \underline{I}' = $\left\{ \begin{array}{l} \text{the threshold where farmer is interested in adopting new technology} \\ \text{for the rice production.} \end{array} \right.$
- \bar{I}' = $\left\{ \begin{array}{l} \text{the threshold where adopting new technologies for the rice production} \\ \text{becomes fully confident.} \end{array} \right.$

An adoption of new technologies makes sense only if $\bar{Q} > \underline{I}'$, since it makes the degree of confidence on adopting new technologies to be positive. If $\bar{Q} \leq \underline{I}'$, an adoption of new technologies is never considered. The degree of confidence on adopting new technologies becomes full (namely, 1) only if $\bar{Q} \geq \bar{I}'$.

Social welfare cost in terms of money is denoted as S . Economic welfare in relation to the informal sector is determined by the way how the agricultural community to which the farmer belong follows their customary obligations. Only rice (r) and water buffalo (b) can

contribute to economic welfare in relation to the informal sector. A paddy rice production is important for farmers' life as an activity to secure their main food and as a part of their tangible and/or intangible traditional assets. A breeding of water buffalo is important because they are used in traditional funeral ceremonies. A proper conduct of a funeral ceremony is considered to be very important in their agricultural community. Farmers have no interest in producing rice and/or water buffalo commercially if the economic welfare after their sales to cover S is acceptable to them.

There are $(n + 1)$ -grades on the quality of stocked rice indexed by numbers $0, \dots, n$. The larger the index numbers is, the higher the quality of rice is. Stocked rices and a harvested rice are characterized by the quality and the quantity. Let $Q_r^t \in \mathbb{R}_+^{n+1}$ be the initial stock vector of rice in period t . Its k -th component is the amount of stocked rice with the quality k , and is denoted as $Q_r^{t,k}$. At the beginning of the period, a farmer sells rice in the market in order to cover the social welfare cost S . A farmer sells the lowest quality rice at first. If the sales revenue is not enough to cover S , he sells the rice with a quality one rank higher, and so on. The sales price of rice is the minimum market price in the period, which is random and is denoted as \underline{P}^t . After the sales of rice is finished, the farmer's family start to consume rice from its stock. They prefer to consume rice with quality as high as possible. Then the paddy rice production starts. Before adopting new technologies, the rice production is performed with a traditional method. However, an experiment of new technologies is always feasible by allocating a small part of his land and effort for it. The paddy rice is harvested at the end of the period. All harvested rices produced with the same method has the same random quality and quantity. They are added to the stock of rice, and all old rices in the stock except that with the lowest grade quality have a vintage down, which is a drop of the quality by one grade. This determines the initial stock vector of rice in period $(t + 1)$.

A technology of paddy rice production depends endogenously on labor for the rice production, the total service of agricultural land owned or managed by a farmer, and the standard per capita productivity of rice production with the method. It is also influenced exogenously by a noise factor, such as a climate condition. All of these factors are potentially stochastic, though the total service of agricultural land is assumed to be constant through time with a traditional method. The labor for the rice production is made random by a stochastic population dynamics. The per capita productivity is assumed to be a function of the labor for the paddy rice production and the total service of agricultural land, hence it is randomized by a stochastic population dynamics. With new technologies in an experiment, the total service of agricultural land becomes random too. Such an experiment also makes random effects on both quality and quantity of harvested rice.

Let $\tilde{\ell}_r^t$ denote the random population of labor for the rice production in period t . It is assumed that the population follows a random walk with reflection barriers $\underline{\ell}$ and $\bar{\ell}$ ($\underline{\ell} < \bar{\ell}$).

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