

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.

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

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 \tilde{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 $\bar{\ell}$ ($\underline{\ell} < \bar{\ell}$).

Let p be the stationary probability that one working person in the family dies in a period. Let α be a stationary probability that one person who can work on fields is added to the family. If $\underline{\ell} < \ell_r^{t-1} < \bar{\ell}$,

$$\tilde{\ell}_r^t = \begin{cases} \ell_r^{t-1} - 1 & \text{with the probability } p(1 - \alpha), \\ \ell_r^{t-1} & \text{with the probability } p\alpha, \\ \ell_r^{t-1} + 1 & \text{with the probability } (1 - p)\alpha. \end{cases}$$

If $\ell_r^{t-1} = \bar{\ell}$, one person is taken out of the family if no member of the family dies, so that $\tilde{\ell}_r^t = \bar{\ell} - 1$ with probability 1. If $\ell_r^{t-1} = \underline{\ell}$, at least one person is brought into the family with two if a member of the family dies, so that $\tilde{\ell}_r^t = \underline{\ell} + 1$ with probability 1.

Let $\tilde{\sigma}^t$ denote the potentially random total service of agricultural land owned or managed by a farmer in period t . With a traditional method, it is kept constant at $\bar{\sigma}$. Let $q_r = \zeta(\ell_r, \sigma)$ be the function that determines the per capita productivity of a paddy rice production by a labor for the production and a total service of the agricultural land. Given any σ , it is assumed that $\zeta(\cdot, \sigma)$ is concave and maximized at $\ell_r^*(\sigma)$. It is also assumed that $\zeta(\ell_r, \cdot)$ is increasing for any given ℓ_r and $\ell_r^*(\sigma)$ is increasing with respect to σ . The random per capita productivity for paddy rice production in period t is denoted as \tilde{q}_r^t , and is determined by $\tilde{q}_r^t = \zeta(\tilde{\ell}_r^t, \tilde{\sigma}^t)$. Let $\tilde{\epsilon}^t$ denote an exogenous random noise factor on paddy rice production, which includes a climate condition and a natural disaster.

A technology of paddy rice production is represented by a production function $f : \mathbb{R}^4 \rightarrow \mathbb{R}_+^{n+1}$. Its variables are a labor on the rice production (ℓ_r), a total service of agricultural land owned or managed by a farmer (σ), a per capita productivity of rice production (q_r) and an exogenous noise (ϵ). The components of its value are all zero except for one component. Let $k(\ell_r, \sigma, q_r; \epsilon)$ be the quality grade of produced rice corresponding to $(\ell_r, \sigma, q_r; \epsilon)$. Let $y(\ell_r, \sigma, q_r; \epsilon)$ be the quantity of produced rice corresponding to $(\ell_r, \sigma, q_r; \epsilon)$. A production function for a paddy rice production is given by

$$f_k(\ell_r, \sigma, q_r; \epsilon) = \begin{cases} y(\ell_r, \sigma, q_r; \epsilon) & \text{if } k = k(\ell_r, \sigma, q_r; \epsilon), \\ 0 & \text{otherwise,} \end{cases}$$

for all $k = 0, \dots, n$.

A process of change in the rice stock in a period t with a traditional paddy rice production is as follows. It is Q_r^t at the beginning of period t . Let $k(\underline{\tilde{P}}^t, Q_r^t)$ be the highest grade of quality for the rice sold for covering S . The rice stock after the sales of low quality rice, denoted as $\tilde{Q}_r^t(\underline{\tilde{P}}^t, Q_r^t)$, is given by

$$\tilde{Q}_r^{t,k}(\underline{\tilde{P}}^t, Q_r^t) = \begin{cases} 0 & \text{if } k < k(\underline{\tilde{P}}^t, Q_r^t), \\ \sum_{k'=0}^{k(\underline{\tilde{P}}^t, Q_r^t)} Q_r^{t,k'} - \frac{S}{\underline{\tilde{P}}^t} & \text{if } k = k(\underline{\tilde{P}}^t, Q_r^t), \\ Q_r^{t,k} & \text{if } k > k(\underline{\tilde{P}}^t, Q_r^t), \end{cases}$$

for all $k = 0, \dots, n$. At this moment, if a farmer cannot cover S by sales of entire stocked rice, he turns his focal sector to the formal one in the next period. Suppose that is not the case. It is assumed that each family member consumes θ units of rice so that total family consumption of rice in quantity is $\theta \times \tilde{\ell}_r^t$. If Q_r^t is sufficiently rich, it will be the case that $\sum k = 0^n \tilde{Q}_r^t(\tilde{P}^t, Q_r^t) > \theta \times \tilde{\ell}_r^t$. If this is not the case, the farmer turns his focal sector to the formal one in the next period. Suppose that the farmer's family does not starve. Let $k(\tilde{l}_r^t, \tilde{Q}_r^t)$ be the lowest grade of rice quality that is consumed by the family of a farmer, where $\tilde{Q}_r^t(\tilde{P}^t, Q_r^t)$ is abbreviated as \tilde{Q}_r^t . The rice stock after the self-consumption, denotes as $\tilde{\tilde{Q}}_r^t(\tilde{\ell}_r^t, Q_r^t)$ is given by

$$\tilde{\tilde{Q}}_r^{t,k}(\tilde{\ell}_r^t, Q_r^t) = \begin{cases} 0 & \text{if } k > k(\tilde{l}_r^t, \tilde{Q}_r^t), \\ \sum_{k=k(\tilde{\ell}_r^t, \tilde{Q}_r^t)}^n \tilde{Q}_r^{t,k} - \theta \tilde{\ell}_r^t & \text{if } k = k(\tilde{\ell}_r^t, \tilde{Q}_r^t), \\ \tilde{Q}_r^{t,k} & \text{if } k < k(\tilde{\ell}_r^t, \tilde{Q}_r^t), \end{cases}$$

for all $k = 0, \dots, n$. At the end of period t , harvested rice from a traditional production is added to the rice stock, so that rice stock at the end of period t is $\tilde{\tilde{Q}}_r^t(\tilde{\ell}_r^t, Q_r^t) + f(\tilde{e}l_r^t, \bar{\sigma}, \tilde{q}_r^t; \tilde{\epsilon}^t)$. Then the old rices suffers a vintage down, so that the initial rice stock in period $(t+1)$, Q_r^{t+1} , is given by

$$Q_r^{t+1,k} = \begin{cases} \tilde{\tilde{Q}}_r^{t,0} + \tilde{\tilde{Q}}_r^{t,1} & \text{if } k = 0, \\ y(\tilde{\ell}_r^t, \bar{\sigma}, \tilde{q}_r^t; \tilde{\epsilon}) + \tilde{\tilde{Q}}_r^{t,k(\tilde{\ell}_r^t, \bar{\sigma}, \tilde{q}_r^t; \tilde{\epsilon})+1} & \text{if } k = k(\tilde{\ell}_r^t, \bar{\sigma}, \tilde{q}_r^t; \tilde{\epsilon}), \\ \tilde{\tilde{Q}}_r^{t,k+1} & \text{if } k \neq 0, k(\tilde{\ell}_r^t, \bar{\sigma}, \tilde{q}_r^t; \tilde{\epsilon}), \end{cases}$$

where $\tilde{\tilde{Q}}_r^t(\tilde{\ell}_r^t, Q_r^t)$ is abbreviated as $\tilde{\tilde{Q}}_r^t$ and $\tilde{\tilde{Q}}_r^{t,n+1} \equiv 0$.

Let $u_r : \mathbb{R}^{n+1} \rightarrow \mathbb{R}$ be a basic utility function for a rice stock at the end of a period. The expected utility for rice stock at the end of period t is $U_r(\tilde{\ell}_r^t, \bar{\sigma}, \tilde{q}_r^t, \tilde{P}^t, \tilde{\epsilon}^t; Q_r^t) = E[u_r(\tilde{\tilde{Q}}_r^t(\tilde{\ell}_r^t, Q_r^t) + f(\tilde{\ell}_r^t, \bar{\sigma}, \tilde{q}_r^t; \tilde{\epsilon}^t))]$.

A funeral ceremony must be conducted properly by a farmer when a person in his family dies. When a family member dies, one water buffalo is sacrificed for his/her funeral. Let $\bar{q}_b(\sigma)$ be the maximum number of water buffaloes needed for field works with the total service of agricultural land σ . It is assumed that the number of water buffaloes bred with the total service of agricultural land σ , denoted as $q_b(\sigma)$, is equal to $\bar{q}_b(\sigma) + 1$. Let U_f be the utility from conducting a proper funeral, and c_b be the constant marginal cost of breeding a water buffalo in terms of utility. Then a farmer's utility from water buffalo breeding with a traditional paddy rice production is $p(U_f - c_b \bar{q}_b(\bar{\sigma})) - (1-p)c_b(\bar{q}_b(\bar{\sigma}) + 1)$, which is constant through time.

The spot economic welfare of a farmer with a traditional paddy rice production in period t , denoted as V^t , is given by

$$V^t \equiv E[u_r(\tilde{\tilde{Q}}_r^t(\tilde{\ell}_r^t, Q_r^t) + f(\tilde{\ell}_r^t, \bar{\sigma}, \tilde{q}_r^t; \tilde{\epsilon}^t))] + p(U_f - c_b \bar{q}_b(\bar{\sigma})) - (1-p)c_b(\bar{q}_b(\bar{\sigma}) + 1) \quad (2.1)$$

Let $I_t \equiv V^t$. Then \bar{Q}_t is either $\frac{1}{n} \sum_{k=0}^{n-1} I^{t-k}$ or $\min\{I^{t+k} | k = 0, \dots, n-1\}$.

A farmer makes experiments to evaluate new technologies. The farmer recognizes the effect of implementing new technology as follows. An effect on production is given by $(\tilde{\beta}, \tilde{\gamma}, \tilde{\phi})$. The random variable $\tilde{\beta}$ is a random effect on the quality of harvested rice in the experiment of new technologies. It takes its value in $\{-1, 0, 1\}$ and the probability of $\{\tilde{\beta} = 1\}$ is higher than that of $\{\tilde{\beta} = -1\}$. The random variable $\tilde{\gamma}$ is a random effect on the quantity of harvested rice in the experiment. It takes its value in the interval $(-1, 1)$, and it is assumed that $E(\tilde{\gamma}) > 0$ and $0 < \frac{\text{Prob}\{\tilde{\gamma} > 0\}}{\text{Prob}\{\tilde{\gamma} > 0\}} < \delta$ where $\delta > 0$ is very small. The output of rice production in the experiment is $(1 + \tilde{\gamma})y(\ell_r, \sigma, q_r; \epsilon)$. The random variable $\tilde{\phi}$ is a random effect on the service provided by the agricultural land that the farmer owns, in the experiment. It takes its value in the interval $(-1, 1)$, and it is assumed that $E(\tilde{\phi}) > 0$ and $0 < \frac{\text{Prob}\{\tilde{\phi} > 0\}}{\text{Prob}\{\tilde{\phi} > 0\}} < \delta$. The service provided by the agricultural land in the experiment is $(1 + \tilde{\phi})\sigma$.

Let $\tilde{f}'(\ell_r, \sigma, \zeta(\ell_r, \sigma), \epsilon)$ denote the production function based on the experiment. It is given by

$$\begin{aligned} & \tilde{f}'_k(\ell_r, \sigma, q_r, \epsilon) \\ &= \begin{cases} (1 + \tilde{\gamma})y(\ell_r, (1 + \tilde{\phi})\sigma, \zeta(\ell_r, (1 + \tilde{\phi})\sigma), \epsilon) & \text{if } k = k(\ell_r, (1 + \tilde{\phi})\sigma, \zeta(\ell_r, (1 + \tilde{\phi})\sigma), \epsilon) + \tilde{\beta}, \\ 0 & \text{otherwise.} \end{cases} \end{aligned}$$

Under the experiment, the economic welfare in period t is

$$E[u_r(\tilde{f}'(\tilde{\ell}_r^t, (1 + \tilde{\phi})\bar{\sigma}, \zeta(\tilde{\ell}_r^t, (1 + \tilde{\phi})\bar{\sigma}; \tilde{\epsilon}^t) + \tilde{Q}_r^t(\tilde{\ell}_r^t, \tilde{Q}_r^t))] + p(U_f - c_b \bar{q}_b(\bar{\sigma})) - (1 - p)c_b(\bar{q}_b(\bar{\sigma}) + 1).$$

In period t , the data from experiments in the current period and past $(n-1)$ -periods, $(\beta_{t-k}, \gamma_{t-k}, \phi_{t-k})_{k=0}^{n-1}$, is observed by the farmer. Let $\pi(\cdot | (\beta_{t-k}, \gamma_{t-k}, \phi_{t-k})_{k=0}^{n-1})$ be the empirical probability on $(\tilde{\beta}, \tilde{\gamma}, \tilde{\phi})$ derived from the data. For a simplicity, it is assumed that the empirical probability is independent of $(\tilde{\ell}_r^{t-k}, \tilde{P}^{t-k}, \tilde{\epsilon}^{t-k})_{k=0}^{n-1}$. The spot welfare in period t based on the experience of consecutive experiments for n periods, denotes as V^t is given by

$$\begin{aligned} V^t &= E_\pi \left[E[u_r(\tilde{f}'(\tilde{\ell}_r^t, (1 + \tilde{\phi})\bar{\sigma}, \zeta(\tilde{\ell}_r^t, (1 + \tilde{\phi})\bar{\sigma}; \tilde{\epsilon}^t) + \tilde{Q}_r^t(\tilde{\ell}_r^t, \tilde{Q}_r^t))] \right. \\ &\quad \left. + p(U_f - c_b \bar{q}_b(\bar{\sigma})) - (1 - p)c_b(\bar{q}_b(\bar{\sigma}) + 1). \right] \end{aligned} \quad (2.2)$$

Let $I^t \equiv V^t$. Assume, without loss of generality, that the farmer starts to experiment the effect of implementing new technologies at the period 0. Let $t \geq n$. Let $\bar{I}^t = \max\{I^{t-k} | k = 0, \dots, n-1\}$ and $\underline{I}^t = \min\{I^{t-k} | k = 0, \dots, n-1\}$. If $\bar{Q}_t \in [\underline{I}^{t-k}, \bar{I}^{t-k}]$, then let $\text{Conf}(\bar{Q}_t)$ be defined by $\frac{\bar{Q}_t - \underline{I}^{t-k}}{\bar{I}^{t-k} - \underline{I}^{t-k}}$. If $\bar{Q}_t < \underline{I}^{t-k}$, let $\text{Conf}(\bar{Q}_t) = 0$. If $\bar{Q}_t > \bar{I}^{t-k}$, let $\text{Conf}(\bar{Q}_t) = 1$. The farmer regards an adoption of new technologies as acceptable in period t only if $\text{Conf}(\bar{Q}_t) > 0$. So assume, without loss of generality, that $\bar{Q}_0 > 0$. In the period $T > n-1$, let $D^T(\cdot)$ be the empirical distribution of $\text{Conf}(\bar{Q}_t)$ for $t =$

$T - (n - 1), \dots, T$. Let μ^T be the mean of $D^T(\cdot)$ and σ^T be the standard deviation of $D^T(\cdot)$.

Let $J : [0, 1] \times [0, 1] \longrightarrow \mathbb{R}$ be a judgment function on confidence in new technologies. It is assumed that $J(\cdot, \sigma)$ is increasing and $J(\mu, \cdot)$ is decreasing. Given (μ^T, σ^T) , the judgment on confidence in technologies is given by $J(\mu^T, \sigma^T)$. Let J^* be the threshold value for judgment above which the farmer adopts new technologies. A farmer implements the new technologies in period $(T + 1)$ if and only if $J(\mu^T, \sigma^T) \geq J^*$. However this implementation should be only for one-time adoption since it is unrealistic that a farmer continue to adopt new technologies when the estimated welfare with experiments on new technologies is constantly below that with a traditional production.

2.3 A THEORETICAL MODEL ON THE ROLE OF AN INTEGRATION OF PALM OIL PLANTATION WITH R&D AND MANUFACTURING OF PHA IN A LOCAL COMMUNITY

FITRIWATI

FUMIHIRO KANEKO eds.

2.3.1 INTRODUCTION

This section investigates the feasibility of hiring locals to Research and Development (R&D) activities directly at a palm oil plantation firm that integrates R&D and manufacturing of Polyhydroxyalkanoates (PHA), in a model of interaction among a firm, a local community and farmer groups in the local community. The goal is to show theoretically that under some condition, a peer effect created by the local community works positively for installing the business in which locals are employed for R&D of PHA without abandoning local agricultural activities. The model is to identify the mechanism that a cooperative effect needed for sustaining R&D is guaranteed by the interaction between the community and the farmer groups. The model gives an example of a mechanism by which a traditional life in rural areas based on agriculture can co-exist with R&D of PHA, in which locals also engage.

The objective of the research is to rationalize the employment of locals to R&D activity. All economic agents, a firm, a local community, and farmer groups are involved in an interaction associated with an installation of R&D for PHA, and farmers must be satisfied with their employment for R&D activity.

2.3.2 THE MODEL AND ROLES OF ECONOMIC AGENTS

In this subsection, an interaction model between the local community, farmer groups and the firm is developed. The goal is to model that the local community controls a peer

effect to coordinate actions of farmer groups in the presence of an opportunity to be hired for R&D of PHA. The local community controls a cooperative behavior of locals with a community signal. The firm figures out an average effort from farmers on R&D and an estimated wage payment ex-ante if the local community identifies itself with the firm. It is to be proved that the local community can achieve a level of cooperation among locals sufficient for the firm to operate R&D. It is expected that a local community has a chance to make locals employed in the R&D division if it can create a strong peer effect in a positive way. There are two mechanisms to create the peer effect, a positive mechanism and a negative mechanism. A positive mechanism comes from the spirit of entrepreneurship and creativity by the young generation in a local community to encourage their cooperative behavior, while a negative mechanism comes from a kind of coercion from the old generation to the young generation. If a mechanism is proper, a peer effect will be created in the spirit of enhancing entrepreneurship. If it is not proper, a bad feeling will be caused among farmers by a peer effect. In the model, the local community gives the signal about the average level of efforts on R&D to the each farmer group, which is used as an instrument to control a peer effect.

2.3.2.1 ROLES OF ECONOMIC AGENTS AND INTERACTION BETWEEN LOCAL COMMUNITY AND FARMER GROUP

In this study, there are three types of players interacting on an installment of an integration of palm oil plantation with R&D and manufacturing of PHA. They are a firm, a local community, and farmer groups in the local community. The way how they interact is shown in the figure 2.1.

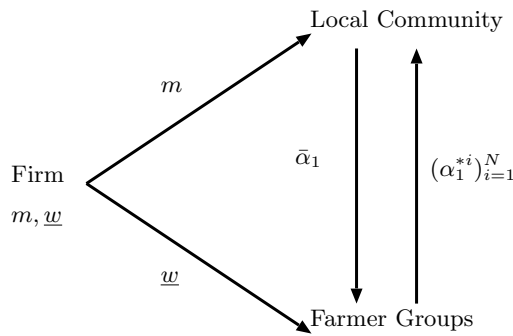


Figure 2.1: Interaction among a firm, a local community and farmer groups

The local community controls the cooperative behavior among farmer groups with a signal to control a peer effect, where the signal represents an average level of efforts on R&D taken by other farmer groups, for each farmer group. The firm is assumed to have a willingness to install R&D for PHA in the area of the local community. The firm intends to employ locals for R&D. It makes the description of jobs and its wage payment policy

public to the local community and the farmer groups. The firm has no direct access to each farmer group, and rely on the local community for information on the willingness to make efforts for R&D by farmer groups. The firm knows that the local community can coordinate the action of farmer groups through a peer effect, but does not know how it works. The firm is ready to offer an incentive to the local community to share the information about the willingness to make efforts on R&D by farmer groups. The incentive of farmer groups for making efforts at the R&D division is influenced by the wage payment scheme in an indirect way through the interaction between the local community and farmer groups. Each farmer group know the agricultural technology used by other farmer groups but does not knows how much effort other groups put in R&D. Each farmer group takes a signal from the local community as the average efforts on R&D to be implemented by other groups. Through a job opportunity at the R&D division offered by a firm, farmers retain their discretion for engaging in agricultural activities, so that they are not be forced to abandon them.

In the following, the behavioral models of a firm, a local community and farmer groups are described each by each under several structural assumptions. It is assumed that there are two mechanisms for creating peer effect, a positive mechanism and a negative mechanism. A judgment on mechanisms by the local community depends on its utility function. The local community signals an average level of effort on R&D that it thinks the best. The optimal level depends on the status quo level, which the local community regards as realizable with no social cost. It is also assumed that there are 5 farmer groups and the firm operates the business for 9 years. If all farmer groups work in R&D division, it means that there are no congestion in the use of agricultural infrastructures. If every farmer groups work for agricultural activities in full time, it means that there is an enormous congestion in the use of agricultural infrastructure that will restrict their agricultural production severely. In such case, the wage payment by the firm is attractive for farmer groups whose marginal utilities of income are high.

2.3.2.2 THE MODEL OF THE FIRM

Firm's objectives is to sustain the average effort level on R&D no less than the level needed for an operation of R&D at which the operation goes smoothly.

A wage payment scheme is elaborated to provide a financial incentive to farmer groups as employees in the R&D division. Since there are 5 farmer groups, 5 job grades are set up. Each job grade has 3 job steps, so that there are total 15 job steps. A promotion makes an employee to step up by one. A promotion policy specifies the length of months to the next promotion. Since the firm operates for 9 years (108 months), the factorization of 108 in prime numbers as $2^2 \times 3^3$ gives 9 potential candidates for a promotion policy. Among them those less than 6-months require far more than 15 steps, so that they are eliminated from

candidates. Those more than 6-months (9,12,18,27,36,108) require less than 12 steps, so that they are feasible. A promotion policy of 6-months is acceptable with the maxed-out at the top job step for the last 18 months. Hence there are 7 promotion policies. The wage payment is based on monthly salary (no bonus), and a promotion brings 12.5% salary increase. The starting salary is chosen to be no less than the minimum salary for R&D workers nationwide \underline{w}^r . The efforts of employees vary in the interval $[0, 1]$, and the firm sets up its partition by 7 subintervals, each of which corresponds to a promotion policy exclusively. It is assumed that the true level of effort can be observed by the firm.

Let \underline{w} be the starting monthly salary satisfying $\underline{w} \geq \underline{w}^r$. Promotion policies are numbered in the increasing order of lengths to the next promotion, and the length to the next promotion under the promotion policy i is denoted as X_i . For the promotion policy i with $i \geq 2$, the total wage payment for 9 years, W_i , is calculated as

$$\begin{aligned} W_i &= \underline{w}X_i(1 + \dots + (1.125)^{\frac{108}{X_i}-1}) \\ &= \underline{w}X_i(1.125)^{\frac{108}{X_i}-1} \left(1 + \dots + \left(\frac{1}{1.125}\right)^{\frac{108}{X_i}-1}\right) \\ &= \underline{w}X_i(1.125)^{\frac{108}{X_i}-1} \frac{1 - \left(\frac{1}{1.125}\right)^{\frac{108}{X_i}}}{1 - \left(\frac{1}{1.125}\right)} \end{aligned}$$

For the promotion policy 1, the total wage payment for 9 years, W_1 , is calculated as

$$\begin{aligned} W_1 &= \underline{w}X_1(1 + \dots + (1.125)^{14} + 3(1.125)^{14}) \\ &= \underline{w}X_1(1.125)^{14} \left(1 + \dots + \left(\frac{1}{1.125}\right)^{14} + 3\right) \\ &= \underline{w}X_1(1.125)^{14} \left(\frac{1 - \left(\frac{1}{1.125}\right)^{15}}{1 - \left(\frac{1}{1.125}\right)} + 3\right). \end{aligned}$$

Let I_i be the subinterval of $[0, 1]$ corresponding to the promotion policy i . The length of I_i , denoted as $|I_i|$, is given by

$$|I_i| = \frac{W_1 + \dots + W_i}{7W_1 + 6W_2 + \dots + W_7}.$$

Hence $I_i = [Z_i, Z_{i-1})$ where $Z_7 = 0$ and, for $i = 1, \dots, 6$,

$$Z_i = Z_{i+1} + \frac{W_1 + \dots + W_i}{7W_1 + 6W_2 + \dots + W_7}.$$

If an observed effort of a worker is in the subinterval I_i , the promotion policy i is applied to the worker. The partition of $[0, 1]$ is visualized in the figure 2.2.

Let $\underline{\alpha}$ be the level of average effort on R&D at which the operation of R&D goes smoothly. Suppose that the firm can obtain the true information on the average level of effort that farmer groups put on R&D from the local community by paying an incentive m to them. Let $\bar{\alpha}_1^*$ be this average level. The firm controls the starting wage \underline{w} and the incentive payment m to achieve $\bar{\alpha}_1^* \geq \underline{\alpha}$ under the ex-ante budget constraint

$$m + w(\bar{\alpha}_1^*) \leq \pi,$$

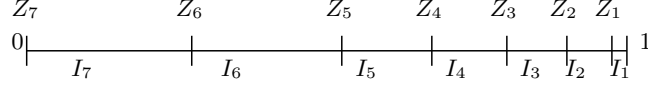


Figure 2.2: Promotion system for the R&D division

where $w(\bar{\alpha}_1^*)$ is the total wage payment to an R&D worker whose effort on R&D is $\bar{\alpha}_1^*$, and π is the total budget size for the R&D division which is determined by the headquarter of the firm and is fixed.

2.3.2.3 THE MODEL OF THE LOCAL COMMUNITY

The objective of the local community is modeled as

$$\text{Max}_{\bar{\alpha}_1 \in [0,1]} [M_+(\bar{\alpha}_1)]^B [M_-(\bar{\alpha}_1)]^{1-B},$$

where

$$\begin{aligned} M_+ &= (1 - \phi)(m + \alpha_0) + \phi 5 \bar{\alpha}_1, \\ M_- &= (1 + \phi)(m + \alpha_0) - \phi 5 \bar{\alpha}_1. \end{aligned}$$

The local community uses $\bar{\alpha}_1$ to signal an average level of effort for R&D taken by other farmer groups to each farmer group. There is a level of status quo α_0 in total effort for R&D which can be realized without any social cost. The coefficient $\phi \in (0, 1)$ is a fixed strength on the effect of a positive deviation of total effort for R&D from $(m + \alpha_0)$ in each mechanism. The coefficient B is the degree of preference on the positive side of a peer effect.

By the definition of M_+ and M_- ,

$$M_+ = 2(m + \alpha_0) - M_-.$$

Hence the problem is reduced to

$$\text{Max}_{(M_+, M_-) \geq 0} M_+^B M_-^{1-B} \quad \text{s.t.} \quad M_+ + M_- = 2(m + \alpha_0).$$

The solution for this problem is

$$\begin{aligned} M_+ &= 2B(m + \alpha_0), \\ M_- &= 2(1 - B)(m + \alpha_0). \end{aligned}$$

The value of the problem is $B^B(1 - B)^{1-B} \times 2(m + \alpha_0)$. By solving for the definition of

either M_+ or M_- , the solution

$$\bar{\alpha}_1 = \frac{2B - (1 - \phi)(m + \alpha_0)}{5\phi}.$$

It is positive and increasing with respect to $(m + \alpha_0)$ if $B > \frac{1-\phi}{2}$, which is assumed from now on. The value of $(1 - \phi)$ represents the degree of inertia in the local community.

2.3.2.4 THE MODEL OF FARMER GROUPS

The objective of a farmer group i is modeled as

$$\begin{aligned} \text{Max}_{\alpha_1^i \in [0,1]} \quad & \exp \left(\min(0, \bar{\gamma} - \gamma_i(1 - \alpha_1^i) - \sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1)) \right) \exp(1 - \alpha_1^i) \\ & + \lambda_i \sum_{j=1}^7 w_j 1_{I_j}(\alpha_1^i) \quad \text{given } \bar{\alpha}_1, \end{aligned}$$

where α_1^i is the per-capita level of effort for R&D by farmers in the group i , λ_i is the marginal utility of money for the group i , γ_j is the service of agricultural infrastructure for the farmer group j ($j = 1, \dots, 5$). The function $\exp(1 - \alpha_i)$ represents a satisfaction from agricultural activity if there is no congestion in the use of agricultural infrastructure.

It is assumed that γ_j is more than 1, for each j . The term $\sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1)$ is the use of agricultural infrastructure services by the farmer groups other than i . A degradation of agricultural infrastructure services caused by a congestion of their use is represented by $\exp \left(\min(0, \bar{\gamma} - \gamma_i(1 - \alpha_1^i) - \sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1)) \right)$, where $\bar{\gamma}$ is the constant full capacity of the agricultural infrastructure. The value of $\bar{\alpha}_1$ will influence the decision of farmer groups. If it is low, the value of $\exp \left(\min(0, \bar{\gamma} - \gamma_i(1 - \alpha_1^i) - \sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1)) \right)$ is reduced to be less than 1. However, if it is not too low, there are much room in the agricultural infrastructure services and the farmer group would not need to worry about the agricultural infrastructure.

2.3.3 THE INTERACTION BETWEEN FARMER GROUPS AND LOCAL COMMUNITY

In this subsection, the interaction between farmer groups and local community is described. The optimal level of effort for R&D is determined by each farmer group based on a given community signal. The resulting average level of effort for R&D over farmer groups becomes a status quo for the local community in the next round of interaction.

Note that the objective function of the farmer group i is written as

$$\exp \left[(1 - \alpha_1^i) + \min \left(0, \bar{\gamma} - \gamma_i(1 - \alpha_1^i) - \sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1) \right) \right] + \lambda_i \sum_{j=1}^7 w_j 1_{I_j}(\alpha_1^i).$$

If the value of $\left(\bar{\gamma} - \gamma_i(1 - \alpha_1^i) - \sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1)\right)$ is negative, then

$$\begin{aligned} & (1 - \alpha_1^i) + \min\left(0, \bar{\gamma} - \gamma_i(1 - \alpha_1^i) - \sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1)\right) \\ &= (1 - \alpha_1^i) + \bar{\gamma} - \gamma_i(1 - \alpha_1^i) - \sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1) \\ &= (1 - \gamma_i)(1 - \alpha_1^i) + \left[\bar{\gamma} - \sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1)\right]. \end{aligned}$$

If $\tilde{\alpha}_1^i$ can be taken so that $\gamma_i(1 - \tilde{\alpha}_1^i) = \bar{\gamma} - \sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1)$, then there is no incentive for the farmer group i to choose α_1^i less than $\tilde{\alpha}_1^i$, since the condition $\gamma_i > 1$ implies that, if α_1^i increases in the range less than or equal to $\tilde{\alpha}_1^i$, the satisfaction from the agricultural activity increases and the wage income also increases. So the constraint for the use of agricultural infrastructure is never binding,

$$\gamma_i(1 - \alpha_1^i) \leq \bar{\gamma} - \sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1),$$

or

$$1 - \alpha_1^i \leq \frac{\bar{\gamma} - \sum_{j \neq i} \gamma_j(1 - \bar{\alpha}_1)}{\gamma_i} \equiv A_i(\bar{\alpha}_1).$$

(Note that $A_i(\bar{\alpha}_1)$ is equal to $(1 - \tilde{\alpha}_1^i)$.) The value of $A_i(\bar{\alpha}_1)$ is increasing with respect to $\bar{\alpha}_1$.

It is assumed that

$$\begin{aligned} \gamma_j &> 1 && \text{for all } j = 1, \dots, 5, \\ \bar{\gamma} &> \sum_{j \neq i} \gamma_j && \text{for all } i = 1, \dots, 5, \\ \bar{\gamma} &< \sum_{j=1}^5 \gamma_j. \end{aligned}$$

For $\bar{\alpha}_1 \in [0, 1]$, the assumption implies that $A_i(\bar{\alpha}_i) > 0$. However, it does not guarantee that $A_i(\bar{\alpha}_i) \leq 1$.

The choice of $(1 - \alpha_1^i)$ is bounded above by $A_i(\bar{\alpha}_i)$. Since $\alpha_1^i \in [0, 1]$, $1 - \alpha_1^i \leq A_i(\bar{\alpha}_i)$ is automatically satisfied if $A_i(\bar{\alpha}_i) \geq 1$. This inequity is, therefore, binding only for the case that $A_i(\bar{\alpha}_i) < 1$. By the definition of $A_i(\bar{\alpha}_i) < 1$,

$$A_i(\bar{\alpha}_1) \leq 1 \iff 1 - \bar{\alpha}_1 \geq \frac{\bar{\gamma} - \gamma_i}{\sum_{j \neq i} \gamma_j} \quad (\text{double-sign corresponds}).$$

The case $A_i(\bar{\alpha}_i) < 1$ is called as the case 1, while the case $A_i(\bar{\alpha}_i) \geq 1$ is called as the case 2. For a further argument, let's introduce α_0^* , α_1^{j*} ($j = 1, \dots, 5$), $\bar{\alpha}_1^*$ defined by

$$\begin{aligned} \alpha_1^{j*} &\equiv \text{augmax} \{ \exp(1 - Z_k) + \lambda_j w_k \mid k = 1, \dots, 7 \} \quad (j = 1, \dots, 5), \\ \alpha_0^* &\equiv \frac{\sum_{j=1}^5 \alpha_1^{j*}}{5}, \\ \bar{\alpha}_1^* &\equiv \frac{2B - (1 - \phi)(m + \alpha_0^*)}{5\phi}. \end{aligned}$$

Case 1

In this case, $1 - \bar{\alpha}_1 > \frac{\bar{\gamma} - \gamma_i}{\sum_{j \neq i} \gamma_j}$. Let $k_i(\bar{\alpha}_1) \in \{1, \dots, 7\}$ be such that $1 - A_i(\bar{\alpha}_1) \in$

$I_{k_i(\bar{\alpha}_1)}$. Then the choice set for α_1^i is $\{Z_1, \dots, Z_{k_i(\bar{\alpha}_1)-1}, 1 - A_i(\bar{\alpha}_1)\}$. If $\alpha_1^i = Z_k$ for $k \in \{1, \dots, k_i(\bar{\alpha}_1) - 1\}$, its utility is $\exp(1 - Z_k) + \lambda_i w_k$. If $\alpha_1^i = 1 - A_i(\bar{\alpha}_1)$, its utility is $\exp(A_i(\bar{\alpha}_1)) + \lambda_i w_{k_i(\bar{\alpha}_1)}$. Note that, if $\alpha_1^{i*} \in \{Z_1, \dots, Z_{k_i(\bar{\alpha}_1)-1}\}$, α_1^{i*} is chosen by the farmer group i . If $\alpha_1^{i*} \notin \{Z_1, \dots, Z_{k_i(\bar{\alpha}_1)-1}\}$, the optimal α_1^i is greater than or equal to α_1^{i*} , with the strict inequality if $A_i(\bar{\alpha}_1) \neq 1 - Z_{k_i(\bar{\alpha}_1)}$. If λ_i is small, then α_1^{i*} tends to be small. For such a farmer group i , the second case would occur. In any case,

$$\frac{\sum_{j=1}^5 \alpha_1^j}{5} \geq \alpha_0^*,$$

with the strict inequality if $\alpha_1^{i*} \notin \{Z_1, \dots, Z_{k_i(\bar{\alpha}_1)-1}\}$ for some i with $A_i(\bar{\alpha}_1) \neq 1 - Z_{k_i(\bar{\alpha}_1)}$.

If the equality holds, it means that each farmer group j chooses α_1^{j*} . In the next round of interaction, α_0 is replaced by α_0^* so that the signal is $\bar{\alpha}_1^*$. If $A_i(\bar{\alpha}_1^*) \geq 1$, then the process goes to the case 2. To simplify the argument, assume (temporarily) that this is not the case for all farmer groups. Then the case 1 repeats with the community signal $\bar{\alpha}_1^*$ for all farmer groups. If $\alpha_1^{i*} > 1 - A_i(\bar{\alpha}_1^*)$, then the farmer group i chooses α_1^{i*} . Otherwise $\alpha_1^i \geq \alpha_1^{i*}$ is chosen with the strict inequality if $A_i(\bar{\alpha}_1^*) \neq 1 - Z_{k_i(\bar{\alpha}_1^*)}$. If the former is true for all farmer groups, then the interaction is stabilized, in that each farmer group i chooses α_1^{i*} in any rounds following this round. Suppose it is not the case, so that $\alpha_1^{i*} < 1 - A_i(\bar{\alpha}_1^*)$ for some i . For such i , its choice is $\alpha_1^i > \alpha_1^{i*}$. Let $\tilde{\alpha}_1^i$ be defined for each i by

$$\tilde{\alpha}_1^i \equiv \operatorname{augmax} \left\{ \exp(1 - Z) + \lambda_i w_k \mid Z \in \{Z_1, \dots, Z_{k_i(\bar{\alpha}_1^*)-1}, 1 - A_i(\bar{\alpha}_1^*)\} \right\}.$$

Then $\alpha_1^i = \tilde{\alpha}_1^i > \alpha_1^{i*}$. For other j 's with $\alpha_1^{j*} \geq 1 - A_j(\bar{\alpha}_1^*)$, their choice is $\alpha_1^j = \tilde{\alpha}_1^j$. Therefore $\alpha_1^j \in [\alpha_1^{j*}, \tilde{\alpha}_1^j]$ for all farmer groups $j = 1, \dots, 5$. In the next round, $\alpha_0 > \alpha_0^*$, so that $\bar{\alpha}_1 > \bar{\alpha}_1^*$ which implies $1 - A_j(\bar{\alpha}_1) < 1 - A_j(\bar{\alpha}_1^*)$ for all $j = 1, \dots, 5$. For all i with $\alpha_1^{i*} \geq 1 - A_i(\bar{\alpha}_1^*)$, its choice is α_1^{i*} . Note that, for them, $\alpha_1^{i*} = \tilde{\alpha}_1^i$. For all i with $1 - A_i(\bar{\alpha}_1) \leq \alpha_1^{i*} < 1 - A_i(\bar{\alpha}_1^*)$, its choice is α_1^{i*} , and $\tilde{\alpha}_1^i > \alpha_1^{i*}$. For all i with $\alpha_1^{i*} < 1 - A_i(\bar{\alpha}_1)$, its choice α_1^i satisfies $\alpha_1^{i*} < \alpha_1^i \leq \tilde{\alpha}_1^i$. Hence, again, $\alpha_1^j \in [\alpha_1^{j*}, \tilde{\alpha}_1^j]$ for all farmer groups $j = 1, \dots, 5$. In the next round, $\alpha_0 \geq \alpha_0^*$. If $\alpha_0 = \alpha_0^*$, the first case in this paragraph repeated. If $\alpha_0 > \alpha_0^*$, the second case in this paragraph applies to this round. In any case, $\alpha_1^j \in [\alpha_1^{j*}, \tilde{\alpha}_1^j]$ for all farmer groups $j = 1, \dots, 5$, so that $\alpha_0 \geq \alpha_0^*$ in the next round.

If the inequality holds, $\alpha_0 > \alpha_0^*$ in the next round and the community signal $\bar{\alpha}_1$ satisfies $\bar{\alpha}_1 > \bar{\alpha}_1^*$, so that $A_i(\bar{\alpha}_1) > A_i(\bar{\alpha}_1^*)$. If $A_i(\bar{\alpha}_1) \geq 1$, then the process goes to the case 2. To simplify the argument, assume (temporarily) that this is not the case for all farmer groups. Then the case 1 repeats for all farmer groups. This case corresponds to the second case in the previous paragraph. Hence $\alpha_1^j \in [\alpha_1^{j*}, \tilde{\alpha}_1^j]$ for all farmer groups $j = 1, \dots, 5$, and $\alpha_0 \geq \alpha_0^*$ in the next round. After this round, the

interactions proceeds exactly as those described in the previous paragraph.

Let $\tilde{\alpha}_0$ and $\tilde{\alpha}_1$ be defined by

$$\begin{aligned}\tilde{\alpha}_0 &\equiv \frac{\sum_{j=1}^5 \alpha_1^j}{5}, \\ \tilde{\alpha}_1 &\equiv \frac{2B - (1-\phi)(m + \tilde{\alpha}_0)}{5\phi}.\end{aligned}$$

The argument so far shows that, in any round of interaction, the status quo value α_0 , the community signal $\bar{\alpha}_1$ and optimal choices of farmer groups $\{\alpha_1^j\}_{j=1}^5$ satisfy

$$\alpha_0^* \leq \alpha_0 \leq \tilde{\alpha}_0, \quad (2.3)$$

$$\bar{\alpha}_1^* \leq \bar{\alpha}_1 \leq \tilde{\alpha}_1, \quad (2.4)$$

and

$$\alpha_1^j \in [\alpha_1^{j*}, \tilde{\alpha}_1^j] \quad \text{for all } j = 1, \dots, 5. \quad (2.5)$$

Case 2

In this case, $1 - \bar{\alpha}_1 \leq \frac{\bar{\gamma} - \gamma_i}{\sum_{j \neq i} \gamma_j}$. Since $A_i(\bar{\alpha}_1) \geq 1$, the optimal choice of farmer group i is α_1^{i*} . Hence this case does not affect on the argument for the case 1, and the properties (2.3), (2.4) and (2.5) holds for any round of interaction even if the case 2 happens to some farmer groups.

2.3.4 ANALYSIS OF INTERACTION BETWEEN FIRM AND LOCAL COMMUNITY

This subsection analyzes the interaction between the firm and the local community. The firm cannot have a direct access to each farmer group, so that it cannot have an exact information on how each farmer group behaves. However, the firm knows that the local community interacts with them by a use of community signal though it does not know how it works. The firm cannot interfere with the interaction between the local community and farmer groups. The firm relies on the local community for transferring relevant information, either the average level of effort for R&D by farmer groups or a profile of efforts for R&D by farmer groups, and would like to pay an incentive m to the local community in return for the information. The firm can influence the behavior of farmer groups indirectly by controlling the starting wage level \underline{w} through the announced wage payment scheme. The interaction between the firm and the local community is explained by a bargaining between the firm and the local community. The firm would like to have a true information about either $\frac{\sum_{j=1}^5 \alpha_1^j}{5}$ or $\{\alpha_1^j\}_{j=1}^5$. The firm is willing to pay an incentive m to the local community if the budget allows. The local community can accept the proposal of incentive payment or reject it. The firm wants to make that a rejection of the proposal by the local community signals that $\frac{\sum_{j=1}^5 \alpha_1^j}{5}$ is less than $\underline{\alpha}$, the average

level of effort required for a smooth operation of R&D. If it happens, the firm raises the starting wage at a pre-specified rate. The firm wants to make that the acceptance of the proposal by the local community guarantees that $\frac{\sum_{j=1}^5 \alpha_1^j}{5} \geq \underline{\alpha}$.

Let us consider the two players involved in this interaction: the local community and the firm as players. The firm needs the true information about the average effort level for R&D from the local community. The firm approaches the local community and gives an incentive payment to tell the true value of either the average effort level or the effort level chosen by each farmer group after several interactions between it and farmer groups. It is assumed that the incentive will be paid only after the firm observes the true value of α_1^j for each farmer group j by employing them. The firm retains the right to refuse the incentive payment if the true average value is different from the reported average from the local community. As a consequence, the local community gives the true information if it accepts the proposal. At first, the firm makes a proposal about an incentive pay and a waiting time. Then the local community decides to accept or reject the proposal within the waiting time by interacting with farmer groups. The budget for R&D division, π , is informed to the local community before the bargaining begins.

The firm's first proposal is represented by a pair (m, ζ) where $m \equiv \pi - 5w(\underline{\alpha})$ and $\zeta > 0$ is a waiting time for a decision by the local community. The local community runs the interaction with farmer groups within ζ . If $\{\alpha_1^j\}_{j=1}^5$ is obtained as the result of interactions within ζ , the local community knows that an accurate estimation of the labor cost is $\sum_{j=1}^5 w(\alpha_1^j)$ and its estimate based on the average effort is $5w\left(\frac{\sum_{j=1}^5 \alpha_1^j}{5}\right)$. So the expected incentive pay by the local community is either $\pi - \sum_{j=1}^5 w(\alpha_1^j)$ or $\pi - 5w\left(\frac{\sum_{j=1}^5 \alpha_1^j}{5}\right)$. The local community has two choices in what information it gives to the firm, either $\{\alpha_1^j\}_{j=1}^5$ or $\frac{\sum_{j=1}^5 \alpha_1^j}{5}$. The one which gives a higher expected incentive pay is chosen as an information to be transferred. Hence $\frac{\sum_{j=1}^5 \alpha_1^j}{5}$ is to be transferred if $w\left(\frac{\sum_{j=1}^5 \alpha_1^j}{5}\right) \leq \frac{\sum_{j=1}^5 w(\alpha_1^j)}{5}$, $\{\alpha_1^j\}_{j=1}^5$ is to be informed otherwise. Either information is transferred to the firm if the proposal is accepted. The local community accepts the proposal if

$$m \geq \max \left\{ \pi - \sum_{j=1}^5 w(\alpha_1^j), \pi - 5w\left(\frac{\sum_{j=1}^5 \alpha_1^j}{5}\right) \right\},$$

and rejects the proposal otherwise. Since $m = \pi - 5w(\underline{\alpha})$, the acceptance by the local community means $\pi - 5w(\underline{\alpha}) \geq \pi - 5w\left(\frac{\sum_{j=1}^5 \alpha_1^j}{5}\right)$, hence $\frac{\sum_{j=1}^5 \alpha_1^j}{5} \geq \underline{\alpha}$ since $w(\alpha)$ is increasing in α . Therefore the firm guarantees the required average level of effort for R&D if the local community accepts the proposal.

If the local community rejects the proposal, $\frac{\sum_{j=1}^5 \alpha_1^j}{5} < \underline{\alpha}$ if $w\left(\frac{\sum_{j=1}^5 \alpha_1^j}{5}\right) \leq \frac{\sum_{j=1}^5 w(\alpha_1^j)}{5}$.

Then the firm raises \underline{w} by a preset percentage rate and make a new first proposal based on the new wage payment scheme determined by the increased \underline{w} .

If the local community accepts the proposal, then the information either $\left\{\alpha_1^j\right\}_{j=1}^5$ or $\frac{\sum_{j=1}^5 \alpha_1^j}{5}$ is transferred to the firm. Then the firm makes a concluding proposal $(m, 0)$ where $m = \pi - 5w \left(\frac{\sum_{j=1}^5 \alpha_1^j}{5}\right)$ if $\frac{\sum_{j=1}^5 \alpha_1^j}{5}$ is informed and $m = \pi - \sum_{j=1}^5 w(\alpha_1^j)$ if $\left\{\alpha_1^j\right\}_{j=1}^5$ is informed, only if $m > 0$. The local community has no reason to reject this proposal since the budget and the ex-ante estimates of labor payment are known to it. The rejection leads to the increase of the labor payment. Since the budget is constant, it decreases the incentive pay to the local community. Hence it accepts the concluding proposal. Finally, a contract of incentive payment is completed with the acceptance of the concluding proposal. If $m < 0$, the firm abandons the plan to install the R&D division in that region so that there is no installment of the R&D division.

2.3.5 IMPLICATION OF RESULTS

The results of the interaction model imply that conditions for a successful installment of the business proposal are 1) Agricultural activities in the area are not going very well, 2) marginal utilities of income for farmers are sufficiently high, and 3) the mechanism to create a peer effect is not coercive.

The results also imply that the R&D division can be installed in rural areas without making farmers give up agricultural activities. The farmer groups are capable of making a balance between agricultural activities and work for R&D.

Yet another implication is that the firm does not need to know about the local community and farmers in detail, such as a religion and regional characteristics of agricultural activities, and do not need to care or understand anything about them. The R&D division of a firm relies on a peer effect in the interaction between the local community and farmer groups to sustain the level of average effort by workers at the degree of a smooth operation. As an intention of the theoretical analysis, the firm may be able to set the average level of effort for R&D of PHA slightly lower than that for R&D of other than PHA. It is because that the determinants of the level of effort in the R&D division would be dominated by work experiences and cooperative behavior in the case of R&D for PHA.